HERS-ST v2.0

Highway Economic Requirements System-State Version

INDUCED DEMAND AND ELASTICITY

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This paper expands upon the concepts of induced demand and their representation in the HERS model. The importance of recognizing induced traffic and induced demand are presented, their separation into long run and short run demand curves is described, and the use of elasticities to make them operational in the model is explained.

For choosing among alternatives that accomplish the same end but in different ways, a life-cycle cost analysis may be sufficient. An example might be the type of pavement or pavement structure: the surface quality will be the same in all cases, over the relevant period of time. In this case, the volume of traffic will not be affected by the choice of pavement. In other cases, however, assuming that volumes are unaffected by improvements is not valid.

Meaning and Application of Elasticity

The term "induced" demand arose in an attempt to describe the apparent relationship that more highway capacity results in more traffic. At issue is cause and effect: would the traffic have been there anyway, without the capacity addition (therefore the traffic caused the road), or was the traffic induced to use the highway because of the available capacity (the road caused the traffic)?

Travel "Induced" by an Improvement

When the alternatives include the possibility of not making any improvement, and the improvements being considered affect the quality of service (travel time, operating costs, and safety), then the volume and type of traffic are likely to be affected by the presence or absence of the improvement. These effects are above and beyond changes in demand that occur due to demographic or economic factors that may grow or decline over time independently of the characteristics of the highway.

For example, if a road is congested, then adding capacity will reduce travel times, and this increase in service level will attract some additional trips that would not have been there without the improvement. Some of these trips will be diverted from another facility, some may result from taking longer or more frequent trips, some from choosing different destinations. In any event, more VMT occurs if the improvement is implemented than if it is not. The additional traffic has come to be known as "induced demand." Pavement and safety improvements may also result in some induced demand.

An Analytic Tool for Representing Induced Travel

"Elasticity" is a term economists use to refer to the degree of responsiveness of the amount of a good that is purchased to the price of the good. Roughly speaking, it is the slope of the demand curve at a given point. The concept of elasticity is useful in constructing an analytic framework for recognizing induced demand. By treating travel time, vehicle operating costs, accident risk, and user charges as being components of the "price" of highway travel, the change in volume resulting from an improvement can be estimated.

If demand is determined by economic and demographic factors external to the highway system, and facilities are designed and constructed to serve that demand, then whether an improvement is made or not has no effect on traffic volume, and demand is "inelastic" (does not respond to price changes). At the other extreme, if demand is created by the construction of facilities and the addition of capacity, and facilities always fill up with traffic, then demand is perfectly or infinitely elastic. Neither extreme is accurate, i.e., demand elasticity is neither zero nor infinite; the reality is that demand is a combination of *exogenous* (external to the highway itself) and *endogenous* (characteristics of the highway such as speed) factors. Travel demand, then, is the result 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.

The elasticity feature in HERS allows traffic volumes to respond to changes in endogenous demand factors, such as pavement quality and congestion. The mechanism for the response is the generalized price of travel—the cost of travel to the user—and an elasticity that relates price to volume. This relationship permits the construction of a short-run demand curve for each funding period (for each project), and the shifting of that demand curve between periods. The traffic forecasts provided for each HPMS section are assumed to capture all of the relevant exogenous factors. Demand elasticity, however, is not provided in the HPMS section data, so it must be supplied by the HERS user.

Definition of Elasticity

The definition of elasticity is the change in quantity demanded, or supplied, as a result of a change in price, normalized so that the changes are in percentage rather than absolute terms. The most common application of the concept is to a demand curve, so that the quantity part is quantity demanded, and the price part is the price of the same good. This form of elasticity is known as demand-price elasticity, and it is the form used by HERS.

Price is generalized for travel demand purposes to include travel time, operating costs, and crashes, as well as user charges. Everything included in this generalized price is an endogenous factor with respect to induced traffic. In slightly more formal terms,

$$e = \frac{\%\Delta q}{\%\Delta p} \qquad [1]$$

where e = elasticity, q = quantity or volume of travel, p = price, and the Δ (delta) means the difference or change in the quantity or the price. The sign is normally negative (price and quantity move in opposite directions), and sometimes the sign is omitted if the relationship is in the expected direction.[1] A "large" or "high" elasticity refers to one that is large in absolute value or magnitude, so that -1.0 is "higher" than -0.2.

Arc Elasticity

A portion of a demand curve is shown in Figure 1. Demand-price elasticity at the point (q_o, p_o) can be measured by taking a small region around it and computing the elasticity as defined above, namely,

$$e = \frac{\Delta q / q_0}{\Delta p / p_0} = \frac{\Delta q}{\Delta p} \times \frac{p_0}{q_0} \qquad [2]$$

This formulation is known as arc elasticity, because it is calculated over some finite segment of the curve. If the initial point on the demand curve is q_0 = 2,000 and p_0 = \$1.00, while Δq = 500 and Δp = -\$0.20, then the arc elasticity from the initial point is

$$e = \frac{500}{-0.20} \times \frac{1.00}{2,000} = -1.25$$

An arc elasticity can be regarded as the average elasticity over some range of demand. Empirically, it might be measured before and after a price change.

