Guidebook on Induced Travel Demand

Prepared for

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Executive Summary

Induced travel demand can result in new, widened or improved highways filling up faster than anticipated.

Induced demand is any increase in travel arising from improved travel conditions. In the case of highway travel, induced travel demand is any increase in vehicle miles traveled attributable to any highway project that increases capacity.

Throughout the twentieth century, the United States implemented a highway development program to rival any the world has seen. These highways formed the infrastructural foundations of modern economic and urban development, but were accompanied by increasingly apparent social, economic and environmental side effects. One of these side effects was traffic congestion, which has often increased faster than forecasted after completion of projects involving new, wider or improved highway segments. The phenomenon of highways filling up faster than anticipated after improving travel conditions has been one of the factors identified as induced travel demand.

This phenomenon is apparent in all modes of transportation and can be explained through the basic economic theory of transportation supply and demand. This theory predicts that travelers respond to a reduction in the travel time cost by increasing their demand for travel. This additional demand affects the overall transportation profile and, in the long-term, may have an effect in shaping urban form.

Induced travel demand can be better incorporated into estimates of traffic and future transportation impacts.

According to federal legislation, planning agencies and project proponents undertake plans and/or impact assessments which estimates traffic, environmental and land use development impacts, and allow comparison of different transportation alternatives. These plans and assessments include estimation of future travel that could better account for the effects of induced demand.

Numerous studies confirm the existence of induced travel demand and its contribution to the impacts of highway and other transportation projects. Induced travel demand effects result in measurable travel growth over and above that which would normally occur as a result of exogenous factors such as population growth and changed demographic characteristics.

These higher than expected traffic volumes are attributed to immediate, near-term and long-term changes in travel behavior in response to changed travel conditions. Immediate responses include changes in departure time, route and mode; near-term responses include changes in trip destination and trip chaining; and long-term responses include increased vehicle ownership, relocation of places of residence and work, and changes in land use development patterns. These responses directly and/or indirectly contribute to additional demand for travel.

Induced travel demand is measured in terms of travel demand elasticities.

Although the existence of induced travel is largely confirmed, methods of measuring and estimating its effects are still under development. Traffic analysts have been able to estimate travel demand elasticities with respect to capacity or travel time changes. These analyses indicate that induced travel demand elasticity with respect to highway capacity is in the range 0.3 to 0.5 in the short-term and 0.5 to 0.9 in the long-term. This means that for every 1 percent increase in highway capacity there is a 0.3 to 0.9 percent increase in the amount of travel demanded. At a cumulative level, an estimated 10 to 30 percent of total metropolitan growth in vehicle miles of travel may be attributable to induced travel demand.

Induced travel demand is connected with debates regarding urban development and land use impacts.

One of the questions surrounding the issue of induced travel demand is its level of contribution to patterns of metropolitan growth such as urban sprawl. Highway skeptics view induced travel as the mechanism behind wasteful and uncontrolled spreading of urban development into areas at the edges of metropolitan regions. Highway advocates, on the other hand, view induced demand as an indication of market demand for urban growth and economic development. In either case, it is clear that highways and other major transportation investments create changes in regional accessibility, travel demand and development patterns. The actual influence of increased transportation capacity on urban form, however, is confounded by policy, economic, technological and social factors which also contribute to metropolitan land use and development.

Induced travel demand effects may or may not be significant enough to alter the rank order of transportation projects and strategies.

Induced travel demand issues have been alluded to in a number of court cases and models involving transportation planning. From these examples, induced travel demand has been variously attributed with increased traffic congestion, environmental impacts, rates of commercial and housing development, and regional economic development. The future effects of induced travel demand affect the balance of costs and benefits predicted for a particular course of action in the transportation field. Updated traffic forecasts to incorporate induced demand effects can therefore alter the forecast effects of projects as well as the rank order of different transportation and access alternatives.

Studies indicate that when induced travel demand is not considered, transportation plans tend to underestimate the traffic and air pollution impacts of highway infrastructure expansions. Transportation practitioners therefore need to be diligent in ensuring that induced demand is properly taken into account in transportation plans and evaluations of all sizes. This can be done through adjustment of existing travel planning tools to include travel demand elasticity, feedback iterations, sensitivity analysis and changes in land use, trip distribution and travel time choice.

Transportation plans that account for induced travel demand can help identify solutions for more efficient and livable communities.

When these factors are taken into account, alternative approaches to addressing congestion and enhancing access tend to become more attractive. While new and expanded highways remain the preferred option for many situations, transit, land use, and pricing options emerge favorably in others. By providing a more accurate indication of traffic and other impacts, transportation plans that successfully account for induced travel demand can help identify solutions that improve accessibility, contain traffic congestion, reduce air emissions and result in more livable communities.

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1 Introduction

1.1 Transportation networks in the United States have provided an important infrastructural foundation to wider economic and social development.

The history of the United States has been marked by growth in the supply and usage of transportation facilities. By the end of the twentieth century, the nation's transportation system included 3,930,000 miles of public roads, 170,000 miles of railroad routes, and 5,300 airports. With rapid economic growth and urban expansion throughout the second half of the twentieth century, US transportation networks provided an important infrastructural foundation to wider economic and social development.

Figure 1.1: Situated between the White House and the Washington Monument, the Zero Milestone reflects the key role of highways and transportation in the United States.

Like the Roman roads of the first century, the United States' vast network of highways, railroads and other transportation facilities were critical to the nation's economic and political progress. In the post-war period, highways in particular were essential to US-style economic development, national defense and personal liberty. Attention was therefore given to funding and constructing a 160,000-mile network of interstate highways and other roads of national importance which now play a critical role in accommodating 2.7 trillion vehicle miles of travel and 1.1 trillion ton-miles of freight each year. Rail and transit systems, which comprise over 41 billion passenger miles of travel per annum, also perform essential transportation services within and between urban areas.[1]

By linking cities and regions with freeways and railways, transportation and road developers created new jobs and boosted economic growth by reducing the transportation costs associated with products. Networks of roads and freeway also facilitated the emerging pattern of highway-based suburbanization as the dominant trend in residential, commercial and industrial development over the last half of the twentieth century.

1.2 Transportation development has been accompanied by increasingly recognized environmental, land use and traffic impacts.

While transportation networks provided the infrastructural framework for modern economic and urban development in the United States, they were accompanied by a number of increasingly apparent impacts. Throughout the history of urban development, the dominant mode of transportation has always been associated with characteristic land use patterns and environmental impacts.

1 Introduction

In the case of pedestrian-based urbanization, land uses were tightly confined within city walls or boundaries set by what was considered a reasonable walking distance, the result being overcrowding and exposure to industrial externalities within the limited urban space.

In the case of rail-based urbanization, land uses were more segregated with suburbs developing away from the central areas and around transit nodes in more "rural" areas. Rail-based sprawl therefore alleviated urban overcrowding, however, corrupt and monopolistic behavior associated with some transit operators led to public dissatisfaction with transit-dependent patterns of urban development.

As highways became the dominant mode of transportation development in the United States, metropolitan land uses spread out over even larger distances and were often labeled as urban sprawl. These patterns of development were associated with high levels of automobile use, resource consumption and environmental impacts, some of which are outlined below:


Photo: Mary Chou

Figure 1.2: Highways and associated land use patterns consume large amounts of land, with impacts on agriculture and environmentally sensitive land.

- Highways and associated land use patterns consume large amounts of land with impacts on agriculture, natural resources and environmentally sensitive land such as wetlands and habitat for endangered species.
- Vehicle emissions associated with road and highway travel are a major contributor to local and regional air pollution that exceeds air quality standards in many cities.
- Vehicle emissions from transportation are also a major component of U.S. greenhouse gas emissions which are the subject of deliberations on global climate change.
- Dependence on automobiles and fossil fuels contribute to concerns regarding international energy security.

1.3 Federal environmental legislation indirectly mandates analysis of induced demand effects.

Federal law requires the analysis and consideration of transportation project impacts on the environment, including land use changes and induced travel demand effects.

Projects to add or expand transportation facilities such as highways generate some induced travel which is reflected in changed traffic flow impacts and patterns of land use development. These changes have a number of environmental effects which are, in turn, regulated by the Clean Air Act Amendments of 1990 (CAAA), the National Environmental Policy Act of 1970 (NEPA) and relevant state legislation. In order to comply with CAAA and NEPA, transportation project assessments need to include accurate estimates of traffic and land use development impacts including those arising as a result of induced travel demand. This connection between induced travel and environmental regulation is illustrated in Figure 1.3.

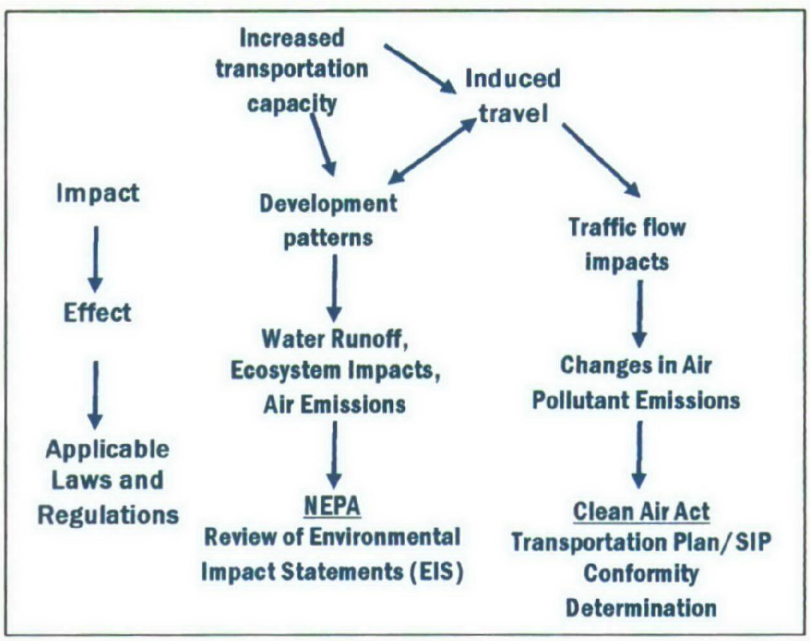

Figure 1.3: Induced travel demand-related impacts, environmental effects and regulations.

If a state or metropolitan area does not meet National Ambient Air Quality Standards (NAAQS), CAAA requires agencies to develop a

State Implementation Plan (SIP). The SIP includes forecasts of future travel volume and anticipated emissions levels for NAAQS non-attainment areas. CAAA also requires that Regional Transportation Improvement Programs (TIPs) are consistent with SIP provisions, and it prohibits the use of Federal transportation funds for transportation projects that worsen air quality. In order to accurately forecast likely transportation emissions and ambient air quality levels for compliance with the CAAA, it is critical that accurate estimates are made of future traffic volumes in the region.[2]

NEPA reinforces this requirement for accurate prediction of traffic and emissions as part of its project-level planning regulations. NEPA requires agencies to prepare an environmental impact analysis when considering a proposal for major federal action, such as transportation projects involving federal monies. Accurate assessment of primary, secondary and cumulative impacts of transportation projects entails estimation of future travel demand, including induced demand arising as a result of the project.[3]

1.4 Federal transportation legislation establishes the framework for transportation funding and analysis.

Transportation planning legislation also requires detailed travel demand forecasting and allows some flexibility between modes of transportation planning.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and its successor, the Transportation Equity Act for the 21st century (TEA-21), set the framework for transportation decision-making, planning and funding in the United States. Unlike previous highway funding instruments, ISTEA/TEA-21 allow funding flexibility between different transportation modes with specific funds, allocated under the congestion mitigation and air quality (CMAQ) program, for projects which aim to achieve congestion mitigation and air quality improvements. The CMAQ program and ISTEA/TEA-21 legislation more generally, were intended to allow for more multimodal approaches to transportation planning and development.

In order to substantiate claims for transportation and highway funds there is a need to accurately assess traffic, accessibility and environmental impacts relative to other transportation projects. To allow for fair comparison between different alternatives, induced travel demand effects should be included in project assessments.[4,5] In practice, transportation project assessments currently give only cursory treatment to induced travel demand effects, and there is no legislated mechanism for analyzing or comparing different modal strategies at the transportation and land use policy level.

In some instances, cross-modal analysis involving induced demand effects will occur for reasons other than fulfilling Federal transportation funding and environmental protection legislation. Public pressure and economic concerns provide incentives for alleviating congestion associated with patterns of transportation development and use. As traffic and environmental impacts continue to affect metropolitan regions across the United States, conventional approaches to transportation assessment and development are increasingly brought into question.

1.5 More fine-grained analysis is needed to understand whether or not investment in a particular transportation policy or project is warranted.

Induced travel demand suggests the need for more fine-grained analysis of transportation capacity effects on traffic and environmental media. The outcome of this analysis is critical to understanding whether or not investment in a particular transportation policy or project is warranted on the basis of both transportation performance, and compliance with air quality legislation.

When undertaking transportation programming and planning, States, metropolitan planning organizations (MPOs) and individual agencies are faced with the challenge of forecasting:

- the effect of investments on congestion reduction and therefore the associated travel time savings, reductions in vehicle speed variation and reductions in emissions; and conversely
- the effect of investments on increasing overall demand for travel (induced travel demand) and therefore associated impacts on con-

tinued or worsened congestion and air quality emissions.

This forecasting effort is made harder by the difficulty involved in separating induced travel demand effects from other sources of traffic increase such as:

- natural growth associated with population growth and demographic change that would have occurred regardless of changes in the transportation system;
- adverse traffic on local and arterial streets associated with entering and exiting the new facility; and
- diverted traffic from other routes on the network to the improved facility.[6]

The quantities and balance between these different factors must be analyzed in relation to the specific application, before one is able to assess whether or not the project or policy is likely to achieve its transportation purpose, and whether or not to deliver a net social benefit.

"Can we build our way out of traffic congestion?"

To many observers, the dilemma of alleviating congestion and highway impacts in the context of induced travel demand raises the question: "Can we build our way out of traffic congestion?"

To answer this question for any one application, there is a need for a deeper understanding of induced travel demand.

1.6 Induced travel demand is a phenomenon that can be better incorporated into transportation analysis.

Induced travel demand is the phenomenon whereby there is an increase in travel arising from an improvement in travel conditions. For example, after highway capacity is increased as a result of lane-expansion or addition, many drivers respond by traveling further or more often to take advantage of the initial travel time savings. This effect has implications for the way that transportation projects are assessed and for the mix of transportation system components that are adopted.

1 Introduction

In recent times, the concept of induced demand has become more widely discussed in media surrounding transportation issues. While many recognize the concept of induced travel demand, there a lack of scientific understanding regarding its existence and relative importance in relation to transportation policies and projects.


The New York Times
January 27, 2000
Do Additional Roads Increase Congestion?

The Seattle Times
September 27, 2000
Study: New Roads Not the Answer to Traffic Congestion

The Cincinnati Post
January 13, 2000
Bigger Highways Just Add to Congestion

The Washington Post
January 13, 2000
More Lanes Often Mean More Traffic, Study Finds

Figure 1.4: Selected newspaper headlines on induced travel demand.

Scientific studies have found that induced travel demand is a real phenomenon and needs to be better addressed in transportation planning models designed to forecast levels of congestion, air quality and land use impacts. Where it is not properly addressed, future congestion and air pollution levels are likely to under-estimated.[7]

As researchers, policymakers, public officials and the public-at-large struggle to understand the relationship between transportation development, land use and quality of life, induced travel demand emerges as one of the most contentious issues surrounding highway projects. An understanding of this phenomenon is critical to making the best possible transportation infrastructure investments.

1.7 Organization of Guidebook Chapters

This guidebook will provide an overview of the concept, applications and implications of induced travel demand based on findings from the range of relevant recent research.

Induced travel demand is defined in Chapter 2 and an explanation regarding the behavioral mechanism underlying induced travel is provided in Chapter 3. This explanation is followed by a discussion of research findings regarding the existence of induced travel demand in Chapter 4.

Having established the form of induced travel demand and evidence for its existence, the likely magnitude of the phenomenon is discussed in Chapter 5. Methods of measuring induced travel demand effects are also discussed in Chapter 5.

The implications of incorporating induced travel demand are assessed in relation to three areas:

- land use patterns, specifically urban sprawl, in Chapter 6;
- transportation planning processes, in Chapter 7; and
- transportation and land use outcomes arising from these processes in Chapter 8.

Conclusions are drawn in Chapter 9 regarding the significance and implications of induced travel demand.

Each of the above topics is discussed in the context of common misconceptions regarding induced travel demand, and accompanied by case studies. References and sources of additional information are provided in Chapters 10 and 11 respectively, in order to direct readers to further detail on the concepts and examples presented.

