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Induced Traffic and Induced Demand in Benefit-Cost Analysis

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Abstract: Subsequent to the US DOT's 1995 "Conditions and Performance" report to Congress, the HERS (Highway Economic Requirements System) model used by FHWA to evaluate national highway investment options was modified to incorporate both short run and long run demand elasticities. The model uses benefit-cost methods to evaluate alternative improvements for sample projects. Demand elasticity in this evaluation allows estimated traffic volumes, as well as the location of the demand curve, to respond to endogenous factors -- such as travel time, operating costs, and accident rates -- that are affected by improvements. Typical improvements are additional lanes, lane or shoulder widening, realignment, resurfacing, and safety enhancements.

Keywords: induced demand benefit-cost

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Concepts of Induced Demand

Frequent references are made in transportation planning to the concept of induced demand, but the term remains ambiguous in its application. The object of this paper is to define the relevant concepts, and show how they can be operationalized in representing demand for purposes of benefit-cost evaluation of capital improvement projects.

Exogenous Forecast

Historically, demand forecasts in urban transportation planning have been based on exogenous variables such as land use, population, employment, and income. Once these variables were measured or estimated, the result was a "point" estimate for traffic or trip volume at one or more points in time. Demand, in this sense, was influenced by neither transportation infrastructure nor price, but existed simply to be served. FHWA's HERS (Highway Economic Requirements System) model used such forecasts up until the most recent version.

Demand Fills Capacity

A contrasting concept has developed, primarily among observers outside of the transportation planning community, that claims that whatever capacity is provided will eventually be fully used. This concept embodies the "build it and they will come" belief. Another term is "latent demand," suggesting that there are willing buyers who will express their demand for travel once the service is offered. In growing urban areas, the evidence from recent decades seemed to support this interpretation. Although not implemented as a formal forecasting method, the implication is that demand is entirely *end*ogenous.

Elastic Demand

Perhaps the first recognition that demand responded to endogenous factors was the claim that congestion is self-regulating, implying an automatic balancing of supply and demand. More recently, the economist's concept of demand being a relationship between price and quantity demanded has become accepted, if not necessarily applied in practice. From this perspective, all endogenous changes in volume are movements along the demand curve, whether they are called latent, induced, or something else. If "price" is generalized to include travel time, operating costs, and accidents, then movements along the demand curve account for induced travel.

Overall, then, travel demand is the result of a combination of both exogenous factors that determine the location of the demand curve, and endogenous factors that determine the price-volume point along the demand curve.

Short Run versus Long Run

The short run can be any period of time over which something remains fixed, but is normally assumed to be a year, for transportation planning. What is fixed might be the capacity of a highway, fuel efficiency of the vehicle fleet, locations of employment, or anything else that takes more than a year to change. Twenty years is sufficient to reach a long run equilibrium, but five years or even less may also be long enough for many kinds of long run adjustments to take place.

Short Run Elasticity

Demand "elasticity" is the responsiveness of quantity demanded to changes in price. Short run demand elasticity tends to be lower (less elastic) than long run elasticity, because more opportunities to increase or reduce consumption can be developed over the long run than in the short run, while short run options do not diminish in the long run. If the price of fuel goes up, for example, highway travelers can reduce fuel consumption by taking fewer trips and chaining trips together, by carpooling to share expenses, by driving in ways that achieve better mileage, and by taking a larger share of trips on transit. In the long run they can also switch to more fuel-efficient vehicles, and change their workplace and residence locations. If the price stays high, vehicle manufacturers will develop and produce more fuel-efficient vehicles, and better transit service will tend to be offered.

Long Run Elasticity

While the distinction between short run and long run demand is really a continuum rather than two discrete states, the separation is useful both conceptually and for modeling purposes. In Figure 1, two short run demand curves are shown in relation to their common long run demand curve (the latter indicated by a dashed line). Demand could be for a facility, a corridor, or even travel in a region. At a "long run" price of p_1 the demand curve D_1 applies, such that changes in the price cause changes in volume along this demand curve in the short run. If the price drops to p_2, for example, then volume will increase to a flow of $v_{1,s}$. If the price stays at that level for the long run, then the demand curve will shift outward to D_2, resulting in the volume v_2 at that price. If the price were then to go back up to p_1, volume would only drop to $v_{2,s}$ in the short run, and eventually back to v_1 in the long run.

For example, secular declines in real fuel prices have led to increases in the size and weight of vehicles and concomitant declines in their fuel economy; if the price of fuel were to increase, gasoline consumption would drop but the vehicle fleet would take time to evolve to a more fuel-efficient average.

Induced Traffic versus Induced Demand

A similar distinction can be made between "induced traffic" (or induced travel) and "induced demand," by applying the short run and long run concepts: demand is assumed fixed in the short run, so changes in volumes are the result of movements along the demand curve, whereas the demand curve itself can shift in the long run. Thus these terms are defined such that "induced traffic" is a movement along the *short run* demand curve, while "induced demand" is a movement along the *long run* demand curve, or an endogenous *shift* in the short run demand curve.