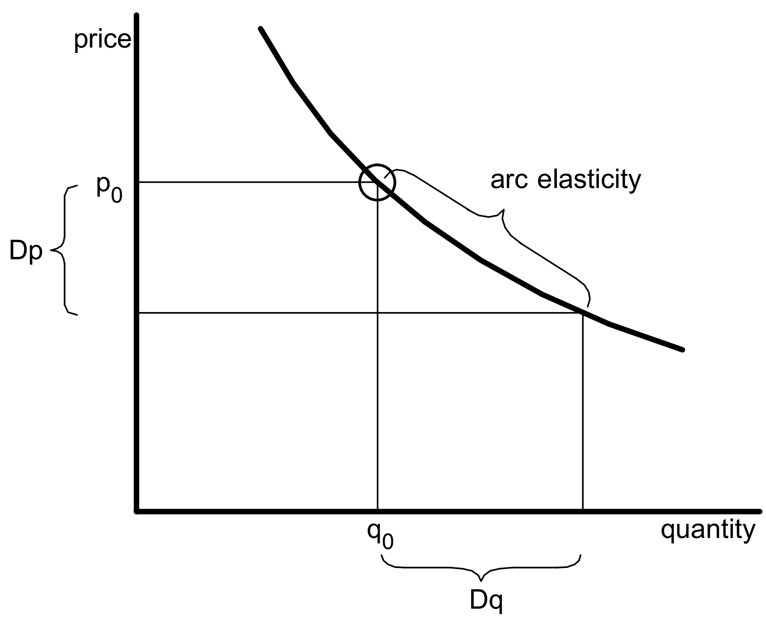

FIGURE 1. **Arc demand-price elasticity.**

[1] Cross-elasticities and supply elasticities are more likely to be positive in sign.

Knowing any four of the five numbers in the elasticity formula allows the fifth to be calculated. In HERS, a typical application is to start from a given price-volume point, estimate the change in the price to the user that will result from an improvement, and use an estimated demand elasticity to calculate the change in volume.

Equation **[2]** makes it clear that an elasticity is derived from the slope of the demand curve and the point on the curve at which it is measured. For a straight line, the term $\Delta q/\Delta p$ is constant, so it is the ratio p_0/q_0 that determines elasticity in moving along the demand curve. This means that the lower right-hand portion of a demand curve will tend to be inelastic, and the upper left portion will tend to be elastic. It also means that the steeper the slope (relative to the q-axis, other things equal) the lower the elasticity. A vertical demand curve is inelastic (low elasticity), whereas a horizontal demand curve is elastic.

Perhaps the first recognition that demand responded to endogenous factors was the assertion that congestion is self-regulating, implying an automatic balancing of supply and demand. From the perspective of the economist's concept of demand being a relationship between price and quantity demanded, 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 crashes, then changes in capacity and alignment alter the "price" and thereby cause movements along the demand curve.

Constant-Elasticity Demand

Although the ratio of p/q necessarily changes in moving along a demand curve, it is possible to construct a curve in which the slope exactly offsets the ratio of p/q so that the elasticity is constant along the length of the curve. Such a curve has the form

$$q = \alpha p^e \quad \textbf{[3]}$$

where α is a constant term that allows the curve to be fitted to any given demand point (price and volume) and also exhibit a pre-determined elasticity (e). HERS uses this constant-elasticity form for its short-run demand curve. The main virtue of this functional form is that the elasticity is always that which is specified, no matter where along the demand curve the price happens to fall. The curve has the appearance of that in Figure 2. The range of price and volume covered by this example are relatively large (measured in percentage terms), and over the ranges more typical of a single section, the curve appears straighter. A demand curve is fitted to each section for each demand period under each improvement alternative.

Short Run versus Long Run

Not only are traffic volumes affected by improvements within the short run encompassed by a single funding period: the demand curve itself may shift from one period to the next according to how improvements (or their lack) have affected the generalized price of highway travel. An improvement in one period that causes the generalized price to remain below the baseline price in the next period will result in an outward shift of the demand curve (higher volume at the same price). The amount of this shift is governed by the difference between the actual price and the baseline price, and the long run share factor (LRS) that is selected by the user. The sum of SRE and LRS is the long run elasticity over the time span of one funding period.

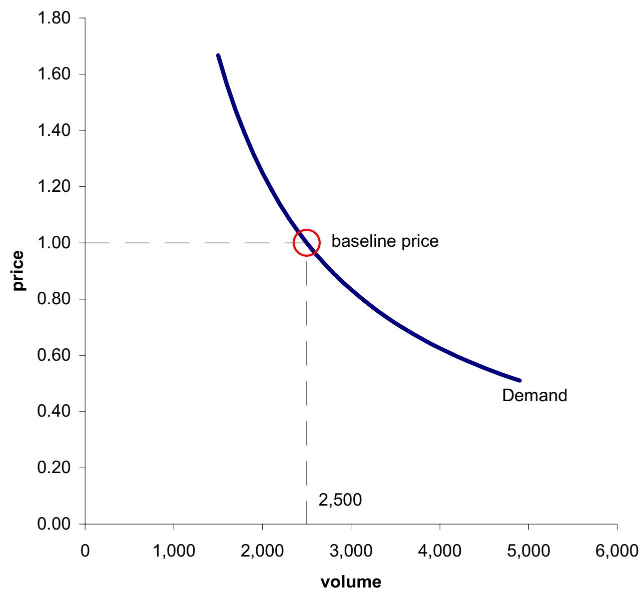

FIGURE 2. Demand curve with constant elasticity.