2 What is induced travel demand?

2.1 Induced travel demand is any increase in travel arising from improved travel conditions.

Induced demand is defined as any increase in travel arising from improved travel conditions.[1] Travel conditions may be improved by reducing travel times, reducing travel cost, improving traveler safety, improving traveler comfort and so on.

Induced travel demand represents the increased use of transportation facilities beyond that which would normally occur if the transportation improvement was not implemented. The precise focus of induced travel demand depends upon the modal, temporal and spatial context under consideration.

In the context of highways, induced travel demand is any increase in vehicle miles traveled (VMT) attributable to any transportation project that increases capacity.[3]

In the case of highway travel, induced travel demand is any increase in vehicle miles traveled (VMT) attributable to any transportation project that increases capacity.[2] Increases in transportation supply capacity might occur through the addition of new lanes or routes to freeway facilities. This change leads to immediate savings in travel times along the facility, particularly during periods of peak-hour congestion. As drivers notice the traffic improvement, some decide to make changes and travel further or more often. The result is an increase in vehicle miles traveled (VMT) along the facility, over and above that which would normally occur. This increase in travel demand may encompass travel by personal vehicles, freight trucks and buses or coaches which use the facility.

In the case of transit, induced travel demand might occur in response to travel time reductions achieved through more frequent or more direct services, as well as in response to reductions in passenger fares and improvements in perceived comfort and safety. Improved travel conditions for transit then induce new passenger demand over and above increases that would normally occur.

Figure 2.1: Induced demand for transit services such as this free city shuttle, can result from improved service frequency, reduced passenger fares and restricted access by other modes.

Converted traffic from one mode to another is generally included in induced travel demand where it is desirable to gain an understanding of changes in vehicle miles traveled (VMT) or air emissions. Where an understanding of passenger miles traveled is desired, converted traffic may be less relevant. In quantifying converted traffic impacts, improved *relative* travel conditions for transit should be considered in addition to improved absolute travel conditions. Improved relative travel conditions may result from treatments to other modes such as parking restrictions, road pricing measures and restricted vehicular access to certain areas.

Common misconception 1:

"Induced travel is diverted traffic from other roadways."

Induced travel demand is generally considered to be distinct from diverted traffic.

Diverted traffic results when people respond to changed travel conditions by switching routes. For example, drivers may respond to highway capacity improvements by taking the improved highway instead of local roads, other highways or other unimproved facilities.

Diverted traffic therefore increases congestion on the improved route but does not increase overall vehicle miles traveled (VMT) since there is no change in the distance traveled or number of trips. It redistributes traffic across the transportation network but does not generate new travel or affect overall mode split.

In situations where transportation analysis is only focused on the route undergoing improvement, diverted traffic might be considered as part of induced travel estimations. It may also be considered where there it results in a change in travel speeds or speed variations Otherwise, where an understanding of changes in total VMT is desired, diverted traffic should be excluded from calculations of induced travel demand.

2.2 Induced travel demand can be explained through the basic economic theory of transportation supply and demand.

Basic economic theory of supply and demand can be used to explain the concept of induced travel demand. For any good, there are short- and long-run supply and demand curves. The point at which these curves intersect is the point of consumption or equilibrium. In this case, the good is travel; supply is the amount of transportation facilities; and demand is the use of these services in the short- and long-run.

As traffic or transportation demand approaches capacity and congestion increases, the user cost including travel time also increases (upward sloping S in Figure 2.2). On the other hand, as the price to individuals using the highway system increases, demand for travel decreases (downward sloping D). The price of travel includes a number of factors such as the capital cost of vehicles and facilities, maintenance costs, fuel, labor costs for freight or public transit, and travel time. The travel time cost is considered to be the most significant factor related to induced travel.[4]

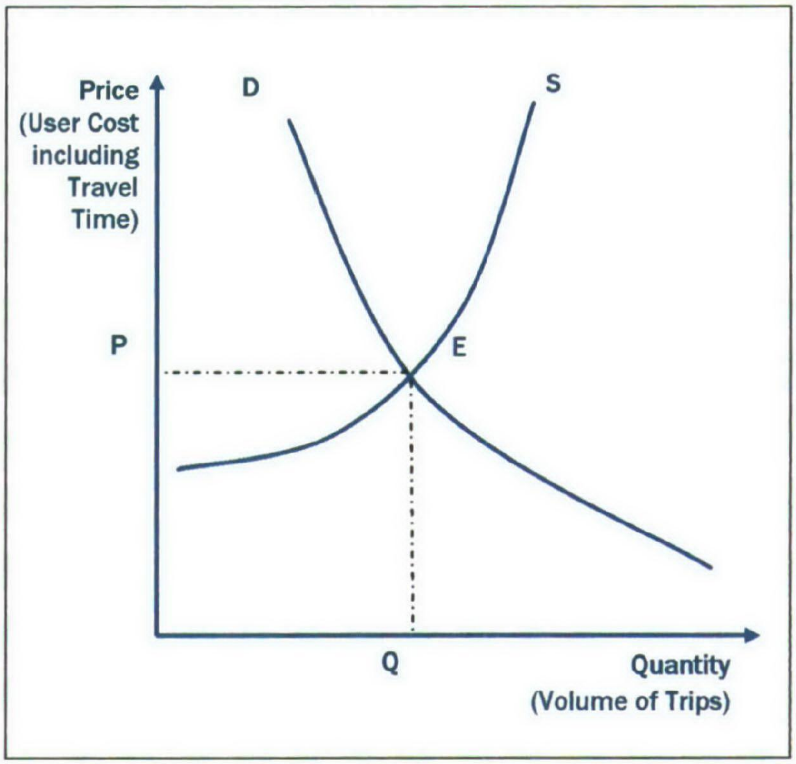

Figure 2.2: Supply and demand curve for travel

Supply and demand curves exist for all modes of transportation, including personal transportation, freight transportation and public transit. For transit, the high capital and labor cost needed to operate the system regardless of the number of passengers, means that while the system is not congested the supply cost per passenger actually decreases with higher passenger loads (downward sloping supply curve S in Figure 2.3). This situation is known as economies of scale. As the system approaches capacity, there may be a need to put on more services and the travel times may be affected

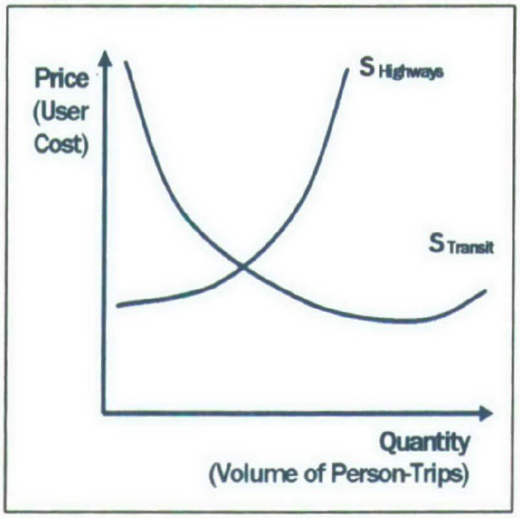

Figure 2.3: Supply curves for transit demonstrate economies of scale due to high initial capital and labor costs to operate transit facilities.

by congestion delays. The supply cost (which includes capital and operating costs and travel time) then increases again as described above. In situations where economies of scale exist, care should be taken when attempting to understand supply-demand equilibria, since there may be more than one equilibrium point.

Induced demand effects can be explained by considering the effect of increasing the supply of transportation on the supply-demand equilibrium. Any increase in the supply of transportation reduces the time cost of travel, all else being equal. Adding an extra lane to a highway reduces congestion and allows travelers to reach their destinations more quickly. Likewise, adding extra services to a transit system reduces the passenger wait time and allows passengers to reach their destinations more quickly. As more users take advantage of this supply and the system becomes more congested, and price (or travel time) for each user increases until it plateaus at a new equilibrium point between supply and demand.

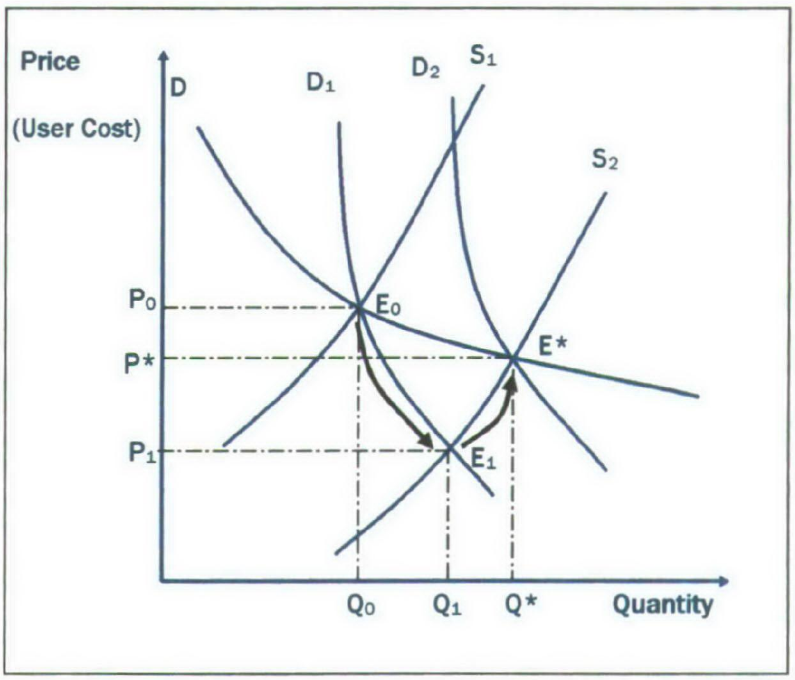

Figure 2.4: Supply and demand for travel, showing the effect of capacity increase.[5]

2 What is induced travel demand?

Figure 2.5: In describing induced travel demand, some observers compare traffic to a gas that expands to fill the available space.[6]

In terms of the supply and demand graph, a transportation addition or improvement shifts the supply curve outwards and downwards (from S_1 to S_2 in Figure 2.4). Given the same short-run demand curve (D_1), this change results in a reduction in travel time or price (from P_0 to P_1) and a shift in equilibrium (from E_0 to E_1). The new equilibrium reflects a higher level of consumption or increase in demand for travel (from Q_0 to Q_1) associated with a decrease in travel time or price. The new highway supply can provide more of the good at a lower cost.

Over time, however, the short-run demand curve shifts outward (from D to $D_{\text{Long Run}}$) to reflect long-run demand. The final equilibrium therefore shifts (to E*) so that the travel time savings (P_0 to P_2) are not as favorable as expected (P_0 to P_1) and the final volume of traffic is higher than expected (Q* instead of Q_1).

2.3 Induced travel is only the portion of increased travel beyond that which would occur anyway, as a result exogenous factors.

In modeling future travel demand on a particular transportation improvement, it is extremely difficult to tease out exogenous factors in order to measure the exact magnitude of induced demand. That is, of the increased quantity of demand for travel over time, it is hard to calculate how much is a direct result of the improvement itself and *not* exogenous factors.

Common misconception 2: "Induced travel is caused by population growth."

Obviously, not all increases in travel are due to induced demand. Induced travel demand is only the increases in total VMT beyond that which would normally occur as a result of:

- population, household and jobs growth;
- increased income;
- increased vehicle ownership;
- fuel price changes;
- increased workforce participation; and
- other demographic characteristics.[7]

Transportation planners generally already account for some increased transportation demand due to exogenous factors separately.

Incorporating induced demand would lead to even higher levels of growth.

2.4 Induced demand differs from latent demand in that it did not exist before the transportation improvement was implemented.

It is also difficult to tease out induced demand from latent demand which is released when an improvement in travel conditions is implemented. Conceptually, latent demand is demand that already exists under original conditions, but is suppressed because consumers are unwilling or unable to pay the current price (including travel time) to use the facility. This unaccommodated demand is released when a transportation improvement takes place. Some traffic planning experts also refer to latent demand as induced *traffic*.[8] Induced *travel*, however, is new demand that did not exist before the improvement but is brought on by the improvement.

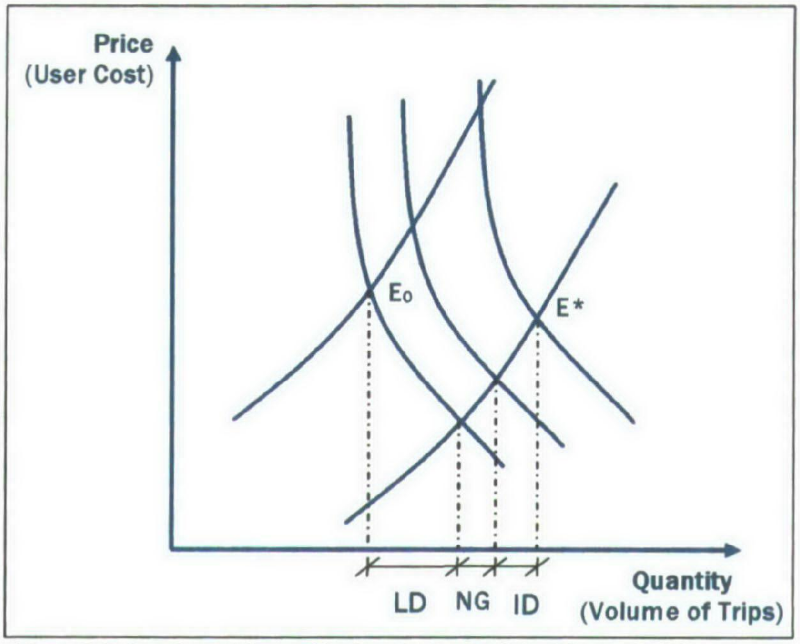

Figure 2.6: Supply and demand for travel, showing latent demand (LD) (sometimes known also as "induced traffic"), natural growth (NG), and induced demand (ID).

Induced travel results in long-term traffic growth which is higher than that anticipated from conventional assessments of travel demand and regional growth.

2 What is induced travel demand?

On an economic supply-demand diagram, latent demand is seen as increased traffic resulting from movement along the original demand curve (LD), whereas induced demand (ID) and natural growth (NG) are increases in traffic owing to an outward shift in the demand curves, as shown in Figure 2.6.

Common misconception 3:
"Induced travel demand is simply the increase in demand that occurs when the price of a commodity is lowered."

Induced travel demand is not simply the increased use of transportation facilities which occurs when the price of a commodity is lowered. As depicted in Figure 2.7, this definition would describe latent demand in the short-term (or the sum of latent demand, induced demand and natural growth in the long-term).

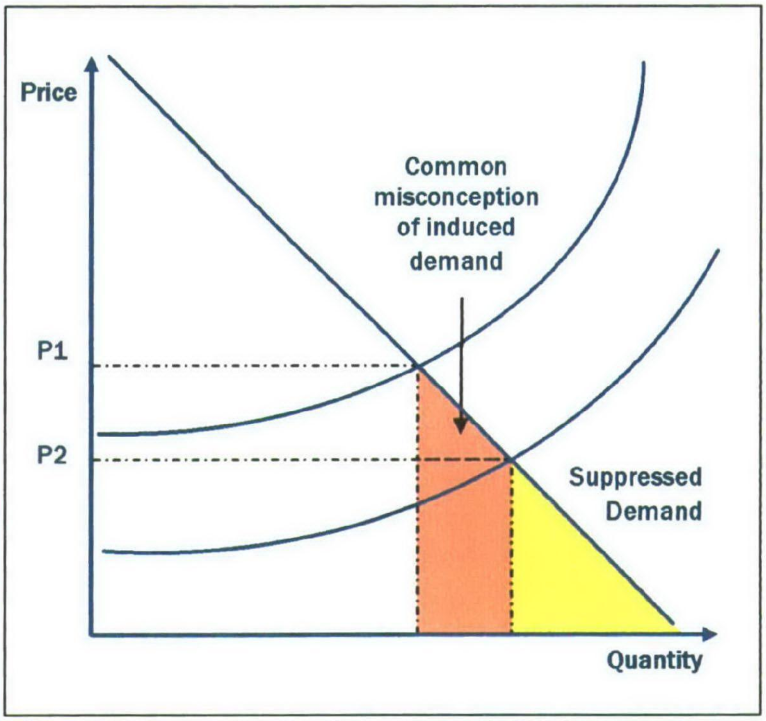

Figure 2.7: Many people confuse induced demand with latent demand as illustrated in this transportation supply and demand diagram.

Rather, induced demand is the increase use of transportation facilities due solely to an increase in capacity or improvement in travel conditions. Some of this increase may be taken into account by current travel demand forecasts, while some may not.