In Figure 1, no time direction is implied on the horizontal dimension; the shape of the long run demand curve does not mean that price declines over time. Nor are the short run demand curves necessarily ordered from one to two; demand could start at D_2 and

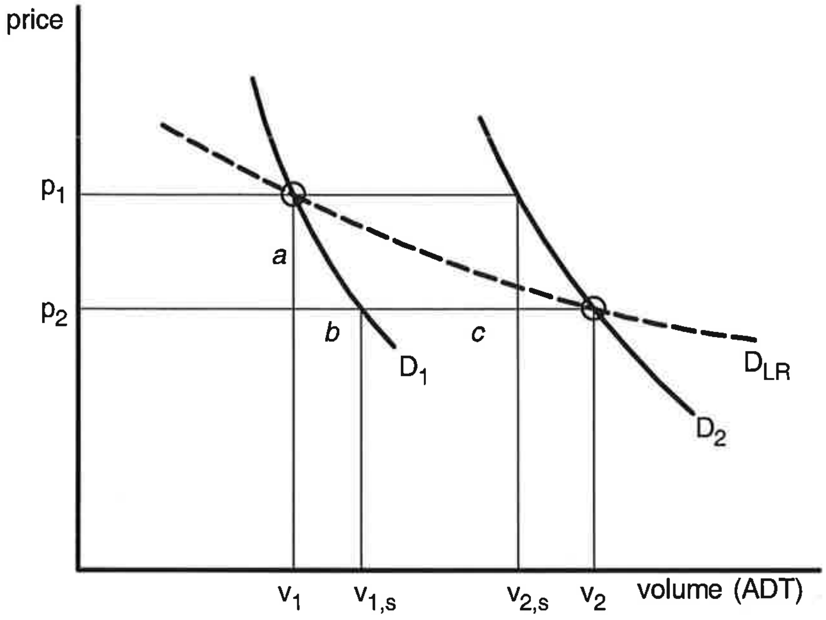

FIGURE 1. **Long run demand with short run demand curves.**

then shift to D_1. The diagram shows only the relationship between price and volume under short run and long run conditions.

Disaggregation of Long Run Elasticity

Long run elasticity -- as with any other demand elasticity -- is a ratio of the percent change in quantity demanded to the percent change in the price of the good. Referring to Figure 1, the first circled point at (p_1,v_1) is taken to represent an existing market equilibrium on both the short run and long run demand curves. The second circled point at (p_2,v_2) represents the long run equilibrium after a price change, which lies on the previous long run demand curve but a new short run curve. The arc elasticity between the two points is

$$e_{LR} = \frac{\Delta v}{\Delta p} \times \frac{p_1}{v_1} = \left(\frac{v_2 - v_1}{p_2 - p_1}\right) \times \frac{p_1}{v_1} \qquad [1]$$

where e_{LR} is the long run elasticity of demand. If the following simplifications are made for ease of presentation,

$$\begin{aligned} a &= p_2 - p_1 \\ b &= v_{1,s} - v_1 \\ c &= v_2 - v_{1,s} \end{aligned} \qquad [2]$$

as shown in Figure 1, then the long run elasticity can be represented as

$$e_{LR} = \frac{b+c}{a} \times \frac{p_1}{v_1} = \left(\frac{b}{a} \times \frac{p_1}{v_1}\right) + \left(\frac{c}{a} \times \frac{p_1}{v_1}\right) \quad [3]$$

where the first term in parentheses is the short run elasticity (e_{SR}) and the second term is the shift in the demand curve over the long run, represented as an elasticity. Thus the long run elasticity is the sum of the e_{SR} and a purely long run component which will be called the long run share, e_{LRS}, defined as

$$e_{LRS} = \left(\frac{c}{a} \times \frac{p_1}{v_1}\right) = \left(\frac{v_2 - v_{1,s}}{p_2 - p_1}\right) \times \frac{p_1}{v_1} \quad [4]$$

so

$$e_{LR} = e_{SR} + e_{LRS} \quad [5]$$

The e_{LRS} component can be interpreted in the same way as a normal elasticity, and can be empirically measured as the difference between the short run elasticity and the long run elasticity estimated for the appropriate time period.[1]

Induced Traffic

As defined above, induced *traffic* is a movement along the short run demand curve. The cause of the movement is a change in price, generalized to include travel time, operating costs, and accidents. Everything included in this generalized price is an endogenous factor with respect to induced traffic.

Common usage of the term "induced" suggests additional traffic, i.e., an increase in volume. Decreases might be called disinduced or deterred or discouraged traffic. For present purposes, however, the term induced refers to any endogenous change, whether positive or negative. Increased congestion or higher tolls, other things being equal, will cause a reduction in volumes. If this occurs in the short run, this is (negative) induced traffic.

Some of the possible sources of induced traffic are:

- Diverted traffic that changes its route onto the improved facility.
- Rescheduled traffic that previously used the facility at a different time (spreading or contracting the peak).

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[1] See Taplin (1982) and Taplin (1997).

- Shifts from other modes -- which may or may not have used the facility before -- including changes in occupancy.
- Destination shifts resulting from the improvement of the facility.
- Additional travel by persons already using, or in the market for, the facility.

Demand forecasts for a new or improved facility always include at least some of these sources, although such estimates seldom explicitly recognize a generalized price as the explanatory variable and do not produce a schedule of price-volume combinations.