Thus it is possible in HERS that improvements in capacity and pavement quality that reduce congestion and operating costs will result in more traffic volume in subsequent funding periods than is forecast by the baseline forecast. The opposite result could also occur, if HERS fails to make improvements and the price stays above the baseline. Via these procedures, HERS acknowledges induced traffic in the short run and induced demand over the long run.

The short run can be any period of time over which something remains fixed. What is fixed might be the capacity of a highway, fuel efficiency of the vehicle fleet, locations of employment, or anything else that changes slowly. The long run is enough time for these characteristics to change. The short run is typically assumed to be about a year in transportation planning, but the dividing line depends upon the practical context.

Short-Run Elasticity

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 may be offered.

In HERS, induced *traffic* is a movement along the short-run demand curve, as determined by a change in generalized price and the SRE. Some examples of induced traffic are:

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

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. For project evaluation, diverted travel and other components of induced demand as measured in consumer surplus represent the net valuation of systemwide impacts.

Schedule Delay and Peak Shifting

As noted above, changes in the generalized price may lead to changes in schedule. Peak congestion may be at least partially avoided by leaving earlier or later than preferred. A reduction in peak travel time will cause some travelers to join the peak because the cost to them of schedule delay (departing at a different time than preferred) is greater then the new peak delay. Thus induced traffic may be diverted from other times as well as other routes.

If the demand curve represents both peak and off-peak (as it does in HERS), then the elasticity will be lower than if peak is separated from off-peak. Because the two periods are so closely interrelated (off-peak demand depends upon peak price, and vice versa), failing to separate them analytically may incorrectly estimate the impacts of policies that differentially affect peak and off-peak demand, such as congestion pricing. HERS has separate delay curves for peak and off-peak travel for some road types, but uses a single daily demand curve for each section.

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 3, 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, but here it refers to a facility. At a "long-run" price of p_1 the volume is v_1 and the short-run 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

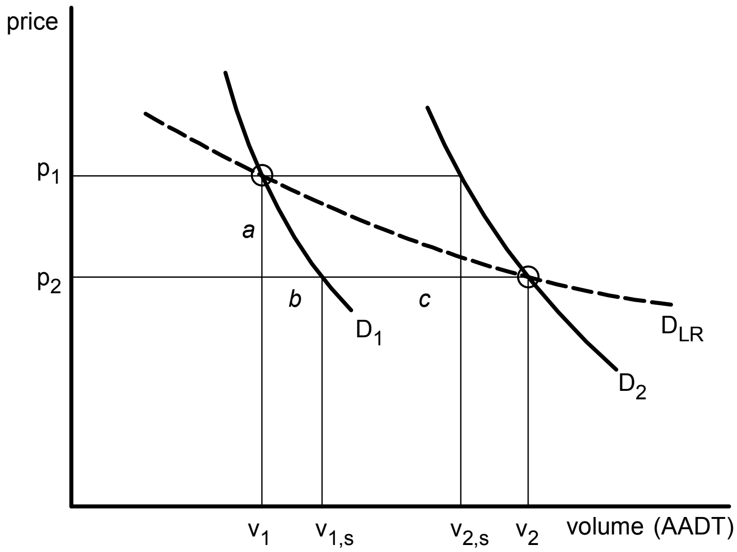

FIGURE 3. Long-run demand with short-run demand curves.

the price stays at that level for the long run, then the short-run 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, but 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. Changes are not necessarily completely reversible: knowledge gained from research leading to advances in technology in, say, fuel efficiency, is not lost when the need is lessened, but its application tends to diminish.

A distinction can be made between "induced traffic" (or induced travel) and "induced demand," by applying the short-run and long-run concepts: the demand curve is fixed in the short run, so changes in volumes are the result of movements along the demand curve, whereas the short-run demand curve 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. An induced shift in the demand curve might be due to:

- Land development that is more compact or spread out as a result of the level of access provided.
- Reduced warehousing facilities stemming from lower freight costs and just-in-time delivery.

- Relatively more transportation used in the production of goods and services because transportation has declined in cost relative to other inputs.
- Relatively more or less personal travel and goods movement taking place on highways relative to other transportation modes, as a consequence of highway improvements.

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 3, the first circled point at (p_1,v_1) is taken to represent a point on both the short-run and long-run demand curves. The second circled point at (p_2,v_2) represents the long run result of a price change, which lies on the same long-run demand curve but a new short-run curve. The arc elasticity between the two points is

$$e_{LR} = \frac{\%\Delta v}{\%\Delta p} = \left(\frac{b+c}{a}\right) \times \frac{p_1}{v_1} \qquad \textbf{[4]}$$

using the definition in **[2]**, where e_{LR} is the long-run elasticity of demand and a, b, and c are lengths marked in the diagram. Short-run elasticity is just

$$e_{SR} = \frac{b}{a} \times \frac{p_1}{v_1} \qquad \textbf{[5]}$$

so the two elasticities differ by a component which can be named e_{LRS}, such that

$$e_{LR} = e_{SR} + e_{LRS} \qquad \textbf{[6]}$$

The e_{LRS} component can be interpreted in the same way as a normal elasticity, and can be measured empirically as the difference between the short-run elasticity and the long-run elasticity estimated for the appropriate time period.[2]

Demand Forecasts

For purposes of evaluating costs and benefits, the overall analysis period for a project (generally the project lifetime, e.g., twenty years) is broken into a series of discrete time periods, during each of which the demand curve is assumed to be fixed. The baseline long-range forecast is used to establish the location of the short-run demand curve for each period.