2 What is induced travel demand?

⊙ Case Study I

Filling up faster: The I-270 Highway Expansion, Washington, D.C.

In the Washington, D.C. region the issue of induced travel became a part of public debate after publication of a Washington Post article regarding the I-270.[7] This freeway runs from Washington DC's Capital Beltway to the outlying areas of Montgomery County, Maryland. In 1989, the state and federal governments attempted to alleviate serious regional traffic congestion along the 6-lane freeway by funding a $200 million project to expand a 13-mile segment of the freeway up to 12 lanes.

According to travel forecasting results, transportation planners expected the I-270 expansion to provide sufficient capacity for the next twenty years. However, trip generation projections did not account for the project's effect on induced travel demand and accelerated housing and commercial development of areas along the corridor.

By 1999, traffic counts along the I-270 exceeded those predicted for 2010, and traffic congestion had already returned to unacceptable levels.

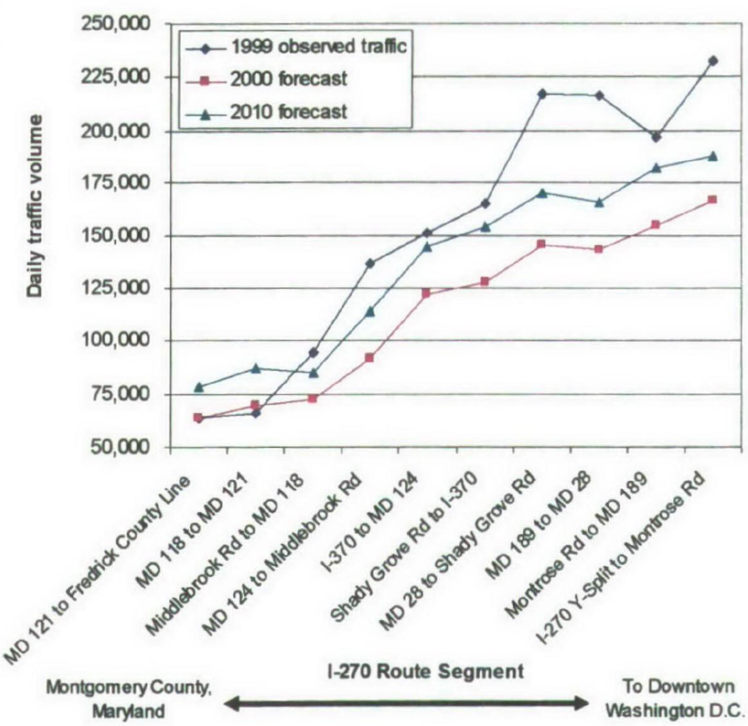

Figure 2.8: Observed and forecast traffic along the I-270.
Source: Washington Metropolitan Council of Governments, 2001

2 What is induced travel demand?

⊙ *Case Study I*

Filling up faster: The I-270 Highway Expansion, Washington, D.C.

The initial travel forecasts were presented in a 1984 study by the Maryland State Highway Administration on traffic impacts of widening the I-270 between the I-270 Y-Split and Route 121. This study used travel demand models developed cooperatively by the Metropolitan Washington Council of Governments (WashCOG). It predicted that daily traffic volumes at the I-270 Y-Split would grow to 166,200 by 2000 and 187,900 by 2010. In 1999, however, observed traffic counts at the Y-Split already reached 232,300, therefore exceeding both the 2000 and 2010 forecasts by 140% and 124% respectively. In several other segments along the route, observed traffic counts in 1999 exceeded 2000 and 2010 predictions by more than 150% and 120% respectively.[10]

Figure 2.9: Road expansion may have resulted in induced travel in the Washington, D.C. area.

In response to public debate surrounding the I-270, the United States Environmental Protection Agency requested that induced demand effects be included in future transportation improvement programs (TIPs) and regional plans. Additionally, WashCOG commissioned external and internal studies to assess the extent to which induced travel demand is factored into regional travel models. The Transportation Planning Board (TPB), the MPO for the Washington D.C. Metropolitan region, also requested that staff examine the issue of induced travel and its inclusion in regional travel forecasting.

Analysis of growth patterns across the Washington D.C. region revealed that regional population, household and employment was significantly

⊙ *Case Study I*

Filling up faster: The I-270 Highway Expansion, Washington, D.C.

higher than forecast along the I-270 corridor, and lower than forecast in several other areas such as the District of Columbia and Arlington County, Virginia. Higher than anticipated traffic volumes along the I-270 corridor subsequent to its expansion were therefore thought to be due largely to shifts in population employment and travel from other areas in the region, rather than entirely new travel.

WashCOG concluded that their travel forecasting model did indeed capture induced travel effects, but it was difficult to separate these effects from other increases in travel. The model covered some categories of induced travel including shifts from one mode to another; changes in travel by time of day; and travel changes resulting from changed demographic and socio-economic factors.

What was not covered in the WashCOG model were new trips generated as a result of increased road capacity and long-term land use changes that would not have otherwise occurred. WashCOG argued that there was a lack of evidence for any measurable change in short-term trip generation. They also claimed that long-term trip generation responses were addressed through inputs of new development patterns to the transportation planning model. Finally, they argued that the model accounted for new longer trips by sending some trips to more distant destinations, or along longer (but faster) routes. Despite its inability to predict traffic volumes to within 30% of actual volumes in several route segments, the reviewers concluded that the travel demand model employed for the I-270 was "State of Practice".

The I-270 expansion brought public attention to the issue of induced travel demand where higher than anticipated traffic growth was observed after the expansion. This issue highlighted the interaction between increased highway capacity and regional land use development. Subsequent analysis demonstrated the difficulty of

3 How does induced travel demand occur?

3.1 Induced travel demand results from immediate, near-term, and long-term reactions to increased transportation capacity.

For every action there is a reaction. Increasing transportation system capacity contributes to travel time savings. In response to travel time or cost savings, people react by making immediate, near-term and long-term changes to their travel behavior (see Figure 3.1).

In relation to highway transportation, these reactions speed up the rate of traffic growth both directly and as a result of changes to land use patterns. This traffic growth then makes peak-hour traffic congestion return to unacceptable levels earlier than anticipated by travel demand models which do not account for induced demand. It may also result in higher overall rates of travel than previously anticipated, leading to greater emissions of local pollutants and greenhouse gases than forecast. Depending on how rapidly congestion returns as a result of induced demand, transportation air emissions may be further exacerbated by that congestion.

"Highway capacity additions that reduce travel time and the day-to-day variability in travel time will induce increased highway use as long as travel times are shorter and the reliability of motor vehicle time is improved, all else being equal"[1]

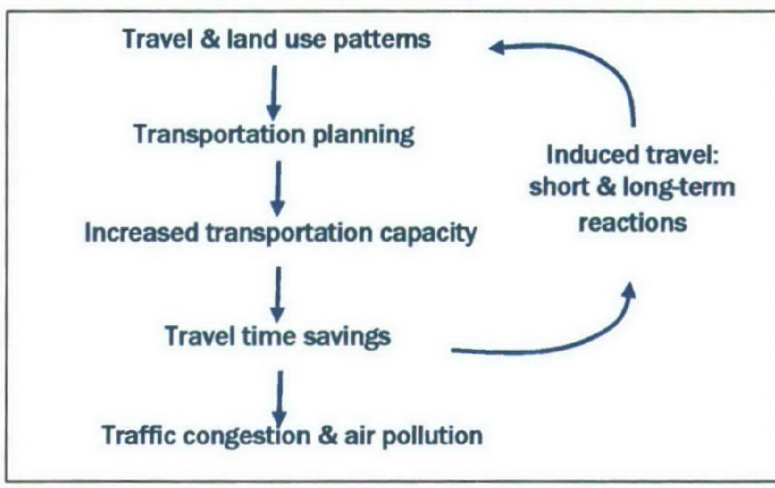

Figure 3.1: Following an increase in transportation capacity, induced travel speeds up the rate of traffic growth so that congestion returns to unacceptable levels earlier than anticipated.

Derived Demand: the demand for a good resulting from the need to achieve some other objective.

Demand for travel is a **derived demand**, meaning that people almost never travel for the sake of transportation itself (i.e. for a joyride) but in order to achieve some other objective and access opportunities for mutual exchange.[2] For example, people may travel to

3 How does induced travel demand occur?

their place of work, education, shopping, leisure or worship, in order to facilitate a mutual exchange of economic or other goods: information, knowledge, wealth, friendship, culture, goodwill, and emotional and spiritual support. Since the demand for other goods and opportunities is only indirectly affected by changes in the transportation system, it is difficult to predict the effect of transportation system changes on travel demand and behavior.

Changes in people's travel behavior occur on three levels: immediate, near-term and long-term.

> **According to the United States Department of Transportation:**
> **"As a highway becomes more congested, the cost of traveling the facility (i.e., travel time costs) increases, which tends to constrain the volume of traffic growth. Conversely, when lanes are added and the highway user costs decreases, the volume of travel will tend to increase."[3]**

In the short-run, people can make a number of immediate adjustments to their day-to-day travel patterns but changes in short-run travel demand are limited. People's demand for other goods is only indirectly affected by changes in the transportation system, and is constrained by factors such as the location of people's housing, schooling and work as well as structural economic, technological and social factors. Transportation costs are just one of many costs involved in accessing goods and opportunities, so while travel time savings reduce the cost of accessing goods and opportunities, it is difficult to predict how much effect this saving will have on overall travel demand.

In the long-run, people are able to make more fundamental changes in their demand for other goods and respond to wider changes in economic activities such as employment shifts. Induced travel demand arising from changes in travel conditions are therefore greater in the long-term.

Mechanisms behind immediate, near-term and long-term changes in travel demand that occur in reaction to transportation improvements are spelt out in the following sections. Since the bulk of analysis regarding induced travel demand has occurred in relation to projects which increase highway capacity, the discussion will mainly focus on these types of transportation changes.

3.2 Immediate traveler reactions include changes in time of day, route and mode of travel.

People respond immediately to an increase in highway capacity in three ways that contribute to continued congestion:

- changing their time of departure to switch from non-peak to peak hour travel (time convergence);
- changing their route to take advantage of added capacity on the improved roadway (spatial convergence); and
- switching their mode of travel from carpooling to driving alone, or from transit to driving (modal convergence).

Figure 3.2: People respond immediately to increased highway capacity through time convergence to peak hour traffic.

This **"triple convergence"** of travel behavior reactions has been used by Downs and other researchers to explain the difficulty of removing peak-hour congestion from highways, especially where the existing equilibrium conditions are already congested.[4]

While a traveler may not increase individual VMT by adjusting their departure times or selecting a different travel route, the changed behavior will tend to have secondary effects that lead to increased VMT in the aggregate. The off-peak traveler who switches to peak travel time reduces congestion during off-peak travel times. This switch may then induce other travelers to make new trips during the off-peak period since the travel cost during this time is now less. The same is true in the second scenario where an individual switches routes. That is, the original route of the individual who shifted routes is now less congested, reducing the travel cost for others and inducing additional trips along the original route.

3.3 Near-term reactions include changes in trip destinations and trip grouping.

In addition to immediate reactions, individuals may also respond to increased highway capacity in the near-term. Here, the near-term is defined as the period during which the location of people's housing, schooling and work remain fixed.[5] People's near-term travel demand reactions include:

- changing some of their trip destinations entirely and traveling further to reach them;

- taking separate trips to carry out different errands and activities instead of making stopovers and grouping trips together; and
- making more trips to new places.

Given that additional highway capacity increases travel speeds and reduces travel costs, some drivers respond in the short-term by traveling faster but taking longer routes and seeking further destinations. For example, after a highway is expanded, an individual might find it more convenient to drive to a national chain store instead of shopping at the local hardware store. This change increases the individual's driving distance.

Some drivers may also choose to "unlink" trips in response to an increase in highway capacity. When congestion is heavy and traffic speeds are low, drivers may minimize their time in traffic by linking a number of destinations in sequence. When a highway improvement relieves congestion and increases travel speeds, an individual may unlink trips and make more separate trips to a single destination. This change increases their vehicle miles traveled (VMT) and contributes to traffic congestion.

Table 3.1: Immediate and near-term behavior changes that promote continued traffic on improved transportation facilities.

Rescheduled Trips	Adjusting departure times in response to facility improvement, spreading or contracting peak hour travel
Changed Routes	Diverting from previous route to improved facility
Mode Shift	Switching from public or alternative transit modes to private passenger vehicles because of improved facility
Destination Shift	Altering destination because of facility improvement
Changed Trip Grouping	Changing the way that trips are grouped together, unlinking trips to different places and for different purposes in response to the facility improvement
Destination Addition	Traveling to entirely new destinations because of facility improvement

3.4 Long-term term reactions include changes in car ownership, location and land use.

In the long-term, transportation development encourages more fundamental changes to people's behavior, in parallel with changes in the location of their activities or housing, and patterns of land use and infrastructure development.

Transportation projects that make historically un- or under-developed areas more accessible, reduce travel and goods transportation costs to these areas. This cost reduction increases the viability of living or carrying out activities in these areas, and undertaking economic or urban development. Subsequently, a number of things can happen over and above what would normally occur in the absence of the transportation improvement:

- individuals relocate their homes to more outlying areas;
- employees change their work location to more outlying areas;
- employers move their businesses to more outlying areas as office, industrial and technology parks are developed;
- developers accelerate land use development of residential neighborhoods, retail centers, and office, industrial and technology parks in outlying areas; and
- households increase their automobile ownership by buying a second or third car.

Photo: Wayne Senville. Copyright Planning Commissioners

Figure 3.3: Retail development in freeway-based suburbs is accessible almost exclusively by private motor vehicles, Williston, Vermont

All these activities have the potential to lead to longer commute or trip distances as people move further out to live and/or work in existing exurban settlements or newly developed areas which have been made accessible by transportation capacity improvements. In many cases, this locational shift is accompanied by a decrease in mass transit usage due to the low density and absence of major mass transit systems in many outlying areas of U.S. metropolitan regions. Furthermore, with a greater proportion of activities being undertaken in these outlying areas, more motor vehicle trips may be required to carry out normal daily activities, such as shopping, because these newly developed areas are often served by "big box" retail developments, accessible almost exclusively by private motor vehicles.

In cases where induced travel demand occurs in relation to major transit improvements, such as rail access to Metropark, New Jersey, complex intermodal effects may occur. Greater transit access would tend to result in increased transit ridership to the area. Given this improved access, it may also result in some induced highway trips as it becomes more viable to carry out activities in the area and linkages to different places are strengthened, or the area develops into a key regional location.

Common misconception 4: "All induced travel represents a net cost to society."

Induced travel may be seen as a cost to both individuals and society. Increased VMT is associated with higher fuel costs, travel time costs, vehicle emissions and impacts. Induced travel arising from transportation improvements may therefore reduce the expected benefits and shorten the effective life of such projects.

On the other hand, induced travel may also allow individuals to access new areas and opportunities for economic and other exchange activities thereby bringing about social benefits. In order to understand whether induced travel represents a net cost or benefit to society, it is necessary to compare costs to the benefits that accrue from induced travel on a case by case basis.

Common misconception 5: "Induced travel is synonymous with urban sprawl."

Some argue that induced travel is wasteful travel brought on by overly-dispersed patterns of land use development, known as urban sprawl. These land use patterns necessitate large amounts of highway development, infrastructure and automobile use, while discouraging more efficient and multi-modal transportation patterns such as those experienced in central cities with extensive transit systems.[6] As development occurs on the fringes of metropolitan regions, traffic is attracted to more far-flung areas of exurban residential development, suburban office parks and edge cities locations. This "centrifugal" force encourages increases in highway capacity and the generation of some induced travel demand.

Not all induced travel however is attributable or connected to sprawl. Induced travel arises as a result of changes to the transportation system which may or may not serve areas of sprawled metropolitan development. Induced travel along a highway expansion in a region of constrained urban growth, for instance, primarily reflects changes in people's travel behavior and not sprawl.

4 What is the evidence for induced travel demand?

4.1 Verification and estimation of induced travel demand requires counterfactual research.

Demonstrating the existence and magnitude of induced travel demand effects is a complex exercise which involves evidence of the travel outcomes of transportation changes as well as counterfactual evidence of what would have occurred if the transportation change had not occurred. This counterfactual evidence can be assessed by examining comparable transportation facilities which did not undergo change, or by comparison to historic traffic growth along the facilities prior to the change in conditions.

Photo: Oregon Department of Transportation

Figure 4.1: Induced travel demand can be assessed from studies of road expansions and closures.

In most cases efforts to understand induced travel demand measure observed the traffic outcome of transportation improvements against forecasts of likely travel demand which could be expected to occur without the improvement. Some research has also taken the reverse approach, whereby travel demands are assessed following a reduction of capacity such as a bridge collapse or road closure.