Partial and General Equilibrium Demand Curves

All demand curves portrayed in this analysis are assumed to be general equilibrium demand curves, even those for the short run. Thus they include traffic shifted to or from other modes or from alternative facilities. A partial equilibrium demand curve, as represented in Figure 2, includes only the travel for those already in the market, whether they are currently taking trips or not (e.g., a person who did not travel at all in this corridor but who chose to do so after the price was reduced, and not by shifting a trip from another time or place). If the demand curve includes diverted travelers (from other modes, routes, times, or destinations), then it will be more elastic than the corresponding partial demand curve because more options are offered. Thus some of the (short run)

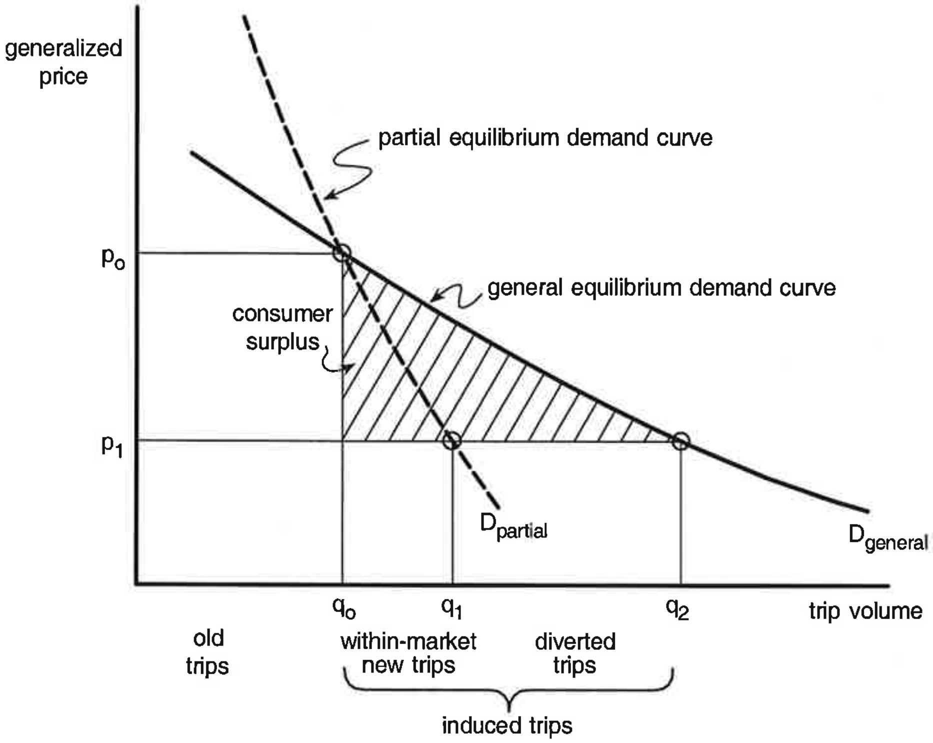

FIGURE 2. Partial and general equilibrium demand curves.

induced travel comes from new trips by persons already in the market, and some comes from trips diverted from other markets.

For every point on the general equilibrium demand curve there is a corresponding partial demand curve, representing the (hypothetical) demand that would occur if there were no substitution between markets. If the price were raised, for example, from a point on the general equilibrium demand curve, a movement up the partial demand curve would imply that the travelers could not divert to another time or facility. Not surprisingly, such a demand curve cannot be observed in practice.

Because demand forecasts usually include diverted trips, practical demand forecasts are aimed implicitly at constructing (or locating points on) a general equilibrium demand curve. If the demand is for a single facility, then induced traffic will appear large relative to previous volumes, because most of the change in trips will be diversions. At the regional level, induced traffic -- if it were actually estimated -- would be a smaller share of total traffic growth because only trips diverted from other regions, plus substitutions between transportation and other goods, make up the induced share.

"Gross" versus "Net" Induced Traffic

In Figure 2, all of the movement along the general equilibrium demand curve stimulated by the reduction in price from p_0 to p_1 is labeled "induced trips." A portion of this induced traffic is labeled "diverted trips." If the diverted trips are removed from the total "gross" induced traffic, the residual might be called "net" induced traffic. Some analysts prefer that the term induced be restricted to mean *net* induced trips, and the others be left as diverted trips.[2]

For some purposes, this usage has an appeal, but the distinction is a difficult one to make. A trip between the same origin and destination but using a different route is clearly a diverted trip, but trips at other times, or to other destinations are less obvious. If the improved facility prompts me to go to a movie instead of renting a video, and the video store is much closer, is this induced or diverted? Suppose I would have walked to the video store? Suppose I would have had the video delivered, and the van would have used the same facility before it was improved? What can be observed directly is that more vehicles use the facility after it is improved, and that trips in the region do not go up by as large an amount as the volume on the improved facility. Labeling which particular travel is "new" and which is "diverted," however, is difficult and probably not necessary.

Induced Demand

For an empirical model such as the HERS model, the overall analysis period for a project (generally the project lifetime) is broken into discrete periods, during each of

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[2] Examples include Dowling (1994) and SACTRA (1994).

which the demand curve is assumed to be fixed. A baseline long range forecast is used to establish the short run demand curve for each period.