[2] A more complete derivation can be found in Appendix B, "Induced Traffic and Induced Demand," in FHWA (2000).

Baseline Price

There is no data item in the HPMS record that indicates the baseline generalized price for the forecast. HERS looks at the current level of service, and assumes that the same delay, operating cost, and crash rates that apply currently will apply in the forecast year, unless the V/C is greater than 1.0, in which case the baseline price is based on a V/C of 1.0.

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. In HERS, all endogenous factors are represented in the generalized price. Capacity and LOS, for example, would both be subsumed under travel time cost, and monetized as part of the price. Because the demand forecast is assumed to be based on a constant (or known) price, the forecast is the sole source of information on exogenous demand factors.

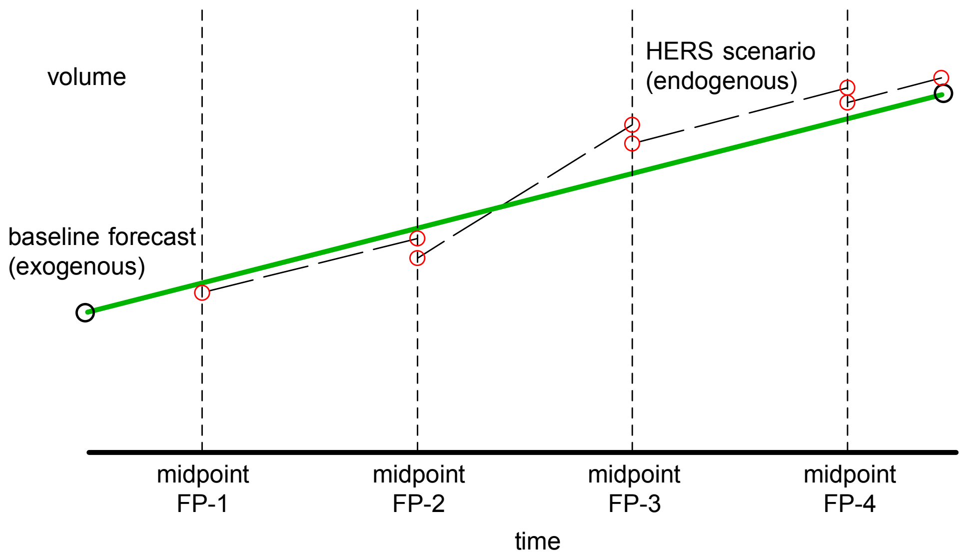

FIGURE 4. Long-run travel forecasts

A forecast is shown in Figure 4, along with a possible HERS scenario in which the forecast volumes are modified as a result of applying short- and long-run elasticities. The forecast embodies the exogenous factors, while the elasticities allow traffic volumes to respond to endogenous conditions. The two dimensions—exogenous factors (baseline forecast) and endogenous factors (price elasticity)—are independent of each other, and one does not substitute or affect the other.

Breaking the Forecast Into Discrete Periods

The long-run short-run distinction is implemented by constructing a short-run demand curve for each of the demand periods (e.g. 3-5 years), and allowing the curve initially established in each period to shift depending upon previous improvements. The forecast becomes a series of discrete points, shown circled in Figure 5, that provide the calibration points for the associated short-run demand curves. The short-run demand curve could be a straight line or any other form calibrated with an elasticity.

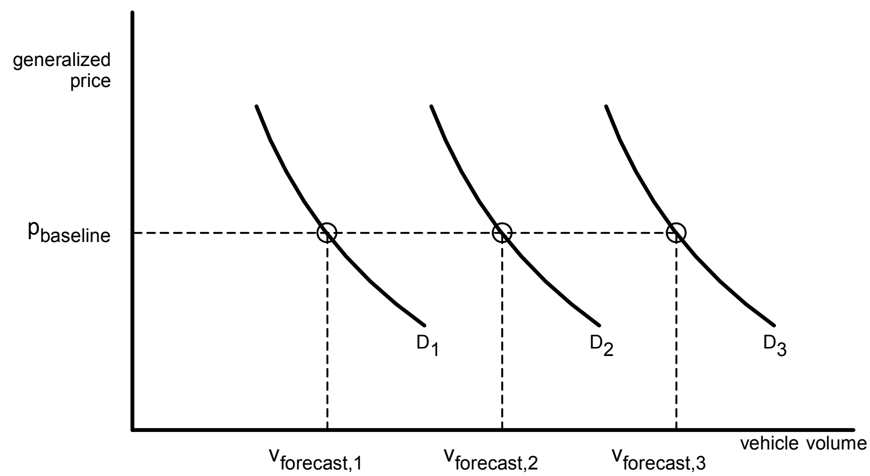

FIGURE 5. Baseline demand forecast for several periods

If we try to imagine a three-dimensional surface which has volume, price, and time as its variables, the three demand curves in Figure 5 would be slices showing different contours at different points in time.