Given the complexity of understanding transportation as a derived demand, it is even more difficult to accurately assess counterfactual impacts of changed travel conditions on this derived demand.

4.2 Research in the United Kingdom and United States confirms the existence of induced travel demand.

Research on induced demand has been conducted for several decades. Historic research has focused on establishing the existence of induced demand, while contemporary research focuses on the magnitude of this phenomenon.

A pivotal point in the history of induced demand research was the release of a 1994 report on "Trunk Roads and the Generation of Traffic" by the Standing Advisory Committee on Trunk Road Assessment (SACTRA) in the United Kingdom. This report highlighted the weaknesses of traffic forecasting procedures used at the time. These weaknesses were demonstrated in traffic observations of specific corridors that had undergone capacity increases. SACTRA found that traffic in these corridors consistently grew at an unexpectedly high rate. It postulated that this growth was not due entirely to exogenous factors such as increased income or GDP and concluded that induced travel is a "real phenomenon" and can af-

4 What is the evidence for induced travel demand?

"Research has not only built a strong case for the existence of induced travel effects, but in some cases suggests that a large fraction of growth in vehicle miles of travel (VMT) is directly attributable to increases in road capacity."[2]

fect the economic evaluation of a transportation project.[1]

Numerous United States studies also confirm the existence of induced travel and point out the inability of current forecasting models to accurately account for it. These include studies by Hansen & Huang (1997), Fulton, Noland, Weszler and Thomas (2000) and Cervero (2001). In some cases, the various sources of induced travel demand are not only found to be in existence but, in the aggregate, comprise a significant proportion of increased travel along the affected routes.

The Transportation Research Board reported in 1995 that most modeling procedures do not adequately capture induced travel effects.[3] Some researchers used econometric techniques to demonstrate the statistical significance of the induced demand phenomenon and to quantify its magnitude. These and other studies yield a range of values for the short- and long-term effects of induced travel demand as it relates to increased roadway capacity, measured in terms of elasticity of demand.

✗ ***Common misconception 6:***

"The amount of induced travel that occurs is so insignificant that it is not a matter of concern"

Research has found that a large fraction of growth in vehicle miles traveled (VMT) is induced travel. Induced travel has been assessed in 50 states and 70 major metropolitan areas in the United States. From these assessments, an estimated average of 10-30 percent of total historical growth in VMT can be attributed to induced travel. In many cases the estimated contribution of induced travel to VMT growth is substantially higher.[4]

Many of the factors which contribute to growth in travel are associated with immediate, near-term and long-term reactions which result in induced travel demand. These factors include:[5]

- Increased Number of Trips Taken (18% contribution to growth in VMT)
- Increased Trip Lengths (35%)
- Decreased Vehicle Occupancy (17%)
- Switching to Driving (17%)
- Increased Population (13%)

4 What is the evidence for induced travel demand?

Studies indicate that a 10 percent increase in highway capacity within a metropolitan region or state results in a 3-5 percent increase in VMT over 1-2 years. A 10 percent increase in highway capacity results in a 5-9 percent increase in VMT over 10-20 years.[6,7] This induced travel can have a significant effect on overall traffic performance.

Common misconception 7: "All (or almost all) traffic that appears on new or widened highways is induced travel"

Some highway skeptics witness congestion on newly built or widened highways and attribute all the new traffic to the highway expansion. Research shows us that the majority, and often the great majority of new traffic is not caused by induced travel but population growth, land use patterns, and economic activity.[8]

Induced travel therefore comprises a significant proportion on traffic growth but is outweighed by other sources of traffic growth such as population and income growth.

While many widely-held and contradictory misconceptions exist in relation to induced travel demand, research indicates that induced travel is not the source of all new traffic, nor is it so small that it can be ignored. Evidence for induced demand indicate that 10 to 30 percent of total historical growth in vehicle miles of travel is attributable to induced travel.[9]

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5 Can induced travel demand be measured?

5.1 Short-term and long-term induced travel effects are reflected in short-run and long-run elasticities for travel.

$$\text{Travel Demand Elasticity} = \frac{(\%\text{ change in demand for good})}{(\%\text{ change in price of good})}$$

Induced demand is generally quantified through some measure of the elasticity of travel demand with respect to travel time, generalized cost or capacity.

Economists use the term **"elasticity of demand"** to refer to the percentage change in the quantity demanded for a good divided by the percentage change in price. For example, an elasticity of demand of 0.2 means that for a 1% decrease in price, there is a 0.2% increase in quantity demanded. If the short-run demand elasticity for travel is zero, or inelastic, then traffic volumes are completely unresponsive to changes in price and the demand curve is vertical. Even if the cost of travel changes, individuals will not change their behavior in response to the price change.

In general, short-run demand elasticity for travel is less elastic than the long-run demand elasticity. Individuals can do more to change their behavior over the long-run and thus have a greater impact on the total quantity demanded than they can in the short run. For example, if gas prices increase significantly, individuals cannot respond immediately in as drastic a way as they can in the long run because they still need to drive to engage in the activities they organized before the price increase. In the long-run, however, they may make behavioral changes, such as switching to public transportation, moving to a location closer to work, or purchasing a more fuel-efficient vehicle to lower their fuel consumption.

5.2 There is a range and variation in estimation of travel demand elasticities.

A specific value for short- and long-run elasticities in any given situation is difficult to establish because it depends on characteristics which are local or individual in nature e.g. income, comprehensiveness of regional mass transit systems, other factors.

Finding a consistent value for travel demand elasticity is complicated by the fact that studies completed to date have differences with respect to:

- methodologies used;

"Price elasticity mitigates to some extent the beneficial aspect of making highway improvements. For example, improving a segment lowers travel costs, some drivers may respond by driving more frequently. As a result, traffic on the improved segment may increase more quickly than anticipated, reducing the future benefits of the improvement."[1]

- data sources;
- time periods; and
- area scales (county, metropolitan region, and state).

Given limitations in datasets and variations in local conditions and study parameters, there are limitations to the conclusions that can be definitively drawn from any one study.

5.3 Travel demand elasticity can be quantified with respect to highway capacity or travel time.

A cumulative assessment of studies demonstrates that the impact of induced demand is considerable and can be seen through a number of elasticity measures. A general range of values for elasticity has also emerged from the studies and can be seen below. Studies suggest that travel demand elasticities fall in the range of 0.3 to 0.5 in the short-run, or 0.5 to 0.9 in the long-run. This range of values can be useful in forecasting models and performing sensitivity analyses to assess how sensitive the net benefit of a project is to the incorporation of induced travel.

Table 5.1: Elasticities of travel demand with respect to lane miles of roadway

Study	Scale	Elasticities	Elasticities
		Short-run	Long-run
Cervero & Hansen, 2000	County	0.6	n.a.
Fulton, Meszler, Noland & Thomas, 2000	County	0.1-0.4	0.5-0.8
Hansen & Huang , 1997	County	0.3-0.7	0.6-0.7
Rodier et al., 2001	Metropolitan Area	0.8	1.1
Noland & Cowart, 2000	Metropolitan Area	0.6-0.8	0.8-1.0
Hansen & Huang, 1997	Metropolitan Area	0.5-0.9	0.9
Johnston & Ceerla, 1996	Metropolitan Area	0.6-0.9	n.a.
Noland, 2001	State	0.3-0.6	0.7-1.0

n.a. = not available / undetermined

5 Can induced travel demand be measured?

As seen in Table 2, there is a wide variation in estimated demand elasticity with respect to transportation capacity (lane miles). Better agreement is observed in studies of demand elasticity with respect to travel time savings. The latter approach however is considered only a partial estimate of demand elasticity since travel time savings represent the intermediate step between increased transportation capacity and increased traffic volume.[2]

Induced demand occurs through the following sequence:

Capacity increase
↓
Travel time savings
↓
Induced travel demand

The greater accuracy of demand elasticity measured with respect to travel time savings is also due to the fact that travel time savings provide a more direct indication of the change in cost to users than capacity chages. The relationship between investment in transportation capacity and travel time savings on the other hand is complicated by the variety of possible user responses and the wide range of conditions under which transportation investment occurs.

Despite data limitations and variations in estimates of elasticity, studies in the U.S. and U.K. find that the theory of induced travel can not be refuted and plays a significant role in travel demand behavior.[3] Provide additional roadway and people will alter their behavior and drive more. Estimates of the percentage of annual growth in VMT which are attributable to capacity increases are in the range 10-30 percent.[4,5] The question now is how to incorporate this body of knowledge into practice.

⊙ Case Study II

Congestion and controversy: The Legacy Highway, Salt Lake City, Utah

The issue of measuring induced demand impacts came to a head in the Salt Lake City Area following the release of the Environmental Impact Statement (EIS) for the Legacy Highway.

The **Salt Lake City Area**, consisting of Salt Lake and South Davis Counties, is an area of rapid population and employment growth. Between 1970 and 1991 the area grew 62% in population and 106 percent in employment. Between 1990 and 2015, it is expected to grow an additional 49 percent in population, 63 percent in employment and 200 percent in land area. This growth has major implications on expected traffic congestion and regional infrastructure needs including highway and transit facilities.[6] In the five counties along the eastern shore of the Great Salt Lake, population and travel growth are expected

5 Can induced travel demand be measured?

⊙ Case Study II

Congestion and controversy: The Legacy Highway, Salt Lake City, Utah

to grow by 60 percent and 69 percent by 2020 respectively.[7]

In response to predicted rates of regional growth, proposals were accelerated for the **Legacy Parkway**, to run north and south from Salt Lake City.[8] This four-lane 14-mile highway, initially known as the West Davis Highway, was one segment of the 120-mile Legacy Highway proposed in the 1960s. In 1996, Utah's Governor Leavitt announced long-range conceptual plans for the Legacy Highway and immediate development plans of the Legacy Parkway. Along with expanding the I-15 and expanding transit, the Legacy Parkway was one part of a three-part "Shared Solution" for travel growth in the area from Salt Lake City and stretching along the eastern shore of the Great Salt Lake.

As the Parkway project underwent planning and the process of preparing an environmental impact statement (EIS) under the National Environmental Policy Act (NEPA), it sparked controversy among tax payer and environmental groups. The Sierra Club and others raised concerns regarding the **traditional travel forecasting models** used, and impacts on wetlands. As a result, the EPA rated the project's 1998 Draft EIS as EU-3 (environmentally unsatisfactory—inadequate),[9] and the Federal Department of Transportation convened a panel of transportation practitioners to peer review the Wasatch Front Regional Council (WFRC) travel demand model.[10]

The **peer review panel** acknowledged the importance of induced travel demand effects and made a number of recommendations to better incorporate integrated regional transportation issues. These included:

- Incorporating an auto ownership model to reflect urban design and accessibility;
- Documenting travel demand model assumptions and validation; and
- Convening a travel demand model steering committee.

Two of these recommendations were incorporated into the project's revised travel demand model. This model forecast a decrease in VMT for the highway alternatives examined thereby **contradicting evidence on induced travel**.[11] Revised model results were incorporated into a Final EIS, which came to the same conclusions as in the Draft EIS and was released in July 2000.

5 Can induced travel demand be measured?

⊙ *Case Study II*

Congestion and controversy:

The Legacy Highway, Salt Lake City, Utah

In October 2000, the Federal Highway Administration approved the Parkway project but construction was stalled by lawsuits, appeals and an injunction. A case by the Sierra Club which included claims of inadequate traffic forecasts was dismissed by District Judge Bruce Jenkins in August 2001, however the decision was appealed in November 2001. In September 2002 the case appeared before the 10th Circuit Court in Denver. The court found that the travel demand model used did not render the Final EIS inadequate, but the Final EIS was rendered inadequate for a number of other reasons. These included a failure to consider impacts to wildlife such as migratory birds; and a failure to properly consider alternatives including an alternative alignment, alternative sequencing of transit and highway options, and integration of highway and transit options.[12]

The Legacy Parkway case demonstrates the increasing public and stakeholder interest in travel demand and land use issues surrounding major transportation investments. This case refers to many of the concepts surrounding induced travel demand and highlights the need for more thorough analysis of alternative investments and environmental impacts. The case highlights the emergence of what may be seen as a national campaign to bring major highway projects under greater scrutiny with respect to the way that they predict future travel demand and impacts. In this context, the measurement and estimation of induced travel demand is likely to become an increasingly prominent issue surrounding future transportation investment decisions.

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6 How does induced travel demand relate to metropolitan development patterns?

6.1 Perceptions of induced travel demand and urban growth issues are often intermeshed and confused.

Induced travel demand highlights the interconnected and complex relationship between transportation investment, urban travel and land use development. For this reason, induced travel demand is often raised as an issue in the debate surrounding patterns of urban transportation and land use development. Though related, the two issues of induced travel demand and urban sprawl often become confused and intermeshed in the growing debate regarding the shape and function of metropolitan regions.

According to the European Environment Agency, urban sprawl is defined as:

> "The physical pattern of low density expansion of large urban area under market conditions into the surrounding agricultural areas. Sprawl lies in advance of the principal lines of urban growth and implies little planning control over land subdivision. Development is patchy, scattered and strung out with a tendency to discontinuity because it leap-frogs over some areas, leaving agricultural enclaves."[1]

Photo: James Howard Kunstler

Figure 6.1: Highway-based urban sprawl is characterized by low density development, separated by roads and parking lots

In the United States, sprawl is characterized by "the conversion of natural or agricultural land to low-density residential enclaves, commercial centers, and business parks, all separated from one another by roads and parking lots."[2] As suggested in these definitions, transportation plays an important role in relation to urban sprawl, however, the two issues are not synonymous.

6.2 Transportation infrastructure provides a skeletal structure for patterns of metropolitan growth such as urban sprawl.

Transportation has always played an important part in the shape and growth of urban areas. The supply of transportation capacity, whether through non-motorized transportation, rail and transit facilities, or road infrastructure, provides a physical skeleton around which metropolitan development can occur. Transportation corridors also act as conduits which reduce travel costs and allow people to access more remote areas on the edge of existing settlements, inducing travel demand. In this way, transportation investments such as rail lines and highways facilitate greater travel and the outward expansion of urban areas.

6 How does induced travel demand relate to metropolitan development patterns?

Common misconception 8:

"Highway construction is entirely unrelated to urban sprawl."

According to the United States Department of Transportation:[3]

"In the longer term...if travel time in an area is reduced substantially for an extended period of time, some people may make different choices about where to purchase a home. If congestion is reduced, purchasing a home far out in the suburbs might become more attractive, since commuters would be able to travel further in a shorter period of time." Highway construction therefore contributes to dispersion and development of new areas on the fringe of metropolitan regions by reducing travel times and improving accessibility to these areas.

In Orange County, California, it was found that "new highways change the geographic pattern of accessibility, that those changes are reflected in [increased] home sales prices, and thus that it is reasonable to conclude that new highways will also create changes in development patterns."[4] The provision of additional highway and transportation capacity, is therefore an important key in growth of travel demand and the development of metropolitan regions.

It should be noted that not all urban sprawl associated with highway investment. Other transportation modes such as rail infrastructure, have a similar effect on encouraging travel and land use development to new locations made more accessible by the transportation system, although rail-based decentralization tends to be of a higher density than that normally considered as "sprawl".

Photo: Ria Hutabarat

Figure 6.2: Highway-based development at the urban fringe such as that in Reston, Virginia, is not necessarily characterized by low-density sprawl.

Additionally, not all highway investment is associated with the type of low density land use development described as urban sprawl. In some cases, a design choice is made to promote more efficient, higher density or pedestrian-oriented communities in areas which were made accessible by highway development. This pattern of development can be seen in Reston, Virginia.

The debate surrounding induced travel demand and urban sprawl is often centered around the issue of net costs versus benefits to society. Some argue that urban sprawl facilitated by transportation investment, represents a rational market response to the demand for transportation services from areas with latent demand for land use development and economic growth. They therefore argue that induced travel may represent an economic benefit associated with increased development in new urban areas. On the other hand, low density development and induced travel which represents unnecessary travel is associated inefficient use of urban infrastructure, widespread environmental impacts and wasteful resource consumption. The balance of costs or benefits should be assessed on a case by case basis with regard to local conditions.

6.3 Land use impacts of additional transportation capacity are greatest in areas where there is less pre-existing transportation infrastructure.

Where a dense network of roads, freeways or other transportation infrastructure already exists, the impact of a single increment of highway capacity on travel demand and land use change is relatively small. However, growing medium sized metropolitan areas appear to experience the greatest induced travel effects.