Baseline Demand Forecast

A demand forecast is a functional relationship between time and traffic volume, assuming a set of conditions. *Exogenous* conditions include population growth, economic growth, land use patterns, and available substitute transportation alternatives. *Endogenous* conditions include capacity, level of service (LOS), and user fees. For the present analysis, all endogenous factors are represented in the generalized price. Capacity and LOS, for example, would both be subsumed under travel time cost, and included in the generalized price.

The baseline long run demand forecast assumes a generalized price, as well as whatever exogenous factors are thought to be relevant by the forecaster. Alternative forecasts under different assumptions might be constructed, as shown in Figure 3. We will assume that one of these scenarios has been selected.

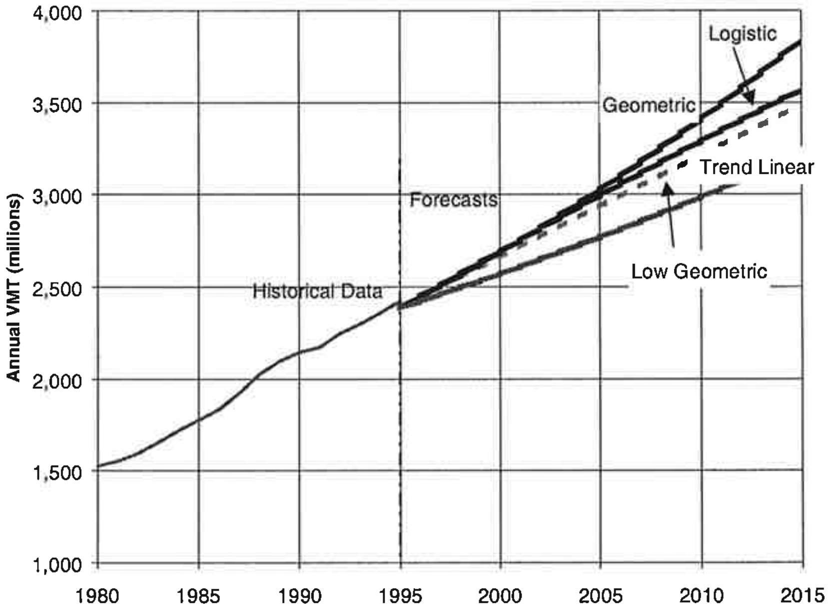

FIGURE 3. Alternative long run travel forecasts

Breaking the Forecast Into Discrete Periods

The distinction between long run induced demand and short run induced travel is implemented by breaking the overall analysis period (e.g., twenty years) into shorter demand periods (e.g. 1-5 years). Each demand period constitutes a short run during which a single demand curve applies for the duration of the period.

Once the overall analysis period is broken into demand periods, the forecast becomes a series of discrete points.[3] These points, circled in Figure 4, provide the origins or calibration points for the associated short run demand curves. The short run demand curve can be a straight line calibrated with an arc elasticity, or a constant elasticity demand curve, or some other functional form that can be fitted to a single price-quantity combination.

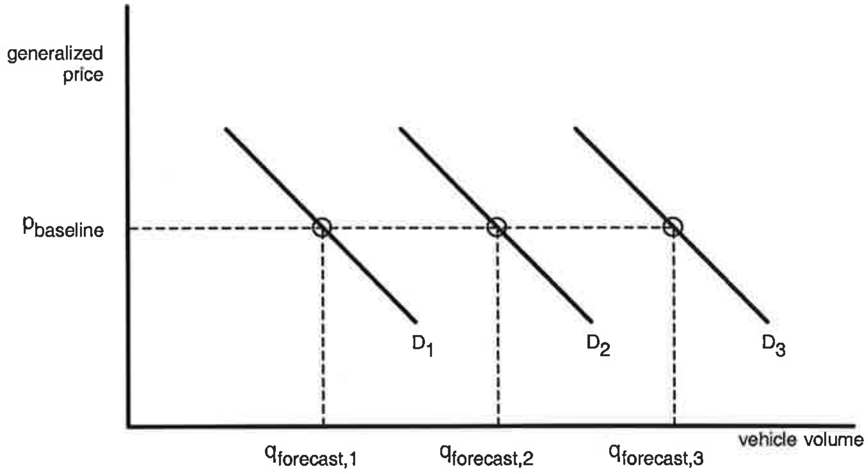

FIGURE 4. Baseline demand forecast for several periods

A single fitted short run demand curve is shown in Figure 5, along with other relevant prices and volumes. The price from the previous period $p_{final,\ t-1}$ is adjusted to account for traffic growth, pavement wear, accident rates, and user fee changes that have occurred since the previous period.[4] The result is $p_{no\ improvement}$. Alternative improvements for the current period are evaluated, and, if any are feasible, the best is implemented. This results in the $p_{improved}$ price, which becomes the initial price for the next demand period. If no improvement is selected, the unimproved price carries into the next period.