Volume, Price, and Time

An effort to show the three dimensions—time, traffic volume, and price—graphically is shown in Figure 6. A conventional forecast displays volume against year, which is the “floor” of this picture. The baseline price for the forecast is assumed to be constant, labeled p_{base} in the diagram. Volume in period two is forecast to be greater than in the first period, so this implies (with the constant price) that the demand curve shifts outward (in this example) as a result of exogenous factors. The forecast in three-dimensional space (from 2 to 2) is projected on the floor plane in the diagram, and is shown as a heavy solid line (the thin line below it is a “grid” line, showing a constant volume).

If an improvement is made at the end of the first funding period, and this lowers the price below the baseline price, to $p_{improved}$, then the volume will increase above the baseline to the volume level labeled “HERS improvement scenario.” The lower price moves downward and outward along the short-run demand curve applicable to the funding period. Alternatively, if the section is not improved, and congestion and pavement condition worsen, the price would move up the demand curve and result in lowered volume relative to the baseline forecast.

Thus the sequence of steps in applying elasticity to the baseline forecast is:

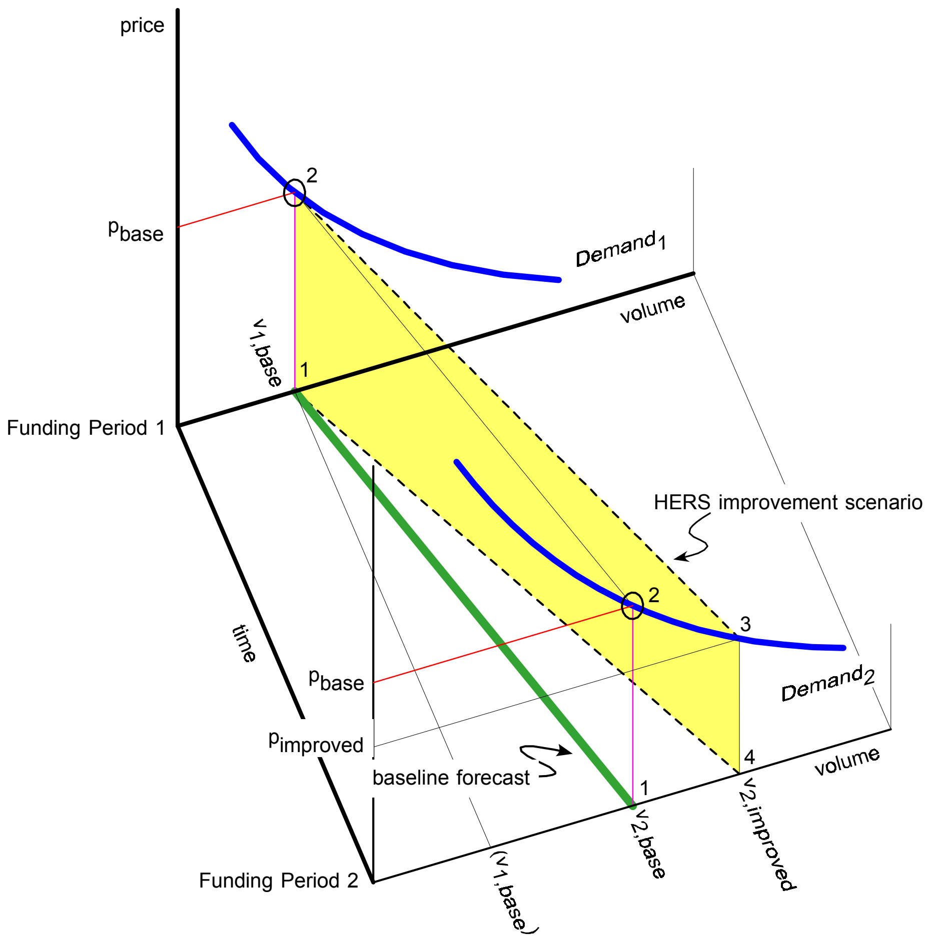

FIGURE 6. Time, volume, and price dimensions.

(1) Extract the time-volume relationship from the baseline forecast provided with the HPMS data for the section, represented in Figure 6 by the heavy line with a “1” at each end.

(2) Infer or derive a baseline price (normally the existing generalized price) for the section and its forecast, indicated by p_{base} and the “2”s.

(3) Fit a demand curve to the price-volume point for the funding period, using the elasticity specified for the section.

(4) Calculate the changes that will occur in the price as a result of improvements or lack of improvements (congestion, pavement condition, safety), marked as “3” in the diagram.

(5) Read the resulting volume from the demand curve, marked as “4” in the diagram.

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 short-run 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 inward in the next period. The former of these two possibilities is shown in Figure 7. The long run share parameter e_{LRS} (LRS in HERS)[3] is applied to the difference between the baseline price and $p_{improved}$ to shift the demand curve from point *1* to point *2* in the diagram. There is no long-run demand curve as such, but the shift attributed to induced demand is a displacement of the short-run demand calibration point along the baseline price line.

Using the number points in Figure 7 as steps in the calculations, the sequence is

(1) Calculate the baseline volume as if the baseline forecast rate of growth started from the previous funding period.

(2) Adjust the volume using e_{LRS} and the amount by which the current price differs from the baseline price; fit the demand curve to this point, using the short run elasticity e_{SRE}.

(3) Move along the short-run demand curve based on the current price to obtain the initial volume in the current FP if price remains the same.