The reason for this difference may be that fast growing areas often have high levels of traffic congestion, and therefore larger amounts of constrained or suppressed travel demand that is released when additional highway capacity is added. Also, these growing areas tend to add more highway capacity to their network in order to keep up with rapid growth. Ironically, these larger increments of highway capacity have the potential to result in even greater induced travel, thereby accentuating the difficulty in keeping up with traffic growth.

Stronger induced travel demand effects observed in areas with less transportation capacity redundancy, reflects a two-way causal link that has been confirmed in statistical studies of induced travel demand.[5] In this relationship, increased highway supply has been found to cause increased traffic levels, while higher traffic levels also cause greater investment in highway capacity.

The relationship between induced travel and more dispersed patterns of metropolitan transportation and land use development suggests that decision regarding highway and transportation expansion, and congestion management need to account for induced travel and potential consequences in terms of accelerated land use development and urban sprawl.

6.4 Urban sprawl is influenced by non-transportation elements such as economic, policy, technological and social factors.

Transportation capacity is not the sole factor influencing land use development, and may be more of a facilitator than a director of land development patterns. Transportation goes hand in hand with many other factors which contribute to increased travel demand, land use development and urban sprawl. These factors are summarized below:[6]

- Rising income levels have been correlated with higher levels of suburban growth and vehicle ownership;
- The maintenance of low fuel prices has promoted widespread automobile ownership and usage, and made more remote areas more accessible;
- Government policies such as federal tax and mortgage policies, made suburban homeownership viable and promoted new residential development away from the urban core;
- The adoption of mass production techniques in the automobile and housing construction industries has made car ownership and suburban home ownership more affordable;
- Service-sector development and dispersed metropolitan land use development favored horizontal manufacturing structures and diminished reliance on centralized locations;
- Development of information technology and advanced manufacturing processes, as well as trends toward outsourcing and globalization of industries, have uncoupled components of economic production and reduced the need for geographic proximity thereby allowing more dispersed production processes.
- State and local zoning laws and regulations promoted development of low density, racially segregated suburbs;
- A lack of state or regional coordination of land use regulation, coupled with the NIMBY syndrome has encouraged businesses to grow in less populated, less regulated, and even unincorporated, areas at the urban fringe; and

6 How does induced travel demand relate to metropolitan development patterns?

- Political fragmentation of local government has also allowed people and businesses to distance themselves from the burden of inner city social and fiscal problems by moving their homes and businesses to the suburbs and beyond.

Urban sprawl is certainly related to induced travel demand arising from increased transportation capacity. However, it also affected by many other economic, policy, technological and social factors which also favor more dispersed residential, commercial and industrial development and increased overall levels of travel.

⊙ ***Case Study III***

Linking highway lanes and land use:

The I-355 Tollway Extension, Chicago,

The Chicago Metropolitan Area is experiencing **rapid transportation growth and urban sprawl**. Will County, situated about 40 miles southwest of Chicago, is on the edge of the Chicago Area and comes under the ambit of the Chicago Area Transportation Study. The County has a population of about half a million and is the third fastest growing county in Illinois, predicted to grow by 200% between 1995 and 2020.[7,8]

To alleviate the pressure of population and traffic growth in the Chicago Area, the **I-355 south extension** was proposed to provide a north-south link between Chicago's radial network, the I-55 and Will County. This 12.5-mile, multi-lane highway project was initially put forward in 1962 and revisited in the late 1980s through a series of public meetings and formal hearings. It was promoted as a means of addressing anticipated congestion in Will County, reducing travel times, and harnessing economic development for an additional 42,000 jobs over ten years.

The Federal Highway Administration (FHWA) released an EIS for the project in 1996. This document adopted traditional traffic analysis techniques with a single trip table and the simple assumptions of no land use change and no travel pattern change. These **land use and travel pattern assumptions** ignored induced traffic effects and were questioned by various citizen and environmental groups including the Illinois Chapter of the Sierra Club. These groups filed a lawsuit against the Illinois Department of Transportation (IDOT), Illinois State Toll Highway Authority, and FHWA in the Federal District Court.[9]

In January 1997, U.S. District Judge Suzanne Conlon rejected the EIS for the I-355 extension claiming that the transportation agencies had failed to take seriously the project's alternatives and environmental impacts.

6 How does induced travel demand relate to metropolitan development patterns?

⊙ *Case Study III*

Linking highway lanes and land use: The I-355 Tollway Extension, Chicago, Illinois

The District Judge stated that "environmental laws are not arbitrary hoops through which the government must jump"[10] and required the agencies to consider the effects of highway construction on development by tying its analyses of alternatives to corresponding socioeconomic and land use forecasts.[11]

After a two-year legal battle against this decision, the IDOT conceded to carry out further analyses of alternatives including updated traffic forecasts, additional analysis of transportation needs and alternatives, and assessment of population impacts.[12] These were outlined in the project's Draft Supplementary EIS released in 2001.[13]

The latter study came to the same conclusion as the former - favoring the southern extension of I-355 - and was approved by Federal Highway Administration in February 2002.

The I-355 project highlighted a number of issues concerning the link between transportation and land use development. Environmental impact assessment requirements were used in relation to this project as a platform for expressing dissatisfaction with conventional transportation planning approaches that fail to account for highway development impacts on urban sprawl. The case demonstrated the demand for new approaches to transportation analysis that acknowledge land use interactions and induced travel demand effects.

7 How can planners account for induced travel demand?

7.1 Transportation plans and project assessments should account for induced travel demand regardless of the scale of the project or plan.

When induced travel demand is not taken into account, transportation plans tend to misestimate impacts on traffic and the environment. For example, where highway investment plans do not account for induced travel demand, they tend to underestimate traffic impacts and overestimate the economic and social value of the plans. They may also underestimate air pollution and environmental impacts arising from increases in overall travel.

Transportation and environmental legislation encourage more comprehensive project assessments, which in turn, allow for improved policy and project selection.[1] Over the last two decades, compliance with CAAA and NEPA has necessitated increasingly precise forecasting and modeling of travel demand and air quality impacts. Analyses of travel costs or air quality that do not fully account for induced travel effects, however, do not adequately provide for informed decision-making and comparison of diverse alternatives. For this reason, the EPA, state transportation agencies and metropolitan planning organizations (MPOs) are working to improve project level analyses to meet federal environmental laws. These improvements inevitably include incorporation of induced travel demand.

Photo: Ria Hutabarat

Figure 7.1: When induced travel demand is not taken into account, transportation plans tend to underestimate traffic impacts.

Planners need to be diligent in ensuring that induced and diverted demands are taken into account when forecasting traffic and air quality impacts. Project evaluation should consider induced demand regardless of the scale of the project (county, region or state). Forecasting models can include some measure of transportation infrastructure capacity as a determining factor in estimating VMT growth. Since the long-run impact of induced demand is greater than the short-run impacts, forecasting models can also incorporate the "lag effect" of travel demand.

Accounting for induced travel demand would allow transportation planners to predict impacts more accurately and compare alternative improvements more fairly.

7 How can planners account for induced travel demand?

Common misconception 9:

"Induced travel is already fully taken into account in the transportation planning process"

Many regional travel demand models do not yet incorporate induced travel effects[2] and therefore fail to accurately estimate the effect of transportation infrastructure expansion and its related environmental costs. Work on induced travel in the United Kingdom found that travel models generally under-predicted traffic by 5 to 14 percent in the first year following the opening of new highway capacity.[3]

Research in the United States indicates that the long-term under-prediction of traffic can range from conservative estimates of 10 percent to 25 percent, and in some cases may be higher. This significant potential for under-prediction of traffic is cause for concern, and explains why in many cases expanded highways fill to capacity much sooner than anticipated during the transportation planning process.

7.2 Transportation planning is affected by state and federal laws and funding arrangements.

The existing highway finance process may in itself discourage more complete quantification of the social costs of highway construction which become apparent when induced travel demand is taken into account. Since many projects are financed largely by state and federal funds, local governments can "buy" local gains by underestimating project costs and overestimating project benefits in order to secure a share of project funds from state and federal sources.[4,5] The difference between projected and actual costs is absorbed by the local agency.

In order to compete effectively in contests for state and federal monies, it is in the interest of local agency to present more cost efficient projects. There is therefore an incentive for local agencies to downplay projected project costs in order for their projects to gain outside funding. Local agencies may downplay costs by omit those costs that are less well understood such as travel costs associated with induced travel demand. After the projects have been implemented, the gap between the real and predicted costs is borne by the local agencies, but at less cost to the local agency than if they had attempted to fund the entire project.

7 How can planners account for induced travel demand?

Common misconception 10: "Induced travel is not at all taken into account in the transportation planning process"

The transportation planning process will generally account for some portion of induced travel, such as route and modal shifts which are routinely calculated within the transportation planning four-step model. Other induced travel demand effects such as changes in destination from the neighborhood store to the suburban mall that result when the highway system is improved may also be incorporated into the transportation planning process.

With the exception of a handful of metropolitan areas in the United States, however, the transportation planning process generally understates the total amount of travel because it fails to account for at least some portion of induced travel.

The Federal Department of Transportation recently incorporated induced travel demand in its forecasting model—the Highway Economic Requirements System model (1999). Previously, demand relationships were assumed to be entirely exogenous, unaffected by infrastructure improvement. In its current form, the model simulates changes in the demand for travel in response to shifts in the condition and capacity of individual sections. It uses a short-run (five-year period) travel demand elasticity of 1.0 and a long-run elasticity of 1.6 with respect to total user costs. The model no longer treats each section in isolation; rather it is intended to simulate equilibrium effects in the network.

Many agencies have redesigned their transportation models to incorporate induced travel demand, but many have not. Many have come under litigious pressure to improve transportation models and achieve designated air quality standards. These include transportation agencies in Atlanta, Georgia, Washington, D.C. and St. Louis, Missouri.

"The four-step process, as it is conventionally applied, will generally understate the amount of induced travel".[6]

7.3 Induced travel demand can be incorporated into transportation planning processes, land use assumptions and feedback mechanisms.

Conventional transportation models generally fail to account for a number of factors associated with induced travel demand, thereby underestimating future traffic impacts of projects.[7]

The four-step model is the most common method for estimating travel demand at the regional level. The model uses inputs regarding traveler characteristics and land use activities in travel analysis zones (TAZs) throughout the region. Travel demand is then estimated according to travel costs and gravity models for transportation demand. This demand is then loaded onto the transportation network and distributed among different modes and routes according to differential travel times.

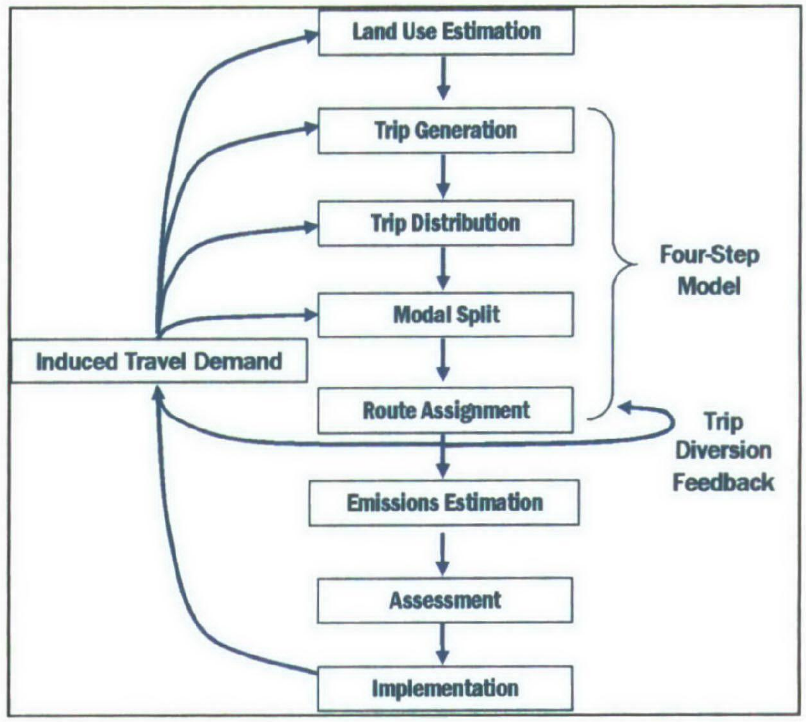

Figure 7.2: Induced travel demand can be incorporated through feedbacks and sub-models of the conventional four-step model.

The main means for incorporating induced travel into the four-step transportation model is through improving the accuracy of planning steps and through:

- better estimation of land use impacts and inputs;
- improved accuracy of all travel demand forecasting steps;
- adjustment of trip distribution (destination choice) estimates to account for induced travel demand;
- additional trip generation estimates specific to the land uses and location;
- inclusion of submodules to address-vehicle ownership, departure time choice and parking;

- improvement of the mode choice module to include -non-motorized transportation and transit; and
- incorporation of feedbacks within the travel forecasting model and into land use inputs as depicted in Figure 7.2.

Other means for improving coverage of induced travel demand in transportation planning include:

- scenario testing;
- alternative land use assumptions;
- sketch planning tools; and
- backcasting of implied elasticities from critical threshold limits.

Many of these measures are currently available and could be adopted more widely to help account for long-term induced travel behaviors in transportation assessments. Techniques are outlined in more detail in the Technical Appendix to this report.

⊙ Case Study IV

Integrating Transportation and Land Use:

The MEPLAN model, Sacramento, California

Photo: Sacramento Regional Transit

Figure 7.3: Using MEPLAN, low-build scenarios with multimodal approaches to transportation became more attractive when induced travel effects were taken into account.

The Sacramento MEPLAN model is one of the most sophisticated models for examining integrated land use and transportation effects such as induced travel demand. The model was developed in 1996 by a team at the University of California, Davis and was applied to the Sacramento region . The UC Davis researchers used MEPLAN to simulate results of a future base case scenario (low-build) and beltway scenario in the Sacramento region for the 25- and 50-year horizons. The researchers found that when land use and trip distribution effects of induced travel were not represented, there were large errors in estimated growth of VMT and emissions. These errors were so large that they changed the rank ordering of the scenarios based on their net benefits. The study therefore demonstrated the significance of incorporating induced travel effects in regional travel demand models.[8]

The Sacramento MEPLAN model is based on the integration between the land use and transportation markets. These markets respond to one another through price signals and other market mechanisms where a change in one market will produce an immediate or "lagged" change in the other market. For example, the attractiveness of a zone is based on input costs including transportation. This zone attractiveness results in certain economic interactions with other zones to create a pattern of

7 How can planners account for induced travel demand?

⊙ Case Study IV

Integrating Transportation and Land Use:
The MEPLAN model, Sacramento, California

different trip types. The resulting traffic then affects transportation costs, which affect the attractiveness of zones. A 5-year time lag means that transportation-caused-accessibility is reflected by a change in the location of activities five years later – thus accomplishing the feedback between transportation to land use. This model is explained further in the Technical Appendix to this report.

MEPLAN was run to examine whether the inclusion of induced travel demand had an effect on predicted growth in travel (VMT) resulting from a future beltway investment scenario in the Sacramento region. The model found that when the trip distribution component of induced demand was included, total predicted VMT was 6 percent higher in 2015 and 10 percent higher in 2040, than that predicted by conventional models (which only account for induced mode choice and traffic assignment effects). When both trip distribution and changed activity locations were included, total predicted VMT was 11 percent higher in 2015 and 17 percent higher in 2040. Finally, when land use changes were also added to the MEPLAN model, total predicted VMT was 13 percent higher in 2015 and 18 percent higher in 2040, than that predicted by conventional models.

Table 7.1: MEPLAN results for induced travel demand effects of a future beltway scenario on vehicle miles traveled (VMT) in the Sacramento region.[9]

Run	Induced travel demand components represented					Change in VMT	
	Amount of developed land	Location of people & jobs	Trip distribution	Mode choice	Traffic assignment	2015	2040
A	✓	✓	✓	✓	✓	+13%	+18%
B		✓	✓	✓	✓	+11%	+17%
C			✓	✓	✓	+6%	+10%
D				✓	✓	0%	-1%

Results from the MEPLAN model found that household trip distribution, and population or employment location effects are the major contributors to induced travel demand. Furthermore, inclusion of induced demand results in significantly different estimates of future travel impacts of alternative land use and transportation policies.[10] When induced travel is not taken into account the secondary effects of highway projects, such as changes in land use, are lost.

8 What are the implications of incorporating induced travel demand for planning?

8.1 Induced travel demand suggests the need to adjust or expand forecasting methods to more accurately predict transportation impacts.