Long Run Shifts in the Demand Curve

Evolution of demand in the long run is built upon what takes place in the short run. Operationally, induced *demand* is defined to be the shift in the demand curve caused by the price in the previous period. If the price in all previous periods is the same as the baseline price, then the demand curve is fitted to the baseline forecast for that period. If an improvement is made in one period that reduces the price below the baseline price, this leads to a shifting of the demand curve outward, according to the percent by which the price in the previous period is below the baseline price. If no improvement is made, the price increases relative to the baseline forecast price, and the demand curve shifts

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[3] In HERS, the demand periods are referred to as "funding" periods, which together make up the overall analysis period.

[4] At present, the generalized price in HERS includes all of the components except user fees; see Table 1.

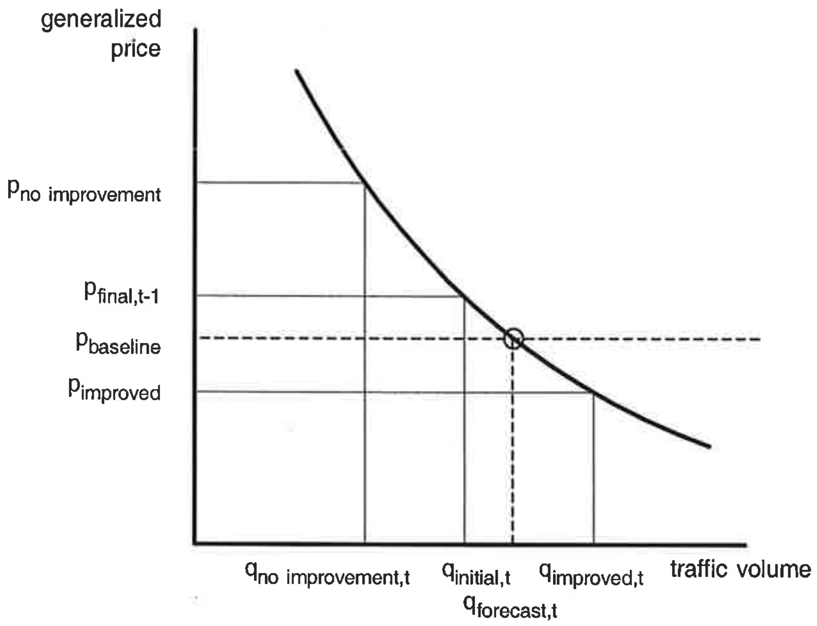

FIGURE 5. **Short run demand showing prices with and without improvements.**

inward in the next period. These two possibilities are shown in Figure 6. For example, a price of $p_{no\ improvement}$ will shift the subsequent demand curve inward from $q_{forecast}$ by a percentage equal to $(p_{baseline} - p_{no\ improvement}) \times e_{LRS}$.

The relationship between the difference in price between the final (improved or not improved) price and the baseline price, for one period, and the horizontal shift in the demand curve in the next period, is the long run share e_{LRS}, as described above.[5] There is no long run demand curve as such, but the shift attributed to induced demand is a displacement of the demand calibration point along the baseline price line.

With induced demand, then, each period's demand curve is a function of the previous period's investment (as it affects price to the user). Investment that keeps the price in each period below the baseline price for the baseline forecast produces demand curves that shift outward farther and farther, compared to the baseline forecast. Similarly, if improvements are not made and price is allowed to rise in each period (due to congestion, pavement roughness, and accidents), the demand curve will be continually shifted inward relative to the baseline.

The magnitude of this shifting -- the sensitivity of long run demand to investment and pricing -- is determined by the e_{LRS} parameter. The shorter the time period for the short run, the lower should be the long run elasticity shift from period to period. If the long run induced demand parameter is zero, the location of each short run demand curve

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[5] See "Disaggregation of Long Run Elasticity" on page 3.

