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Evaluation Framework for Commercial Vehicle Responses to Congestion Pricing

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*Evaluation Framework for Commercial Vehicle Responses to
Congestion Pricing*

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ABSTRACT

In this report, a framework for analyzing the impacts of congestion pricing on commercial vehicles is developed based on microeconomics principle and past theoretical studies of congestion pricing. The model can be used to assess the short-run impacts of congestion pricing, as well as other forms of toll roads, on the welfare of commercial vehicle operators.

The report starts out by identifying the relationship between value of time and the welfare gain/loss induced by the introduction of congestion pricing on an existing facility. Under the assumptions employed in this study, which limit the scope to the short-run analysis, the essential information required to use the model are the roadway and vehicle operating characteristics, toll schedule, and the cumulative distribution for the value of time. Also, the marginal social cost function with respect to traffic volume must be known to analyze the overall impact on the society. The report also explores potential approaches to derive empirical demand and supply functions within a short-run framework.

Keywords: Congestion Pricing, Transportation Demand Management, Value of Time, Commercial Vehicle

EXECUTIVE SUMMARY

Congestion pricing is a scheme that imposes a substantially higher toll on road users during the congested periods to account for the greater marginal cost of travel at those times. Without congestion pricing, the social cost of traffic congestion always exceeds the private cost since the social cost is a combination of private cost and external cost.

As exemplified by the openings of toll roads in Orange/San Bernardino (SR 91) and San Diego (I-15) Counties, marginal-cost pricing of roadways no longer exists only in theory. As congestion priced facilities become more ubiquitous, there will be a need to explore their broader impacts beyond reductions in congestion. From a policy perspective, two fundamental issues that must be explored are the net benefit to the society, and the distributional impacts. These two issues are best explored using a microeconomics framework.

Assume that several facilities, including a toll road, connects an origin and a destination. There is a fixed amount of demand for the travel between two locations. The travelers will choose one of the alternative routes if and only if the generalized cost (i.e. the sum of the opportunity cost of travel time and the vehicle operating cost) of travel is less than that for taking the tolled facility. Taking the utility maximization approach, the probability of choosing the tolled facility can be expressed as:

$$\Pr\{\text{choosing toll road}\} = \Pr\{\alpha < [OP_2 - OP_1 - \text{Toll}] (T_1 - T_2)^{-1}\}$$

Where, T and OP are travel time and vehicle operating cost, and the subscripts 1 and 2 indicate the tolled facility and the alternative routes, respectively. The value of time, α , can be considered as a random variable that follows some distribution specific to each group of users. If we let F_α be the cumulative distribution function of α , then

$$D(\text{toll road}) = \Pr(\text{choosing toll road}) = F_{\alpha} [(OP_2 - OP_1 - \text{Toll}) (T_1 - T_2)^{-1}]$$

Therefore, if the cumulative distribution of the value of time is known, the demand can be defined as a function of the toll, and the differences in the operating costs and travel times between the tolled and alternative facilities.

The methodologies to identify the value of time of commercial vehicles can be divided into two categories. One is based on observing the time-money trade-off behavior of the motor carriers. The other derives value of time by calculating the opportunity cost: the cost of operating a truck for a unit time is calculated by summing maintenance, fuel, depreciation, licensing and labor costs (note that in this method, the vehicle operating cost is included in the value of time calculation). The two methods usually produce different values of time since the first method measures perceived value while the second method measures actual cost savings. The results from the past studies indicate that the commercial vehicle value of time varies between \$13 and \$30 in 1993 dollars.

Based on the framework presented, it is evident that if the roadway and vehicle operating characteristics and value of time are known, then welfare analysis can be performed to identify the distributional impacts of congestion pricing under a given toll schedule. The change in the consumer surplus for each segment of market can be calculated by integrating the demand function between the equilibrium traffic volumes with and without the toll. To determine the net benefit to society, consumer surplus, toll revenue, and reduction in social cost must be added together. The net social benefit is:

$$\text{Net Social Benefit} = \text{Toll Revenue} + \text{Change in Cost} + \text{Change in Consumer Surplus}$$

To calculate the second term, the social cost curve must be identified. The social cost function relates the traffic volume to the generalized cost to society, which should include marginal changes in travel time, pollution, and maintenance cost.