Incorporating induced travel demand has implications for transportation planning and modeling. Over the past two decades, increasingly complex and sophisticated traffic and air quality forecasting models have been developed to better predict transportation outcomes and environmental compliance. Incomplete inclusion of induced travel effects for new highway projects, however, results in a routine underestimation of facility usage once projects to increase capacity are implemented.[1] This inaccuracy can skew decision-making criteria and shift the rank ordering of transportation alternatives.

In order to incorporate induced travel demand into transportation planning processes there is likely to be a shift in the way that traffic and travel forecasting occurs. This shift may involve use of more sophisticated travel forecasting models such as the MEPLAN model developed at UC Davis. Alternatively, it may involve expansion of existing models and planning processes (such as the LUTRAQ plan developed for the Portland region) to account for a broader range of parameters and objectives that relate to induced demand. In any case, addressing induced demand is likely to bring about a shift in transportation forecasting models toward new or expanded models that are currently available or being developed.

In order to assess the balance of costs and benefits arising from induced travel and transportation impacts more generally, forecasting models may also feed into to microeconomic analyses of specific project impacts. At present there is no specific requirement for microeconomic analysis of transportation projects, however, as questions arise regarding induced travel demand, there is increasing need to clarify costs and benefits through microeconomic analyses. For example, these analyses might clarify the extent of additional travel that leads to greater access to opportunities and economic development.[2] On the other hand, they may also assess the extent of "wasteful travel" that contributes to overall traffic, environmental impacts and secondary impacts resulting from associated land use changes without providing improved access.

8.2 When induced travel demand is better taken into account, transit, land use and pricing options become more attractive alternatives.

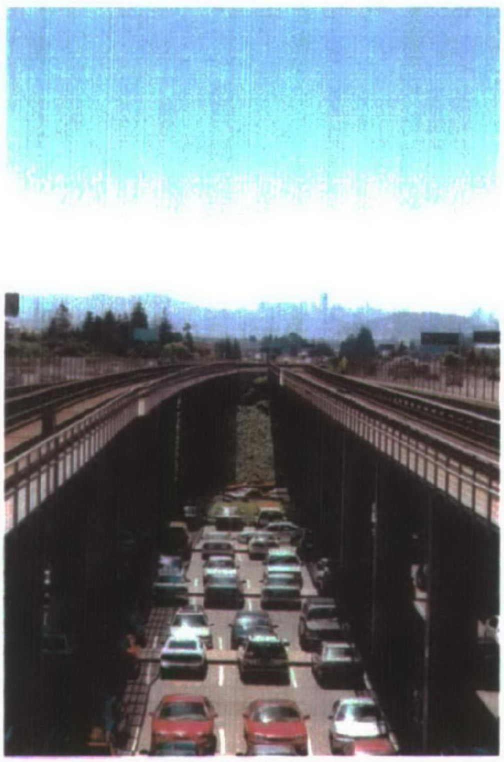

Photo: Ria Hutabarat

Figure 8.1: When induced demand is incorporated in the planning processes, park-and-ride facilities and other transit and land use options increase their relative attractiveness

Federal, state and local governments spend billions of dollars each year on transportation improvements that aim to reduce congestion, facilitate economic growth, and improve air quality.[3] These objectives are often not achieved in the optimum manner, partly due to the fact that decisions are based on models that misestimate the traffic and environmental impacts of transportation alternatives by neglecting induced demand effects.[4]

As induced travel demand is incorporated into transportation plans and models, there is likely to be a shift in the overall estimation of costs and benefits arising from transportation projects and plans. Specifically, the inclusion of induced travel demand tends to result in lower estimated travel time savings and higher estimated environmental impacts resulting from highway investments. In some cases, this shift in costs and benefit may be enough to change the ranking of alternatives.

When induced travel demand is more fully incorporated in transportation assessments, more integrated transportation and land use options to addressing congestion and enhancing access become relatively more attractive. These options include transit, urban design, and integrated transportation and land use planning.

In the case of regional transportation planning in Sacramento (see Case Study IV on page 45), the omission of induced travel demand effects resulted in travel time savings and air quality benefits being overstated for highway alternatives. Subsequently, transit, land use and pricing options became more attractive once induced travel demand effects were incorporated.

In the case of the Western Bypass proposal for the Portland metropolitan region (see Case Study V on page 51), the incorporation of induced travel demand effects also resulted in a substantial change to transportation priorities. The Bypass proposal was replaced by alternative suburban land use and transportation patterns and neighborhood design, consistent with LUTRAQ principles. These patterns feature moderate density, pedestrian-oriented neighborhood development, connected by a regional transit system.

In Illinois' I-355 project on the other hand (see Case Study III on page 39), the inclusion of induced travel demand effects was not significant enough to change the rank ordering of projects for a specific corridor. Likewise, in the Legacy Parkway case (see Case Study II on page 31), updated travel forecasting processes presented in the Final Supplemental Environmental Impact Statement (EIS) did not result in a substantial change to the proposed project and were considered adequate by the court. The EIS was rendered inadequate, however, on the basis of other issues.

Considering all four of the above case studies, it might appear that induced travel demand effects more substantial shifts in transportation priorities (to more multimodal solutions) when they are considered at a regional level prior to specific project level analyses. This difference may be due to the fact that regional analyses are better able to incorporate travel demand impacts of land use change, or that the proponents for the regional models were less attached to a particular mode of transportation development.

Common misconception 11:

"Heavy traffic on new or expanded highways is a sign that highway planners are fully successful in anticipating where highway capacity is needed."

Some advocates of expanded highway capacity suggest that a successful highway is one that enjoys a high level of usage.

Research shows that in California highway capacity has generally been provided in the appropriate places to meet the growing demand for travel. In this sense, highway planners have been successful in using public resources to construct highways that are well-used.

At the same time, however, this high usage rate may also be a sign of a skewed assessment process where induced travel was not fully taken into account. Research indicates that traffic growth tends to follow the provision of highway capacity and at least some portion of traffic is induced travel demand that highway planners failed to anticipate in the planning process.[5]

8 What are the implications of incorporating induced travel demand for planning?

Common misconception 12: **"Heavy traffic on new or expanded highways is a sign that highway planners are entirely unsuccessful in anticipating where highway capacity is needed."**

While highway planners have been generally successful in providing highway capacity where there is demand, they have generally failed to:

- anticipate the full extent of induced travel demand;
- reflect the full costs of system usage; or
- recognize the range of transportation and land use alternatives.

Inadequacies in incorporating induced demand and reflecting full costs, are manifest in heavy traffic along new or expanded highways. This traffic is not a sign that highway planners are entirely unsuccessful but may reflect a failure in providing appropriate pricing signals to users.

The persistence of heavy traffic on some new or expanded highways may also reflect other sources of regional population, economic and traffic growth. In these cases ongoing traffic could demonstrate the success of highway planners in predicting and facilitating access to future areas of metropolitan growth.

While many uncertainties exist in relation to transportation-land use interactions, several mechanisms are available for more fully incorporating induced travel demand effects in new or existing transportation forecasting processes. By addressing induced travel demand effects, the focus of transportation plans and projects tends to shifts from simply containing congestions, to also enhancing access, reducing air emissions and directing the growth of more livable urbanized areas.[6]

8 What are the implications of incorporating induced travel demand for planning?

⊙ *Case Study V*

Integrating multiple planning objectives:

The LUTRAQ model, Portland, Oregon

Portland's Land Use, Transportation and Air Quality Connection (LUTRAQ) model represents the first effort in the United States to model the land use, transportation and air quality connection at a regional level.[7] LUTRAQ started as a local effort to oppose a proposed suburban freeway, known as the Western Bypass. This freeway was promoted in 1988 as a means of ameliorating traffic congestion in the Portland Metropolitan area of Washington County, Oregon.

Community groups and citizens opposed the freeway asserting that poor land use patterns, and not inadequate highway capacity, was a major reason for traffic congestion in the County. With the help of a team of experts, they designed an alternative regional land use pattern to demonstrate that there were viable alternatives to the highway proposal. Their demonstration focused on moderate density, pedestrian-friendly neighborhoods, connected by a regional transit system. This effort evolved into a national demonstration project to develop alternative suburban land use patterns and design standards, and evaluate their impact on auto dependency, emissions, mobility and energy consumption.

It was based on the following underlying principles:

- Focus the community towards transit
- Encourage a variety of uses
- Create streets for people
- Provide public open spaces
- Design the community for livability
- Involve citizens in the creation of their community

According to the LUTRAQ plan, 75 percent of jobs and 65 percent of households in the Portland metropolitan area could be transit-served at market densities – compared to 16 percent of transit-served development under the highway plan. The LUTRAQ plan was also expected to lead to a 10 percent greater reduction in traffic congestion without adding any road capacity.[8]

The LUTRAQ plan was considered by the Oregon Department of Transportation as one of five alternatives for a Major Investment Study (MIS) conducted in 1994. This study found that LUTRAQ outperformed the Bypass alternative in almost every category and, in 1997, the Bypass project was abandoned. LUTRAQ principles were adopted by the Portland regional government organization as part of the Region 2040

8 What are the implications of incorporating induced travel demand for planning?

⊙ Case Study V

Integrating multiple planning objectives:

The LUTRAQ model, Portland, Oregon

Growth Concept in 1994, which featured land use designations with concentrated growth in centers and corridors served by transit.

LUTRAQ demonstrates the potential for incorporating induced travel demand and integrated land use, transportation and environmental objectives into existing regional transportation modeling processes. Under the LUTRAQ model, recognition is given to transportation impacts of urban design and land use changes. LUTRAQ does not involve sophisticated new modeling techniques, but rather a reorientation of existing processes to accommodate a wider spectrum of issues. The resulting transportation and land use designs arising from LUTRAQ-style processes have a lower reliance on automobiles and a greater mix of transit- and pedestrian-oriented options.

The LUTRAQ model demonstrates the potential for broadening existing regional transportation planning processes to encompass components of induced travel demand. It also demonstrates the implications of incorporating induced travel demand and transportation-land use interactions, on transportation and regional planning processes that result in more transit- and pedestrian-oriented communities.

9 Conclusions

9.1 Induced travel demand is a real phenomenon which results in new or expanded transportation facilities filling up faster than anticipated.

Induced travel demand is a phenomenon whereby vehicle miles traveled increase in response to increases in transportation capacity aimed at relieving congestion. This travel increase occurs as a result of short-term and long-term travel behavior reactions to take advantage of new travel time benefits. Reactions include people traveling further, taking more trips and relocating their places of work and residence. As people's travel patterns change, traffic congestion again increases and the highway fills up faster than anticipated.

Long-term induced travel demand effects are a function of the link between transportation and land use. Land developments spur transportation improvements to new development areas, and conversely transportation improvements stimulate land development to areas that have been made more accessible. In both cases, increased transportation capacity allows for more vehicle miles of travel.

Induced travel is a real and significant phenomenon that has been substantiated through numerous studies and evidence.[1]

9.2 Quantifying elasticities of travel demand depends upon circumstances but there is a general range of estimates.

While numerous studies agree on the existence of induced travel demand, quantification of the phenomenon is less certain and must be done on a case-by-case basis. Efforts to quantify induced travel effects generally focus on the elasticity of travel demand with respect to highway capacity or travel time.

Estimates for elasticity of demand with respect to travel time are more consistent than capacity elasticity of demand with respect to lane miles (or capacity), suggesting uncertainty about the relationship between increased capacity and reduced travel time. The best estimates indicate that 10 to 30 percent of growth in VMT is attributable to induced travel demand. For highway travel, estimates of travel demand elasticity with respect to capacity are in the range 0.3 to 0.5 in the short-run and 0.5 to 0.9 in the long-run. For non-highway modes, more complex intermodal effects may

9 Conclusions

Photo: Mary Chou

Figure 9.1: Patterns of freeway and other transportation development shape land use and economic growth

also come into effect whereby an increase in capacity in one mode (such as development of a new rail line) can lead to increased travel by the improved mode as well as inducing more travel by other modes (such as parallel highways). The exact magnitude of induced travel demand effects can only be determined on a case-by-case basis, taking into account local conditions.

The complexity of induced travel demand may suggest the need for further development of travel demand modeling capabilities and improved understanding of transportation—land use interactions. On the other hand, most aspects of induced travel demand are able to be reflected to some degree in existing modeling processes as demonstrated in the Portland's LUTRAQ model.

9.3 Incorporating induced travel effects may result in different transportation and land use outcomes.

Incorporating induced travel demand into transportation analyses would allow planners to more accurately predict the traffic and environmental impacts arising from transportation projects. Such improvements would facilitate compliance with environmental regulations, as well as allowing for more informed transportation and land use policy decisions.

More informed transportation and land use decisions are, in turn, likely to result in different transportation outcomes. In some cases such as the Chicago's I-355 project, the inclusion of induced travel demand was not found to be significant enough to change the outcome of the project. In other cases, the inclusion of induced travel demand in regional models, such as Portland's LUTRAQ model and Sacramento's MEPLAN model, resulted in radically different transportation decisions. After induced travel demand was factored into these models, alternative transportation modes and integrated approaches to transportation and land use development became more attractive.

Given that induced demand is related to transportation-land use interactions, the difference between the Portland/Sacramento studies and the Chicago example suggest the stronger effect of, and need for, incorporating induced demand into metropolitan transportation assessments before specific corridor assessments occur.

9.4 Recognizing induced travel demand as part of transportation outcomes will better meet economic, social and environmental objectives.

Transportation infrastructure has historically played an important role in the economic and social development of metropolitan areas across the United States. By building networks of roads, freeways and transit systems, urban planners and developers facilitate a range of exchanges and activities both within and between urban areas. These activities shape regional patterns of land use, economic growth, environmental performance and social development.

By including all relevant factors in transportation and regional assessment processes, planners and decision-makers are able to better understand the costs and impacts of projects, and better achieve their goals with respect to the efficiency and character of metropolitan regions. The omission of induced travel demand results in underestimation of highway project costs and impacts, and hampers thorough understanding and assessment of regional transportation, land use and environmental conditions.

Induced travel demand has significant implications for the shape of transportation facilities and metropolitan development in the United States. By incorporating induced travel effects into transportation forecasting models, planners can build greater accuracy into forecasting models and better recognize the relationship between transportation capacity, behavioral responses and land use patterns. This improvement would allow decision makers to plan for urban and regional systems which lead to enhanced access, and more efficient transportation, integrated land uses and livable communities.

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12 Further information

For more information on how to incorporate induced travel demand, land use and environmental effects into transportation planning:

- US EPA's Induced Travel Demand Guidebook and Best Practice Manual *http://www.epa.gov/otaq/*
- Federal Highway Administration's Spreadsheet Model for Induced Travel Estimation (SMITE) *http://www.fhwa.dot.gov/steam/smite.htm*
- Sacramento's MEPLAN model for integrated transportation-land use planning *http://www.fhwa.dot.gov/planning/toolbox/sacramento_methodology_land.htm*
- Portland's Land Use Transportation Air Quality Program (LUTRAQ) *http://www.friends.org/resources/lut_reports.html*

For more information on EPA programs relating to induced travel demand, please contact:

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URL: http://www.epa.gov/otaq/

TECHNICAL APPENDIX

APPENDIX A: SUMMARY OF BEST PRACTICES

INCORPORATING INDUCED TRAVEL DEMAND INTO TRANSPORTATION PLANNING PROCESSES

APPENDIX B: PROCESS ORIENTED TECHNIQUES

B.1 CONSULTATION WITH LAND USE AND ENVIRONMENTAL PROFESSIONALS

In seeking to understand the magnitude of induced travel demand effects relating to a particular transportation proposal, transportation planners may benefit from consulting with land use and environmental professionals This consultation would aim to estimate the long-term land use, traffic and environmental effects expected to arise from transportation capacity expansion or improvements It would specifically examine effects which relate to travel demand growth over and above that predicted to occur without any expansion or improvement

Consultations with land use and environmental professionals would focus on regional or corridor-level forecasts of population, housing, employment and transportation impacts. Forecasts and future land use scenarios would take into account exogenous factors such as

- Population, household and jobs growth,
- Increased home and vehicle ownership,
- Increased income,
- Fuel price changes, and
- Increased workforce participation

Consultations with land use and environmental professionals may encompass a number of techniques to gain counterfactual evidence and understanding of travel and land use futures relating to the particular project or plan These techniques might include.