(4) Calculate the actual price ($p_{no\ improvement}$) in the current period allowing for growth in traffic, pavement wear, and other factors, without any improvements. This becomes the base alternative for the FP.

Incorporating induced demand, then, allows each period's demand curve to be 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 crashes), 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 length of the funding or

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[3] See “Disaggregation of Long-Run Elasticity” on page 1-8, and section 6.3.3 of FHWA, *HERS Technical Report* (December 2000).

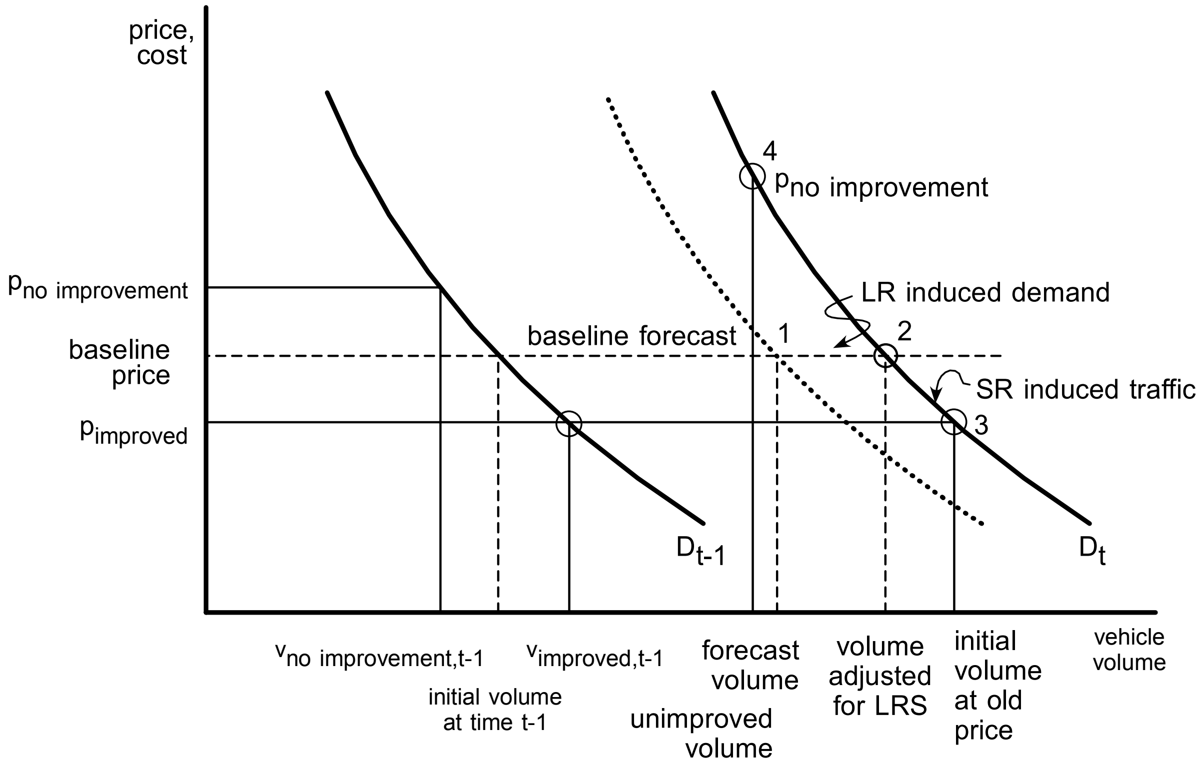

FIGURE 7. **Long-run induced demand shift from one period to the next.**

demand period, 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 is determined entirely by the baseline forecast, without regard for improvements made in any previous demand period. Short-run movements along the demand curve can still occur, depending upon the short-run price elasticity, but there will be no cumulative endogenous effects from one period to the next. Alternatively, with a high e_{LRS}, induced demand could alter the baseline forecast, even to the point of potentially offsetting the trend of the initial forecast.

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).

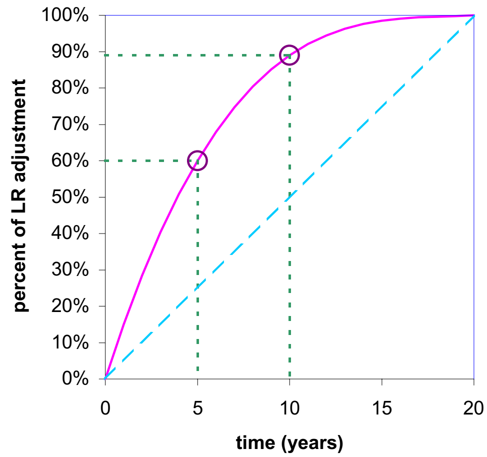

FIGURE 8. Path to long-run equilibrium.

An approximate adjustment curve is shown in Figure 8. Although the curve is fitted to specific data—such as 60% adjustment within a quarter of the time to long-run equilibrium—the empirical data are only vaguely suggestive and the shape of the curve undoubtedly varies with the context.[4] This curve, however, can be used to estimated values for LRS depending upon funding period length.