1. INTRODUCTION

As exemplified by the openings of toll roads in Orange/San Bernardino (SR 91) and San Diego (I-15) Counties, marginal-cost pricing of roadways no longer exists only in theory. Considering the early popularity of both facilities and the emergence of several additional proposed projects, it may not be too long until congestion pricing gains favor among the politicians and the public, and becomes a common congestion management tool in urban areas. However, as congestion priced facilities become more ubiquitous, there will be a need to explore their broader impacts beyond reductions in congestion. From a policy perspective, two fundamental questions that must be explored for any projects are:

1. Does it result in a net positive benefit to the society as a whole?
2. Who will gain or lose?

These two issues are best explored using a microeconomics framework, which will, in turn, help us understand specific issues such as optimal toll schedules and the use of toll revenues. Fortunately, since the 1970's numerous papers concerning impacts of congestion pricing have been published. Most of the theoretical issues covered in this section have been discussed rather thoroughly in the past. However, a consensus has never been reached nor has concrete evidence been presented to show that congestion pricing actually benefits society. There is much more work to be done. One of the reasons prior studies failed to produce decisive support for congestion pricing is the lack of empirical data. For example, seemingly simple issues such as whether if congestion

pricing is regressive or progressive has never been fully resolved (Kulash, 1974). In the near future, as the number of congestion pricing projects increases, opportunities will emerge to collect empirical data and put some of the long-standing theoretical debates to rest. This report strives to design an empirical study framework based on past theoretical works, to specifically address issues concerning the impact of congestion pricing on commercial vehicles.

2. BACKGROUND

In this section, the general concept of congestion pricing is presented using a simple example in which a toll is imposed on a road that connects an origin-destination pair. Diagrammatic analysis is used to illustrate the welfare impacts of congestion pricing under a simple scenario. While there are other methods of applying congestion pricing such as cordon lines (e.g. Singapore), it is hard to imagine that such an ambitious plan can gain political acceptance in this country in near future. Although it may be quite interesting to analyze the differences in welfare gains and distributional impacts among different tolling schemes, this report will concentrate on the congestion pricing of bottleneck facilities.

Congestion pricing is a scheme that imposes a substantially higher toll on road users during the congested periods to account for the greater marginal cost of travel at those times. Without congestion pricing, the social cost of traffic congestion always exceeds the private cost since the social cost is a combination of private cost and external cost.

To understand the distributional impacts of congestion pricing, it is essential to separate the costs that are borne directly by users from those that are borne by the entire society. The private cost is the perceived cost for the users of the facility. The private cost includes vehicle operating cost, maintenance, the opportunity cost of travel time, and tolls. The social cost can be considered as the external costs that are not perceived by

travelers. When a traveler chooses to use a roadway, the decision is based on the private cost. He/she is oblivious, for example, to the marginal increase in travel times for other motorists that results from the addition of his/her automobile to the traffic stream. This increase in the travel cost for all travelers can be considered an externality, since it is not reflected in the choice process of the newcomer. Social cost includes other externalities, such as road maintenance cost, as well as environmental and health costs. It is important to consider those costs since one of the arguments against congestion pricing is that it may result in redistributing welfare from road users to the whole society including non-users when the toll revenue is not used exclusively to improve the condition of the tolled facility. Therefore, critics argue, congestion pricing is just another scheme by the government to collect tax. When only congestion cost is considered, the above argument is valid; however, it overlooks the fact that each trip also incurs some costs, such as environmental and health costs, to the non-users, and they may have to be compensated.