- Policy or technical committees,
- Comparison with comprehensive plans, and
- Quantitative techniques for land use assessment such as regression, linear programming, discrete choice / logit analysis and microsimulation

Consultation with land use and environmental professionals is an important process in gaining a greater understanding of the cross-sectoral impacts expected to arise from a transportation improvement This process may encompass a diverse range of techniques and can assist in understanding the long-term land use and induced travel demand implications of transportation proposals

B.2 DELPHI LAND USE FORECAST METHOD

The Delphi technique is a common technique for accounting for transportation-land use interactions This technique was developed by the Rand Corporation in the 1950s and applied in various projects The Delphi technique has been applied to transportation-land use interactions in the following contexts

- The US 301, Maryland
- Santa Clara County, California
- Longview, Texas
- New Hampshire

The Delphi technique is a systematic way of using expert opinion through a consensus building approach It aims to predict the land development impacts of a project through a cooperative forecasting process using expert opinion and best judgment The steps involved in undertaking the Delphi technique are as follows.

- Gather a group of experts in relation to the particular project or issue These might include local officials, developers, academics, environmental stakeholders and others
- Conduct a questionnaire regarding transportation-land use forecasts and expectations under a range of conditions.
- Facilitate iterative discussion with panel members, using a moderator
- Undertake analysis of anonymous participant responses as well as consensus findings of the group

The Delphi technique is a lower cost method for estimating land use and long-term induced demand effects of a particular project It benefits from the cumulative understanding of a range of different experts and develops estimates through a consensus building approach This process enhances stakeholder ownership and acceptance of the resulting transportation and land use forecasts, and allows them to influence the direction of the project early in the planning process

The technique is limited by a lack of detail and inability to simulate actual transportation-land use interactions and processes The long time horizon of the projections makes it impossible to evaluate the accuracy of Delphi applications within the transportation-land use field at this early stage

B.3 ALTERNATIVE LAND USE INPUTS

In order to incorporate long-term transportation - land use interactions in transportation, economic and environmental impact assessments, there is a need to assess the likely land use changes resulting from transportation activities The use of alternative land use assumptions is one of the most common methods for reflecting long term induced travel demand effects in transportation assessment processes. Alternative land use assumptions have been widely applied to travel models across the world and around the United States

Using alternative land use assumptions, different population, employment and housing assumptions are adopted to test alternative scenarios or model sensitivity These assumptions are fed into the four step transportation planning model to provide new trip generation rates, and new travel profiles

The steps involved in developing alternative land use inputs are as follows

- Assess policies regarding land use (activity location), zoning, and economic market development in the area of interest
- Forecast socioeconomic factors based on development under different land use zoning regimes, market development scenarios and potential urban land use policies
- Develop estimates of resulting population, employment and housing parameters arising from these socioeconomic factors
- Use these estimates as alternative land use inputs to the transportation planning process

The alternative land use inputs techniques reflects the uncertainty of land use and urban futures and provides an indication of the sensitivity of transportation and land use models to different policy and development scenarios This technique has the advantage of drawing upon existing socio-economic variables and developing a range of estimates for land use and transportation parameters. As with travel modeling more generally, the alternative land use inputs technique is limited by user creativity and understanding of potential land use policy alternative.

APPENDIX C: CORRIDOR-SPECIFIC MODEL ADJUSTMENTS

C.1 IMPROVING EXISTING TRAVEL DEMAND MODELS

Several adjustments can be made to existing travel demand models such as the four-step model in order to improve the incorporation of induced travel demand effects and the overall accuracy of travel demand modeling These adjustments focus on improving the estimation of trip distribution, and ensuring that mode choice and route assignment effects are covered

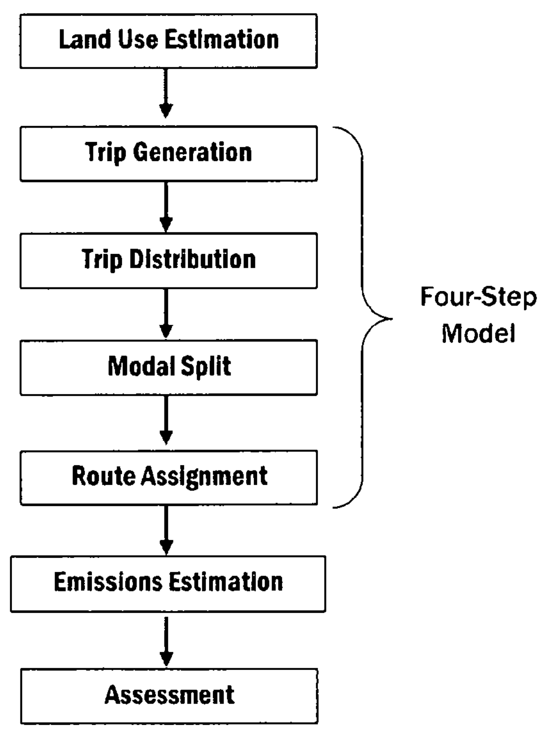

Figure C.1 Expanded four-step travel demand modeling process

Trip generation

Estimates of trip generation provide a measure of the trips generated to and from each zone according to demographic features (trip productions) such as the number of households, household size, income and vehicle ownership, and activity features (trip attractions) such as the number of jobs and size of activity centers (e g schools, shopping centers and recreational facilities)

Improving the accuracy of these estimates, and therefore improving the incorporation of induced travel demand, might include

- estimation of more fine-grained trip generation rates with respect to land use features (e g disaggregation of generation rates for land use type according to features such as density and distance from traditional CBD); and
- inclusion of the induced trip generation component of total travel demand elasticity including trip chaining

Table C.1: Commonly used trip generation rates have a wide standard deviation which masks a wide range of land use conditions and features.[1]

Land use	Time unit	No. studies (avg no. units)	Weighted average trip generation rate	Range of rates	Std devn
Single family detached housing	Weekday	348 (198)	9 57 trip ends per dwelling unit	4 31 - 21 85	3 69
General office building	Weekday	78 (199)	11 01 trip ends per 1000 sq ft gross floor area	3 58 - 28 80	6 13
Shopping center	Saturday	123 (450)	49 97 trip ends per 1000 sq ft gross leasable area	16 70 - 227 50	22 62
Low-rise apartment	Weekday, peak hour (1 hour bet 7-9 am)	26 (255)	0 47 trip ends per occupied dwelling unit	0 25 - 0 86	0 70
General office building	Weekday, pm peak hour	172 (691)	0 46 trip ends per employee	0 16 - 3 12	0 70
Shopping center	Peak hour (1 hour bet 4-6 pm)	401 (383)	3 74 trip ends per 1000 sq ft gross leasable area	0 68 - 29 27	2 73

Trip distribution

Trip distribution estimation provides a measure of how trip productions and attractions are linked by estimating the number of trips between each zone for each trip purpose This destination choice is based on the availability of housing, jobs and activities (gravity), the distance and travel time to reach activities (friction), and other pricing assumptions (e g. parking, tolls, fares, auto operating costs).

Estimates may be improved through·

[1] Institute of Transportation Engineers, "Trip generation trip generation rates, plots, and equations" 6th ed (Washington, D C Institute of Transportation Engineers, 1997)

- estimation of more fine-grained trip generation rates with respect to time (e g hourly instead of daily trip generation rates), and
- inclusion of the induced trip distribution component of travel demand elasticity

These adjustments have been found to significantly improve estimation of short-term induced demand

Mode split

Mode split estimation provides a breakdown of trips by mode according to the availability of transportation services or options, the relative travel time costs; and other factors (such as the number of transfers and perceived safety) Within the United States, a mode shift component of induced travel demand is covered in most travel demand models. Mode shift analyses generally include auto and transit (heavy rail, light rail and bus) trips, with transit trips broken down by walk-access and drive-access Non-motorized transportation trips are not usually included in analyses

Estimation of the mode shift component of induced travel demand may be improved through inclusion and valuing of traveler time for a fuller range of modes including bicycle, walking and transit

Route assignment

Route assignment divides trips on each mode between available corridors (e g region-wide corridors), routes (e g improved highway vs local roads), and lanes (e.g HOV, HOT, general purpose lanes) This choice is made on the basis of relative travel times affected by congestion along different possible pathways, and other relative costs such as tolls This route shift component of travel demand estimation is a standard part of regional travel demand estimation techniques in the United States

Estimation of the route shift component of induced travel demand may be improved through more fine-grained travel demand estimation with respect to time (e g. hourly instead of daily estimates)

C.2 AUGMENTATION OF EXISTING TRAVEL DEMAND MODELING

In addition to improving the accuracy of existing components of conventional travel demand modeling, induced travel demand may be incorporated through a number of processes that are generally omitted from demand models These include methods to account for

- variations in population and employment growth scenarios,
- inter-regional movement and development,
- vehicle ownership effects on travel demand,
- parking pricing effects, and
- time of day of travel

Population and employment growth scenarios

Different population and employment growth scenarios can be tested under different transportation build scenarios Population and employment growth scenarios affect both land use inputs and trip generation rates to the travel demand model

Inter-regional movement and development adjustments

With induced travel demand effects and greater accessibility to outlying regions, travel demand models may account for inter-regional movement and land use development beyond the existing regional boundaries This demand may be incorporated by allocating population and movement to a number of "gateways" at the periphery of the region, or expanding the region under analysis

Vehicle ownership sub-module

Vehicle ownership levels are affected by the land use characteristics of household size, income, density and accessibility These land use characteristics vary across the region and can be fed into a vehicle ownership sub-module. The vehicle ownership sub-module then feeds into the trip generation module of the travel demand modeling process

Parking sub-module

In growing metropolitan regions, travel demand is also affected by parking availability and cost at trip destinations The inclusion of a parking sub-module may then assist in improving the accuracy of estimates of the mode shift component of induced travel demand

Departure time choice sub-module

Finally, other induced demand effects may be included through using departure time choice sub-modules to allow for shifts between peak and off-peak travel For example, in the San Francisco Bay Area, travel demand models allow for shifts between the morning peak hour (6 30–8 30am) and off-peak times (before 6 30am or after 8 30am)

C.3 SMITE (SPREADSHEET MODEL FOR INDUCED TRAVEL ESTIMATION)

SMITE is one tool for incorporating travel demand elasticity measured in terms of VMT arising as a result of transportation improvement projects More specific elasticities may also be incorporated into transportation demand modeling processes These may be broken down into demand elasticities arising as a result of

- land use change,
- additional trip generation,
- trip distribution, and
- other sources of induced demand

SMITE is a simple spreadsheet model that was developed by Patrick DeCorla-Souza and the US Federal Highway Administration (FHWA) [2,3] It undertakes a corridor-level analysis of road projects to estimate the effects of induced travel on travel time savings and air emissions These impacts are estimated by using travel time price elasticities

Based on studies undertaken in the United States and the United Kingdom, the U S FHWA estimated long-term elasticity of travel demand with respect to travel time to be in the vicinity of -0 4 and -0.6 for road projects in urban areas This means that where a road project is estimated to produce a travel time reduction of 10 percent, this reduction will be counteracted by an increased travel demand of about 5 percent as people take advantage of the initial travel time savings Where road projects take place in rural areas, the elasticity of travel demand with respect to travel time is higher than that of urban projects and has been estimated to be in the vicinity of -1 3

Using SMITE, induced travel is incorporated into travel demand forecasts as follows

- Travel demand elasticity with respect to time is selected and inserted into the traffic forecasting spreadsheet for the project
- Values of induced freeway VMT and induced arterial VMT are calculated by multiplying this elasticity with the calculated change in travel time owing to the transportation improvement
- This induced VMT is used to adjust initial travel time savings calculation

The sensitivity of predicted VMT, travel time savings and emissions levels to different values of elasticity and congestion can also be assessed using SMITE in order to gain a more accurate understanding of likely induced travel demand effects The program accounts for an adjustment in the proportion of trips taken by different routes along the corridor so the predicted induced demand does not include the effect of trips that are rerouted from one road to another

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[2] Patrick DeCorla-Souza, "Using SMITE to Estimate Induced Travel and Evaluate Urban Highway Expansion" (n d)

[3] United States Department of Transportation, "Spreadsheet Model for Induced Travel Estimation (SMITE)" http //www fhwa dot gov/steam/smite htm

C.4 FEEDBACK MECHANISMS

One of the most well known mechanisms for incorporating induced travel demand into transportation forecasts is through the employment of feedback mechanisms within the four-step transportation planning process These feedback loops allow the travel demand models to be adjusted to account for travel demand reactions to initial changes in conditions

The technique for implementing feedback loops involves taking the model output for use as an input to the process Three types of feedbacks can occur in the transportation modeling process These are:

- Internal feedback within each step,
- Feedback between assignment and trip distribution, and
- Feedback from transportation outcomes to land use inputs

All three types of feedbacks improve the quality and accuracy of travel demand estimates and therefore the coverage of induced travel demand in transportation forecasts Models can employ single or multiple feedbacks and may choose to improve outputs by averaging results following each iteration of the model

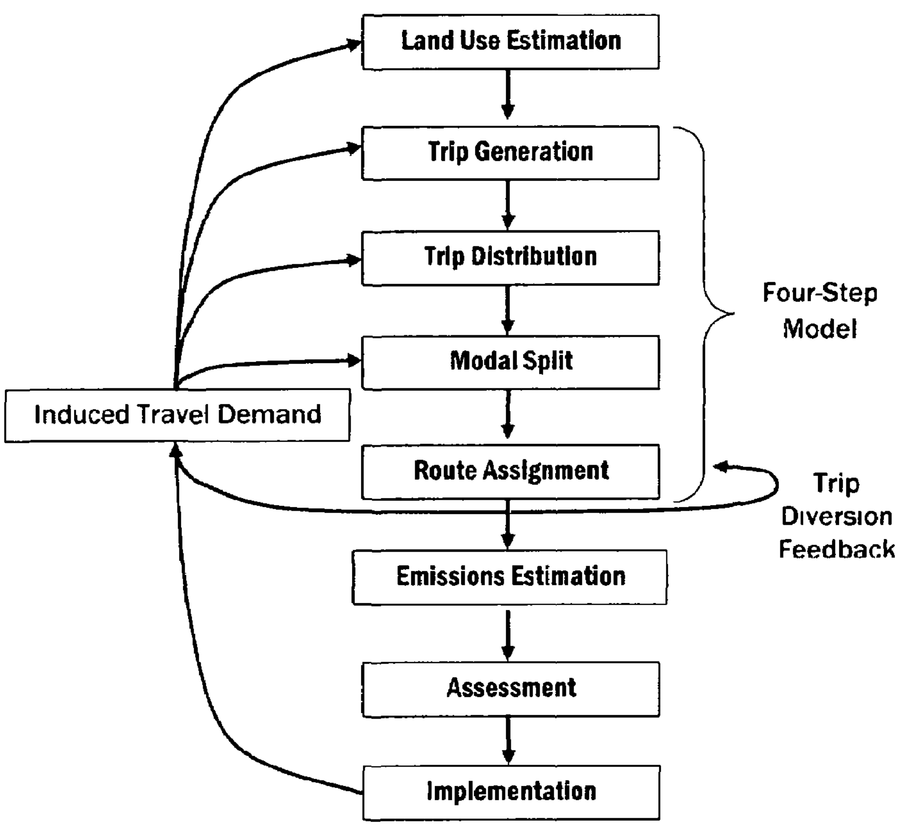

Figure C.2: Feedbacks within the travel modeling process

Internal feedbacks are generally undertaken for the purposes ensuring that there is balance or equilibrium within the transportation network For example, iterations of the route assignment step ensure that each route has the same number of vehicles entering and exiting the route This internal feedback also reflects trip diversion, that is, people shifting to different routes as a result of changes to levels of service arising in response to the transportation improvement project

More sophisticated feedbacks include those between components of the four-step model These feedbacks are often implemented for the purposes of improving the convergence of model results (although non-feedback methods of improving convergence may be less time consuming) They also assist in reflecting induced travel demand effects of transportation improvements They include feedbacks from the route assignment step to

- modal choice – reflecting people's decisions to change their mode of travel on the basis of the level of service experienced on the route previously chosen,
- trip generation – reflecting people's decisions to undertake more trips and less trip linking in response changes in system capacity and level of service, and
- trip distribution – providing a measure of people's decisions to change where they undertake activities in response to levels of transportation service

In the short term, people may change where they shop or undertake recreation in response to congestion, while in the long-term they may change where they work or live To accurately assess long-term land use change and air quality impacts of transportation improvements, there is therefore a need for feedback between transportation outcomes and land use inputs This feedback reflects long-term effects on housing, commercial and industrial development as a result of making areas more accessible

After each feedback, the travel demand model is reassessed with new demand levels based on expected choices made on the basis of relative travel times and costs. While feedback mechanisms are conceptually useful for improving travel demand modeling processes, they are technically complex and time consuming to implement in any sizable region

APPENDIX D: REGION-WIDE TOOLS AND TECHNIQUES

D.1 SMART GROWTH INDEX (SGI)