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 uncertainty 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 three or more.[5]

The parameter sought is the elasticity of vehicle travel with respect to its own price, including user fees, operating costs, and travel time. Studies undertaken to date suggest that short-run elasticities tend to fall in a -0.5 to -1.0 range, and long-run elasticities from -1.0 to -2.0; a within-period short-run elasticity for a 5-year period would thus be

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

[5] The empirical evidence and methods for estimating highway travel demand elasticities are covered in Appendix C, "Highway Demand Elasticities," in FHWA (2000).

-0.6 to -1.0 and the between-period elasticity from -1.0 to -1.6, yielding an e_{LRS} of about -0.4 to -1.0.

Length of Funding Period

The funding period, in HERS, is a period of time (e.g., 2-5 years) over which demand is assumed to remain constant; this does not mean that traffic volumes do not change (they change in response to price and SRE) but, rather, that the demand *schedule* is fixed. Benefits are aggregated over the funding period using the demand curve fitted to the baseline point, so travel time savings and consumer surplus are derived from the volumes and elasticity applicable to the funding period.

The SRE represents a relatively immediate response to a change in price (e.g., up to one year). In HERS, these responses are aggregated over some period of time, referred to as a funding period; the length of the funding period does not affect SRE. Longer run effects are captured in the shift in the demand curve between funding periods, as determined by LRS. The longer is the funding period, the larger the share of long run adjustment takes place over the span of a funding period, as represented in Figure 8. Conceptually, the LRS can be thought of as a supplement to SRE that moves the short-run demand curve part of the way to the ultimate long-run demand curve. In Figure 9, a

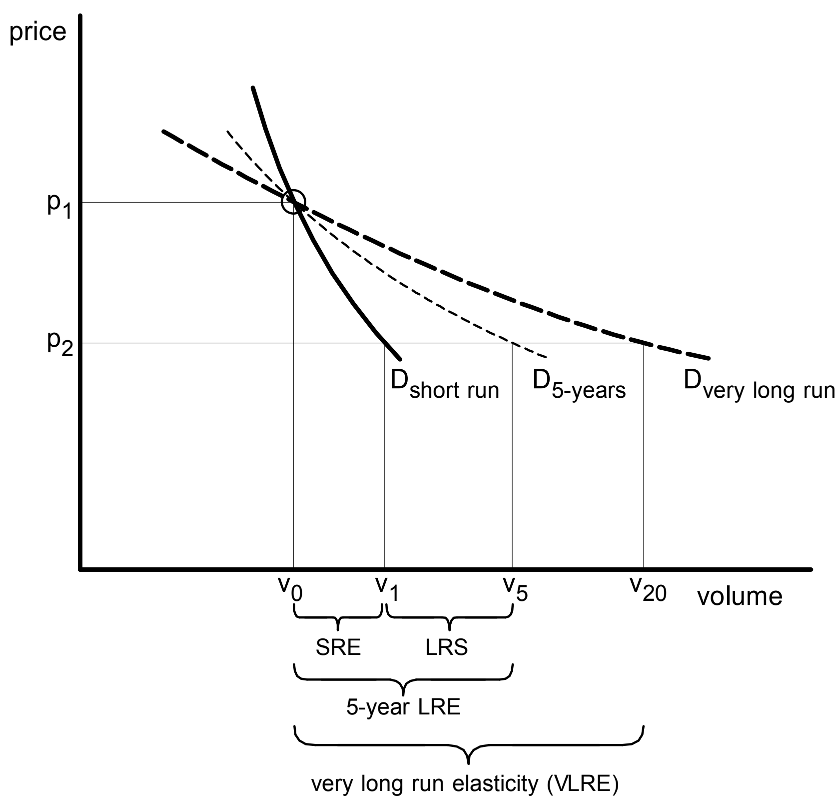

FIGURE 9. Short-, intermediate, and long-run demand curves.

hypothetical 5-year "long-run" demand curve is shown between the short-run and the "very" long-run demand curves.

Approximation of the Long Run

Because HERS funding periods are finite in length and usually less than twenty years, HERS never reaches a true long run equilibrium. Thus the "true" long-run elasticity is not implemented directly; instead, the LRS elasticity shifts the demand curve between funding periods in the direction of the long run. The longer the funding period, the relatively greater will be the shift in the demand curve between periods. If the funding period could be twenty years long (not practical in HERS), the LRS in HERS would be equal to the purely long-run component of elasticity (the "true" LRS).

The SRE in HERS corresponds directly to the conceptual meaning of short run elasticity, so the input value for SRE is used by HERS as is. The LRS is then calculated from the LRE and the SRE, using the curve shown in Figure 8. If, for example, short-run elasticity is chosen to be -0.6, and LRE is -1.4, then the purely long run component of total elasticity is -1.4 - (-0.6) = -0.8. If the funding period is 5 years, then 60% of the adjustment takes place in 5 years, and the LRS is 60% of -0.8, or -0.48.

Table 1 shows, for the range of funding period lengths recommended for use in HERS, the percentage of long run change that occurs between funding periods of that length, and the LRS scaled to those percentages if (LRE - SRE) = -0.67. For a 5-year funding period, this yields an LRS of -0.4. If, for example, SRE = -0.6 and LRE = -1.27, then the LRS in HERS should be -0.4. The first column in Table 1 are numbers read off the curve in Figure 8.

TABLE 1. LRS for alternative funding period lengths

FP length (years)	cumulative percent adjusted	Given LRE-SRE = -0.67 then LRS =
1	15%	-0.10
2	28%	-0.19
3	40%	-0.27
4	51%	-0.34
5	60%	-0.40
6	68%	-0.45
7	75%	-0.50

source: Volpe spreadsheet.