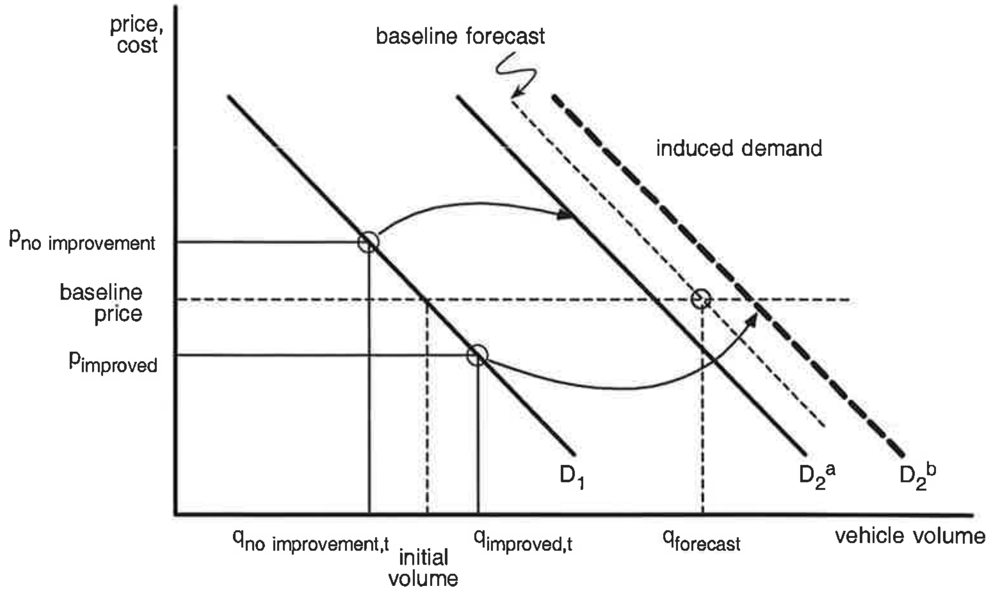

FIGURE 6. **Long run induced demand shift from one period to the next.**

would be determined by the baseline forecast, without regard for which, if any, improvements were made in any demand period. Short run movements along the demand curve could still occur, depending upon the short run price elasticity, but there would be no cumulative endogenous effects from one period to the next. Alternatively, with a high e_{LRS}, induced demand could potentially offset the trend of the initial forecast, leading to growth in demand (from keeping the price low) despite a declining forecast, or causing a decline in demand despite a growth forecast (traffic is deterred by congestion and bad pavement, as a consequence of no improvements).

Getting to the Long Run

Empirical estimates of the two elasticities depend upon the length of the short-run time period and the rate of adjustment to changes in price. The length of time between a change in conditions and a new equilibrium is somewhat arbitrary because other conditions change before equilibrium is reached, but the process is one of accelerating initial response followed by gradual refinement. In the context of highway volume adjustments in response to changes in the generalized price of travel, the short run is up to a year. The long run -- allowing for changes in residence and workplace locations -- begins within a year but may not run its course for upwards of twenty years. Such changes are not likely to be motivated solely by changes in transportation prices, but may take transportation user costs into account when the change is made for other reasons (new job, change in income, change in family).

An approximate adjustment curve is shown in Figure 7. Although the curve is not fitted to specific data, it reflects the generally observed pattern roughly half the adjustments take place within five years of the change in the price of travel.[6]

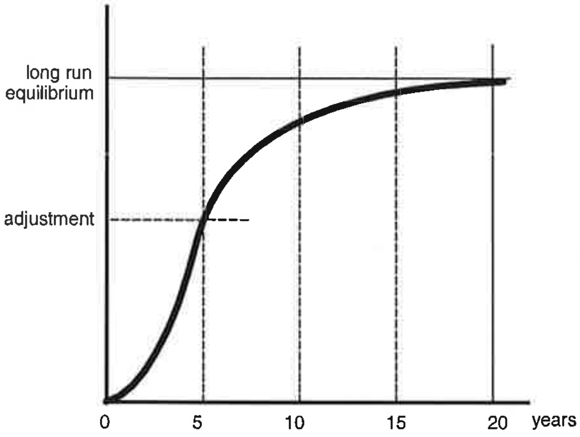

FIGURE 7. **Path to long run equilibrium.**

Empirical Estimates of Short and Long Run Elasticities

Many studies have estimated travel demand elasticities, but one of the difficulties in interpreting these results is the ambiguity of the time frame that is applicable to the data. Another confounding problem is the ambiguity of the base of the observed elasticity; because most of the empirical cases observe a change in a small component of the total price of travel, the base for computing the percentage change in price is often not obvious and may not be given explicit treatment. The potential differences are large, e.g., a factor of five.[7]

The parameter sought is the elasticity of vehicle travel with respect to its own price, including user fees, operating costs, and travel time. Empirically, it is possible to estimate elasticities for different lag periods, using spontaneous price changes and econometric techniques to control for other influences such as general inflation. Ideally, say, one-year and five-year travel elasticities could be estimated, and the former subtracted from the latter to derive the "pure" long run factor, e_{LRS}. Studies undertaken to date suggest that the short run elasticity is around -0.8, while longer run elasticities are at least -1.0 to -1.5, yielding an e_{LRS} of -0.2 to -0.7.[8]

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[6] Hansen, et al. (1993) study the time lag in response to highway capacity increases; Cairns, et al. (1998) study responses to reductions in capacity.

[7] Refer to Lee (1998), Appendix C to Camus and Weinblatt (1998)

[8] Some studies to refer to are Goodwin (1996, 1992); Pells (1989).; and Williams and Yamashita (1992). Another empirical and conceptual problem stems from the different sets of user options available depending upon the form of the price change. An increase in a congestion toll, for example, can be shared among vehicle occupants, whereas an increase in congestion is fully imposed on all occupants and cannot be reduced by sharing the cost. Ideally, different elasticities should apply to time costs and money costs, and perhaps to different components of operating cost. The HERS model applies a single short run elasticity to all user costs.

Project Evaluation

Improvement projects are evaluated in HERS within a benefit-cost framework. One or more improvement types (e.g., resurfacing, additional lanes, reconstruction to expressway standards) is proposed for evaluation, and the project generating the maximum net benefits is selected.

Impacts of Improvements

Each type of improvement changes user costs by some amount, as well as resulting in other operating benefits. Reductions in running costs, travel time, and accidents are both reductions in price and real benefits. Savings in agency (maintenance) costs and externalities (e.g., air pollution) are real benefits but not included in the price, whereas savings in user fees are not real benefits. Thus the impacts of each improvement can be estimated from its induced traffic volume (based on the price and demand curve) and variable cost savings. These net operating benefits (*NOB*) are estimated for the current period, and subsequent periods, over the lifetime of the improvements. Any improvement whose *NOB* over its lifetime exceeds its capital costs is considered feasible; among feasible improvement projects, the one generating the highest net benefits is preferred.