Incorporation of transportation-land use interactions, including induced travel demand, into region-wide transportation planning and analysis tools can be done through sketch tools such as the Smart Growth INDEX developed by Criterion Planners/Engineers and Fehr & Peers Associates with the support of the U S EPA It was designed to help communities that have a geographic information system (GIS) but may not have access to a four-step *travel demand model or may wish to conduct quick sketches prior to undertaking the four-*step process [4] It is therefore applicable for neighborhood, small regional and site level analysis of land use impacts on travel and emissions SGI has applications in California, Oregon and Florida. Other pilot projects are currently being run in relation to

- Impacts of different transportation investment and land use development scenarios for the rapidly growing high-tech area along the I-495 corridor in Boston, Massachusetts,
- Impacts of brownfield development at three sites in Wilmington, Delaware, and
- Growth boundary, open space preservation, infill and alternate density strategies as part of a comprehensive planning process for Indianapolis, Indiana [5]

The SGI model relates land use and transportation planning with environmental impact indicators including travel and emissions These indicators provide an understanding of likely community growth over a period of up to twenty years (forecast) or at a single point in time (snapshot) Sketches may be conducted as part of a wider regional planning process or in relation to a particular project, neighborhood or transportation corridor Indicators defined under the SGI model are outlined in Table E 1

[4] Criterion Planners/Engineers and Fehr & Peers Associates Smart Growth INDEX Getting Started Guide (US Environmental Protection Agency, November 2000) http //www epa gov/smartgrowth/pdf/getting_started_guide pdf (Retrieved 8 May 2002)
[5] US EPA "Smart Growth INDEX Pilot Project Descriptions" Smart Growth (28 November 2000) http //www epa gov/piedpage/index/pilotabstracts pdf (Retrieved 8 May 2002)

Table D.1: **Indicators Described by SGI**[6]

Category	Forecast indicators	Snapshot indicators
Land use	- Growth compactness - Population density - Incentive area use for housing - Jobs / workers balance	- Population density - Use mix - Jobs / workers balance - Land use diversity
Housing	- Housing density - Housing transit proximity - Residential energy use - Residential water use	- Residential density - Housing share single-family, multi-family - Housing proximity transit, recreation - Residential energy and water use
Employment	- Employment density - Employment transit proximity	- Employment density - Employment transit proximity
Travel	- Vehicle miles traveled (VMT) - Vehicle trips - Vehicle hours traveled arterial, freeway - Vehicle hours of delay arterial, freeway - Mode share auto driver, auto passenger, transit, walk/bike - Auto travel cost	- Sidewalk completeness - Pedestrian route directness - Pedestrian design index - Street network density and connectivity - Vehicle miles traveled (VMT) - Vehicle trips - Auto travel costs
Environment	- Emissions oxides of nitrogen (NOX), oxides of sulfur (SOX), hydrocarbon (HC), carbon monoxide (CO), particulate matter (PM), greenhouse gases	- Open space - Park space availability - Emissions CO, HC, SOX, NOX, PM, carbon dioxide (CO2)

Induced travel demand is incorporated into SGI's transportation – land use analyses through elasticities of travel demand with respect to land use and design variables The resulting travel demand represented by the variables vehicle miles traveled (VMT) and vehicle trips (VT), that in turn become inputs to air quality models for the region Elasticities used within the SGI model are based on typical values found from a number of recent studies As partial elasticities they control for other elements of land use and design, and are added together to reflect the over all travel demand elasticity By incorporating elasticities with respect to land use features, the SGI model allows planners to bring the effect of densities, land use diversity, and pedestrian-friendly design into account in their assessments of transportation and land use development [7]

[6] Criterion Planners/Engineers (November 2000) Smart Growth INDEX Process Guide US Environmental Protection Agency http //www epa gov/livability/index/Community_Process_Guide pdf (Retrieved 8 May 2002)

[7] Reid Ewing and Robert Cervero, "Travel and the Built Environment A Synthesis *Transportation Research Record* 1780 (2001) 87-113

D.2 3DS SPREADSHEET MODEL

The 3Ds spreadsheet model was developed for the US EPA for use in Smart Growth INDEX model The 3Ds spreadsheet model is a sketch tool that quantifies the impact on travel of the neighborhood built environment characteristics known as the 3Ds

- Density,
- Diversity (mix of land uses), and
- Design

This model relates neighborhood and regional characteristics to the amount of vehicular travel generated using partial elasticities for travel demand These partial elasticities vary according to the three design characteristics listed above

Table D.2: SGI Partial Elasticities of Travel with Respect to the Built Environment[8]

Land Use or Design Variable	Vehicle Trips (VT)	Vehicle Miles Traveled (VMT)
Local Density	-0 05	-0 05
Local Diversity	-0 03	-0 05
Local Design	-0 05	-0 03

The 3D spreadsheet provides a tool for measuring transportation–land use interactions in site level analyses, land use plans and urban designs It is capable of wide, minimal-cost application nationwide

[8] Reid Ewing and Robert Cervero, "Travel and the Built Environment A Synthesis *Transportation Research Record* 1780 (2001) 87-113

D.3 INDEX 4D MODEL

INDEX 4D was also developed for the U S EPA for use in Smart Growth INDEX model and an update to the 3Ds spreadsheet INDEX 4D extends the 3Ds tool to reflect impacts on travel of regional accessibility, a parameter referred to as "Destinations" [9] Like SGI and the 3Ds spreadsheet, INDEX 4D helps to relate neighborhood and regional characteristics to the amount of vehicular travel generated using partial elasticities for travel demand

INDEX 4D reflects a greater range of studies in its estimates of elasticity and provides better information regarding the impacts of pedestrian-oriented design The accessibility factor (Destination) reflects the fact that Density, Diversity and Design have less impact on travel in more outlying area than central city areas For example, improved pedestrian facilities will tend to have less impact on reducing VMT in a suburban neighborhood than an infill development area, because the level of longer trip distances and higher automobile dependence in the former limits the ability of such measures to effect a modal shift

Table D.3: INDEX 4D Partial Elasticities of Travel with respect to the Built Environment[10]

Land Use or Design Variable	Vehicle Trips (VT)	Vehicle Miles Traveled (VMT)
Density	-0 043	-0 035
Diversity	-0 051	-0 032
Design	-0 031	-0 039
Destinations	-0 036	-0 204

[9] Criterion Planners/Engineers and Fehr & Peers Associates INDEX 4D Method Technical Memorandum (US Environmental Protection Agency, October 2001) http //www crit com/pdf/FourDmethod pdf (Retrieved 20 May 2002)
[10] ibid

D.4 REGIONAL ANALYSIS MODELS: MEPLAN

The Sacramento MEPLAN model was developed in 1996 by a team at the University of California, Davis. The model was applied in the Sacramento area to examine induced demand effects and forecast region-wide land development and travel impacts of alternative build scenarios for the 25- and 50-year time horizons.

The MEPLAN model combines state-of-the-art integrated land use and transportation modeling techniques to produce separate a.m., p.m., and off-peak traffic assignment models. Given that traditional forecasting models produce only average daily traffic assignments, MEPLAN is able to yield more accurate emissions analysis.

The model is based on the integration between the land use and transportation markets. These markets respond to one another based on price signals and other market mechanisms where a change in one market will produce an immediate or "lagged" change in the other market. The MEPLAN model assumes a 5 year time lag. For example, transportation caused inaccessibility will be reflected by a change in activity location five years later The model below depicts the relationship between the two markets.

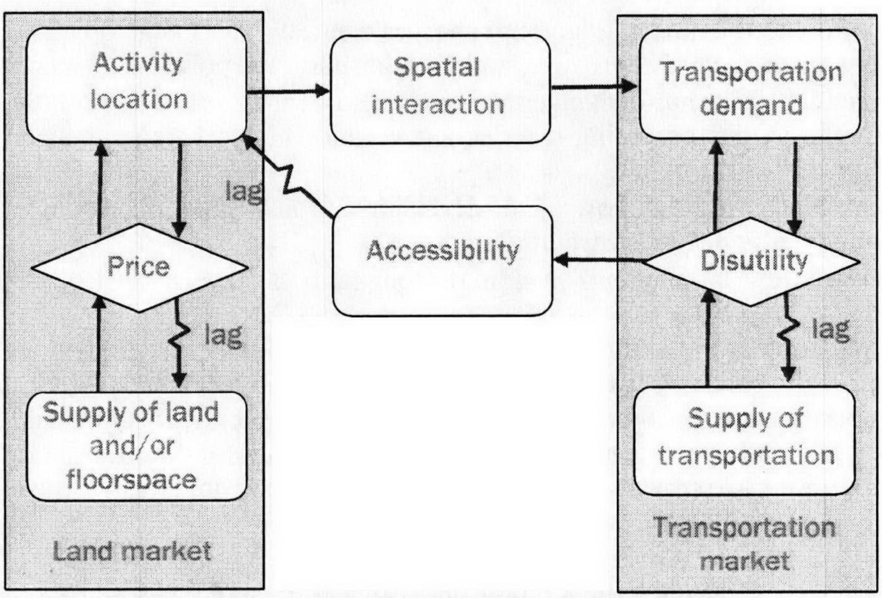

Figure D.1: The Sacramento MEPLAN model interactions

MEPLAN is a "quasi-dynamic" model involving the following steps:

- A social accounting matrix (SAM) is developed at the zonal level. This table reflects input-output relationships among four factors: industries, households, building floor space, and land (e.g. relating the units of floor space, industrial land, workers and other inputs to a particular industry).
- Using SAM, a <u>land market model</u> is developed whereby logit models of location choice are used to allocate volumes of activities in the different sectors to geographic

zones The attractiveness of zones is based on the costs of inputs (including transportation costs) and location-specific effects

- The resulting patterns of economic interactions among activities in different zones are used to generate origin-destination matrices of different types of trips
- Using these matrices, a multimodal <u>transportation market model</u> is generated Nested logit analysis is used to determine mode choice and stochastic user equilibrium is used for the traffic assignment model (with capacity restraint)
- The resulting network times and costs affect transportation costs, which then affect the attractiveness of zones and the location of activities This incremental change is then fed into the land market model in the next time period, thereby introducing lags in the location response to transport conditions

Research using the MEPLAN assessed the significance of accounting for induced travel effects, and found significant differences in impacts of alternative land use/transportation policies [11] When induced travel is not taken into account, the secondary effects of highway projects, such as changes in land use, are lost Research using MEPLAN showed that

- Trip distribution effects and locations of population and employment are the major contributors to induced travel effects
- Incorporation of induced demand & land use changes considerably change predicted VMT and emissions impacts of alternative land use-transportation policies
- These differences are sufficient to change the rank order of scenarios, with land use, transit and pricing options becoming more attractive once induced travel demand effects are included
- Household and employment follow land development, and land development follows accessibility provided by transportation
- Households move further from employment in the long term (2040 versus 2015)

MEPLAN, though sophisticated, has a number of limitations As with any sketch-planning model, the tool is coarse Its precision is dependent on the quality and availability of local (zone level) data on households by income, employment by industry, supply of zoned land, average prices for zoned land by category, social accounting matrices, transportation networks by mode, trips by trip purpose, mode, and time of day, distributions of travel distances by purpose, and origin-destination matrix of total trips

The MEPLAN model does not include a function for the change in time of day of travel, or variations in population and employment growth for different build scenarios Additionally, there is no accounting for social equity, or the net benefit to all travelers. For example, one can reasonably imagine that a high-build freeway scenario would allow the traditional higher income suburban resident that is highly auto-oriented to reap greater benefits than lower-income, urban residents who rely on transit for mobility Despite these limitations, MEPLAN demonstrates that a useful model of urban land use and transport interaction can be developed within this framework in the United States using existing data sources

[11] Caroline J Rodier, John E Abraham, Robert A Johnston and John Douglas Hunt, "Anatomy of Induced Travel Using An Integrated Land Use and Transportation model in the Sacramento Region" *Preprint for the 79th Annual Meeting of the Transportation Research Board* (2001)

D.5 REGIONAL ANALYSIS MODELS: LUTRAQ

The Land Use, Transportation and Air Quality (LUTRAQ) model was the first regional model in the United States to examine the land use, transportation and air quality connection The 1993 model was initiated by community groups in Portland in response to a proposed suburban freeway, known as the Western Bypass It aimed to demonstrate alternative transportation and land use options for ameliorating traffic congestion in the Portland Metro area It has now evolved into a national demonstration project to develop alternative suburban land use patterns and design standards and evaluate their impact on auto dependency, emissions, mobility and energy consumption

The LUTRAQ project recognized the strong link between transportation and land use that resulted in long-term induced travel demand and persistence of traffic congestion It did not focus on traditional travel forecasting but used an alternative transportation planning process, based on integrated transportation, land use and environmental principles outlined in Table E.4.

Using these principles, alternative land use and transportation options were developed These focused on moderate density, pedestrian-friendly neighborhoods connected to regional transit systems, and designs that reduce auto dependency, emissions, mobility, and energy consumption The LUTRAQ alternative was then compared to other regional transportation option in terms of forecast traffic and environmental outcomes [12]

Table D.4: LUTRAQ Principles[13]

Principle	Subcategory	
Focus the community towards transit	i	Provide the community with frequent and reliable transit service
	ii	Locate the primary transit stop at or near the center of the community
	iii	Provide direct access to the transit center
	iv	Extend the community no farther than ½ mile from the transit stop
A variety of uses	i	Zone for a variety of uses
	ii	Encourage a range of services and employment opportunities
	iii	Provide a range of housing options
Create streets for people	i	Use street design to limit automobile speed and volumes
	ii	Connect streets to form a usable network
	iii	Create safe, attractive, and accessible transit stops
	iv	Build safe and inviting sidewalks and crosswalks
	v	Provide a network of safe and convenient bikeways

[12] Calthorpe Associates, Cambridge Systematics Inc and Parsons Brinkerhoff Quade & Douglas, "The LUTRAQ Alternative" (Portland, Oregon 1000 Friends of Oregon, 1992) http //www friends org/resources/lut_vol3 html [cited May 15, 2002]

[13] Parsons Brinkerhoff Quade & Douglas Inc , "Making the Land Use Transportation Air Quality Connection Technical Report" (Portland, Oregon 1000 Friends of Oregon, 1997) http //www friends org/resources/lut_vol8 html [cited May 15, 2002]

Provide public open spaces	i	Provide open spaces for individuals and group recreational uses
	ii	Provide places for solitude
	iii	Preserve natural areas for water quality, air quality, and wildlife habitat
Design the community for livability	i	Construct porches on houses, to create eyes on the street
	ii	Locate commercial and office buildings for easy access by pedestrians
	iii	Include windows along the front face of commercial, retail, and office buildings
	iv	Place parking beside or behind buildings, in small lots
	v	Place larger parking areas in structures
	vi	Maintain a human scale in community design
Involve citizens in the creation of their community	i	Acknowledge the expertise that exists in the community's residents, business people, and supporters
	ii	Use both local experience and outside technical expertise as resources

At market densities, analysts found that the LUTRAQ transit-served communities could serve 75 percent of new jobs and 65 percent of new households This was in comparison to the 16% of new development that would be transit-served under the existing land uses and Western Bypass plan Additionally, the LUTRAQ plan was forecast to provide a 10 percent greater decrease in congestion levels than the Bypass proposal, without adding road capacity

The LUTRAQ plan became one of five alternatives that ODOT studied in the 1994 Major Investment Study (MIS) on the Bypass In this MIS, LUTRAQ outperformed the Western Bypass alternative in virtually every category, and in June 1997 the Bypass project was abandoned

At the time of the MIS, the Portland Metro (the Portland regional government organization) was studying land use and transportation issues for the region through 2040. This study resulted in adoption of the Region 2040 Growth Concept which was adopted in 1994 and guided by the same elements and principles as the LUTRAQ plan The Region 2040 Growth Concept, like the LUTRAQ plan, concentrated growth in centers and corridors served by transit and replicated 91 percent (by area) of the land use designations outlined in the LUTRAQ plan

LUTRAQ has resulted in successful transportation modeling practices to forecast how transportation design effects land use patterns and identified alternative land use patterns that result in significantly less reliance on automobiles The LUTRAQ project produced 11 technical reports looking at connections in transportation/transit land use, marketing and implementing LUTRAQ principles locally These reports cover issues that were not common to planning practice at the project's outset Since the LUTRAQ project, however, these connections are more commonly recognized Some of the topics include transportation impacts of pedestrian oriented design, travel behavior in transit oriented developments, the impact of land use mixing on trip production and mode choice, the value of small-scale site design choices in promoting non-automobile travel, and the ability of land use changes to increase the viability of transit operation in suburban areas National recognition of these issues has paved the way for new approaches to travel demand forecasting and transportation-land use planning