Thus the concepts of short- and long-run elasticity match up with the HERS parameters as shown in Figure 10. The empirical magnitude for short-run elasticity is the same as the HERS parameter, SRE. The purely long-run component is the result of subtracting the SRE from the long run elasticity for the same good. The "true" LRS is then scaled down to the HERS LRS parameter according to the length of the funding period, using the adjustment percentages in Table 1.

Adjusting the Overall Elasticity to the Specific Section

For project evaluation in HERS, the short- and long-run elasticities are applied to traffic on the section being evaluated. Empirical elasticities pertain to travel in general, and they must be adjusted for the characteristics of the specific section. The adjustments currently made are three:

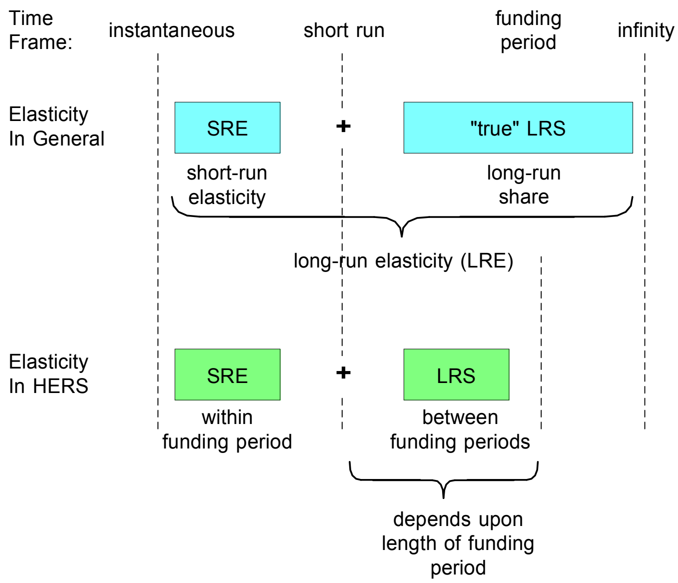

FIGURE 10. HERS elasticity parameters.

Occupancy: Some components (money costs, such as fuel and user charges) of the generalized price can be reduced for the individual traveler by sharing the cost among occupants of the vehicle, while other components (travel time and accident risk) cannot be so reduced. Those components that can be shared create an incentive for ridesharing, so that higher operating costs or tolls will lead to higher occupancy as one response to higher prices. Lowering money prices has the opposite effect, leading to lower occupancy. This feature in HERS, in conjunction with the explicit price component, allows for testing of the impacts of higher or lower user fees, such as through fuel excise taxes changes.

Section Length: An improvement to a section reduces the price of travel on that section, but has little or no effect on the price per mile of the rest of the vehicle trip. If the section is very short, then it has only a small effect on the price of any vehicle trips, and not much response in terms of induced traffic would be expected. Because HERS constructs price in units of volume per day (AADT) rather than the price per trip on the facility, the length of the section is implicitly ignored. Rather than reconstructing the price for each section, HERS adjusts the elasticity to take account of section length. This is done by multiplying the elasticity by the ratio of the section length to the length of a typical vehicle trip on the functional class, as shown in Table 2.

TABLE 2. Average Trip Length and Diversion Elasticity parameters.

Functional System			Average Trip Length	Diversion Elasticity
1 R Int	Rural	Interstate	15.0	-0.1
2 R OPA	Rural	Other Principal Arterial	12.0	-0.2
3 R MinArt	Rural	Minor Arterial	10.0	-0.4
4 R MajColl	Rural	Collector	8.0	-0.4
11 U Int	Urban	Interstate	12.0	-0.4
12 U OFX	Urban	Other Freeway and Expressway	10.0	-0.4
14 U OPA	Urban	Other Principal Arterial	8.0	-0.6
16 U MinArt	Urban	Minor Arterial	6.0	-0.6
17 U Coll	Urban	Collector	4.0	-0.6

source: Volpe estimates.

Diversion: Sources of empirical data on elasticities seldom include diversion as a means for avoiding or lowering the generalized price (an exception is the effect of changing the toll on a toll road). When an improvement reduces the user cost on a particular section, some—perhaps large—portion of the additional traffic is drawn from alternative parallel routes. The magnitude of diversion elasticity depends upon the opportunities for selecting another route. In rural areas, especially on arterials, route choice options occur relatively infrequently, compared to urban areas and lower functional classes. The diversion elasticities shown in Table 2 are intended to reflect diversion potential typical for the functional class, and are added to other sources of induced demand.

The effect of the occupancy adjustment is small, except perhaps for a major shift in user fee policy, such as congestion pricing. The adjustment for section length tends to reduce section elasticities from the input values, because most sections are much shorter than the average trip. Diversion elasticities tend to increase the section elasticities, but generally not enough to offset the section length adjustment.

Interpreting Demand Forecasts

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

(1) Baseline Price. Although the generalized price behind a demand forecast is seldom made explicit, such attributes as LOS and crash 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 is assumed.

(2) Long-Run Demand Feedback. Constructing or expanding a facility stimulates or permits some additional travel in the long run even if the price is unchanged from the baseline. Hence, 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, at the baseline price. 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.

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