For a given improvement, *NOB* can be represented by the shaded area in Figure 8. Ben-

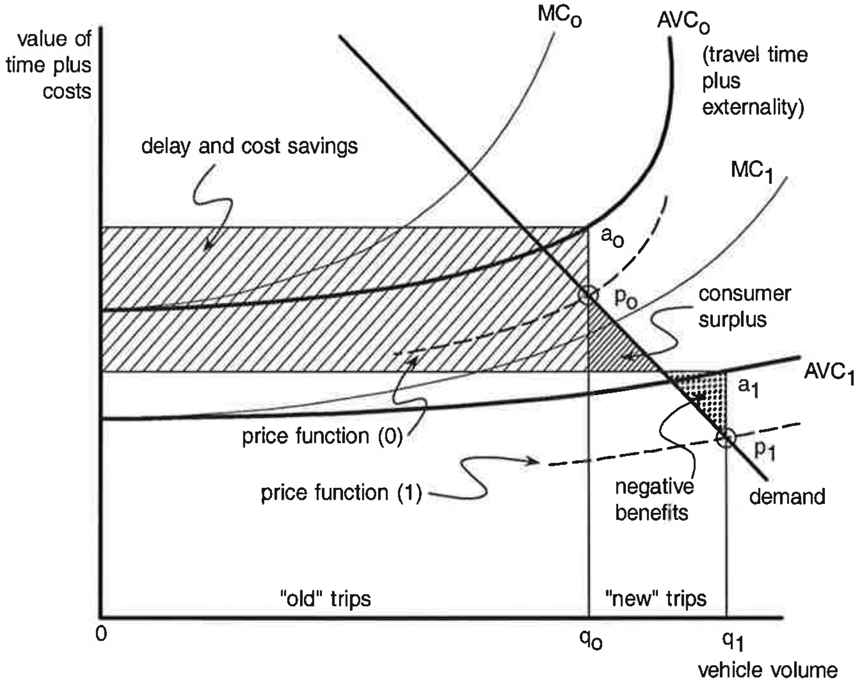

FIGURE 8. **Project Net Operating Benefits (*NOB*).**

efits can be divided between those realized on “old” trips (the volume occurring in the no-improvement alternative), and incremental benefits on “new” trips. The diagram shows typical “second-best” conditions, meaning that the price to users is not necessarily efficient, i.e., it is not equal to marginal cost.

Marginal Cost, Average Cost, and Price

In general, at any given volume, marginal cost, average cost, and price to the user are all different. Marginal and average cost are mathematically related, and will differ if any component of cost varies with volume (or *v/c*); because unit travel time costs rise with congestion, for most volume levels marginal cost lies above average cost. Price includes user charges, which are transfers and not costs, and excludes externalities, which *are* costs. The measurement of *NOB* depends upon which of these concepts is applicable for each type of benefit:

> **Marginal Cost:** *MC* is the guide for efficient pricing, so if $p = MC$ at all volumes, then net benefits in the short run are maximized for the facility. In this special case, price and marginal cost are the same. As represented more generally in Figure 8, marginal costs are labeled as MC_0 and MC_1 for the base and project alternatives.
>
> **Average Cost:** Total variable cost can be measured as either the area under the marginal cost curve or the average variable cost times the volume, the latter being a rectangle.[9] Because users are faced with average rather than marginal travel time costs, it is frequently assumed that price and average cost are the same, but this usually is not true. Average variable costs corresponding to the two marginal cost curves are indicated as AVC_0 and AVC_1.
>
> **Price:** Price is the cost to the user, to include time, accidents, and running costs as well as money payments conditional on usage. The price function for each alternative is shown by a dashed line.

Cost components that are included in each of these three measures are shown in Table 1. The diagram will look different if the price function lies above average cost rather than below as shown, but the calculations are the same.

Price-Volume Combinations

The point p_0 in Figure 8 is the initial price and volume combination for the funding period. The demand curve is derived from the baseline forecast, the difference between p_0 and p_{baseline}, the assumed form of the demand curve, and the short run elasticity e_{SR}.

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[9] *NOB* can be derived in several ways, depending upon how cost and benefit components are specified. If areas under the marginal cost curves are used instead of average costs, for example, then *NOB* consists of the area under MC_0 up to q_0, minus the area under MC_1 up to q_1, plus the area under the demand curve from q_0 to q_1. The net of these areas in the diagram would follow MC_0 up to the volume q_0, then vertically down to p_0, along the demand curve a short way to MC_1, out MC_1 to a volume of q_1, vertically down to p_1, back along the demand curve to MC_1, and back along MC_1 to the vertical axis. Note that this area is exactly equal to the area shown in the diagram, but the two do not allocate the benefits to “old” and “new” trips in the same way.

TABLE 1. Price and Cost Components

	Marginal Cost	Average Cost	Price	HERS
Travel Time				
Uncongested Time	y	y	y	y
Excess Delay	MT	AD	AD	AD
Running Cost				
Fuel	y	y	y	y
Vehicle Maintenance	y	y	y	y
Vehicle Wear	y	y	y	y
Accidents (internal)	y	y	y	y
Parking (internal)				
Vehicle Ownership				
Infrastructure				
Pavement Wear	y	y		y
Maintenance and Operation	y	y		y
Fixed Capital				
Parking (unpriced)				
Externalities				
Air Pollution	y	y		y
Water Pollution	y	y		
Noise and Vibration	y	y		
User Charges				
Tolls			y	
Excise Taxes			y	
Other Fees			y	

y = cost component is included in the total for the column category

MT = marginal time cost is included

AD = average delay cost is included

HERS = component is explicitly recognized in the Highway Economic Requirements System (HERS) model

The price p_0 is derived from the price at the end of the last period, plus any changes that occur in the present period, such as increased delay, pavement wear, accident rates, and user charges. This price p_0 is the unimproved price $p_{\text{no improvement}}$ in Figure 5. Only those components listed in Table 1 under "Price" pertain to determining the initial and improved volumes. For example, both fuel costs and fuel excise taxes are included in the prices p_0 and p_1, but air pollution is not.

The impacts of an improvement alternative are summarized by the improved price p_1 (p_{improved} in Figure 5). The intersection of this price with the demand curve sets the vol-a negative benefit (i.e., traffic induced by underpricing produces externalities that exceed internal benefits).

Externalities caused by induced trips diverted from other facilities may not be adding to the total emissions of pollutants. The only way, however, to incorporate changes in externalities in related markets (e.g, parallel facilities) is to measure the difference in the total inefficiency with and without the improvement project, not just one item (e.g., pollution or congestion) at a time. The magnitude of such differences in related markets is likely to be small relative to benefits in the primary market.

Multi-Period Evaluation

The above steps describe a static equilibrium analysis conducted within a single short run period. For each improvement alternative, the steps are repeated for each demand period over the lifetime of the improvement. Once the lifetime NOB are accumulated for each alternative and compared to its costs, the investment choice is made for that highway section and another section is evaluated. After all feasible investments are identified for the current funding period, the analysis is repeated for the next demand or funding period, until a program of improvements has been selected for the overall analysis period. In this way each alternative is evaluated for each section in each demand period, incorporating both short run and long run induced demand.

Interpreting Demand Forecasts

Two aspects of the demand forecasts are of particular interest. One, already mentioned, is how to impute a presumed price to the forecast. The second is whether long run feedback of transportation investments on the demand curve has been incorporated into the forecast.

> **Baseline Price:** Although the generalized price behind a demand forecast is seldom made explicit, such attributes as LOS and accident rates may be, and others can be guessed. Pavement quality is probably assumed to be good, and operating costs are typical for the conditions (terrain, vehicle type, congestion). As a default, the current LOS can be assumed.
>
> **Long Run Demand Feedback:** Constructing or expanding a facility will induce some travel in the long run even if the price is unchanged from the baseline. In principal, then, the baseline forecast should include growth in travel that will result from traffic-generating activities that choose to locate in such a way as to take advantage of the services provided by the facility. The long run elasticity amplifies this effect up or down, but does not substitute for it.

If forecasts are based on historical patterns over a time horizon of half a dozen years or more, then the feedback effect is implicitly built in. Whether it needs to be made explicit or refined is an open question, but the impacts of errors in out-year forecasts are suppressed somewhat by discounting.

Conclusions

Some of the ambiguity and confusion that surrounds the discussion of induced demand might be dispelled by applying the following definitions and principles:

(1) The term *induced* means a movement along a travel demand curve as a result of changes in *endogenous* factors, which can be represented as components (time, running cost, money) of a generalized price.

(2) The measurement of induced travel is dependent upon the *market* for which the demand curve is defined; induced travel defined at the facility level will include traffic diverted from parallel routes, while induced travel at the regional level will include only trips that are new to the region.

(3) A useful distinction can be made between short run demand and long run demand: movements along the *short* run demand curve amount to *induced traffic*, whereas movement along the long run demand curve constitutes a *shift* in the short run demand and can be called *induced demand.*

(4) Benefit-cost evaluation of projects requires that baseline demand forecasts be adjusted to take into account induced demand, both short and long run; this is simply to say that improvements that change user costs should be evaluated in the light of whatever changes in volume will actually occur. Such demand curves are referred to as general equilibrium demand curves.

(5) If the short run elasticity is zero, then traffic volumes are unresponsive to changes in price within a single demand period, and the demand curve is vertical. If the long run share (i.e., excluding short run effects) elasticity is zero, then there are no long run effects (e.g., no investment in highway-related facilities or land use changes) stimulated by highway pricing and investment policies. Empirically, neither of these conditions applies: short run elasticities are roughly -.5 to -.9, and long run elasticities are larger in magnitude by at least -.2 to -.5, yielding a long run elasticity of at least -1.0.

(6) For benefit-cost analysis, changes in variable costs determine the magnitude of benefits, while changes in generalized price lead to induced travel.

These concepts are readily made operational, and most of them are incorporated into the current version of the HERS model.

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