To understand the mechanism of congestion pricing, it is useful to consider a simple example. Assume that a facility connects an origin and a destination. There is a demand for the facility that is determined by the generalized cost of travel using the facility. The demand curve for the facility, which gives the level of latent demand for a given travel cost, has a downward slope with respect to the generalized cost of travel. The supply curve for the road describes the relationship between this generalized private cost and the traffic volume (in most cases, volume-capacity ratio is used to normalize the value). In this example, the supply function is defined in a generic manner since there is no uniformly accepted closed-form expression for the relationship between the generalized travel cost and traffic volume (or volume-capacity ratio). It is true that the form of the supply function affects the outcome of the economic analysis in some cases (Evans, 1993); however, for the time being, the supply curve can be defined as an increasing function with respect to traffic volume without a loss of generality. Also, it is more realistic to

assume that the slope of the supply curve becomes greater as the volume approaches and exceeds the capacity.

An illustration of both private and social cost is presented in Figure 1. The figure also illustrates that in order to move the equilibrium point from the current location to the optimum consumption level, the private cost of travel must be increased so that it equals the social marginal cost [Mohring, 1975]. This is achieved by imposing a toll of BF. At the new price level, the true cost of travel is correctly reflected in the market price of travel, and by the First Theorem of Welfare Economics, a Pareto efficient resource allocation can be achieved. Several authors (such as Daganzo, 1995, and Evans, 1993) point out that the toll inevitably results in a loss of consumer surplus when the revenue from the toll is excluded from the analysis. Before the toll, the consumer surplus is the area GEI. After the toll, the consumer surplus is reduced to the area GHB. Thus, the loss in consumer surplus is the area HBEI. The toll revenue is equal to the area HBFJ. Society's gain is the area ABCD, since the cost to society is the area under the social marginal cost curve. In order to evaluate distributional impacts, an analysis should be first performed without taking into account the use of the toll revenue and the reduction in the social cost. This is because from the road user's stand point, the reduction in social cost has little effect on utility. If the analysis indicates that particular groups of travelers are made worse off by the toll, then the revenue can be used to compensate them for their losses.

Since each traveler pays the same toll to receive the same amount of time savings (if they stay on the road) while the marginal utility (i.e. value of time) gained from the time saved differs, some travelers receive more benefit from reduced congestion than the others. This is because the optimal toll is calculated by using the average value of time. In addition, some travelers will choose not to use the facility because of the toll. Specifically, there are three types of travelers. The first consists of those whose valuation of the trip is less

than the cost due to the addition of the toll. The traffic that falls between points C and D, in Figure 1 represents this type of traveler. Since they are "forced" off the road by the toll, their utility is less than the level before the toll. Therefore, they are worse-off after the toll. The second type is those whose valuation of the trip remains higher than the cost after the toll, but their value of time is not high enough to offset the additional expenditure. They are also made worse off by the toll since their consumer surplus is reduced by the amount equal to the difference between the toll and their monetary valuation of the travel time reduction. Finally, the third group of travelers is those whose valuation of the trip remains higher than the cost after the toll and their valuation of the time saving due to the reduction in congestion is higher than the toll. These are the only people who are better off after the toll since their consumer surplus is actually increased by the difference between the toll and their valuation of the time savings.

The only difference between the second and the third types of travelers is their value of time. The difference between the two types of travelers can be expressed in the following manner:

$$\begin{aligned}
 [c(v_0)-c(v_1)]/\alpha + [fs(v_0) - fs(v_1)] - p/\alpha &< 0 && \text{for Type II} \\
 &> 0 && \text{for Type III}
 \end{aligned}$$

Where, α is the value of time in \$/minutes, p is the toll in \$, and v_0 and v_1 are the traffic volumes with and without toll, respectively. The time-flow function, $fs()$, calculates the travel time for a given traffic volume. The operating cost function, $c()$, relates the traffic volume to the vehicle operating cost (excluding the time cost), which may be insignificant for passenger vehicles but may be considerable for large vehicles. Therefore, the generalized cost(in minutes) of travel for a volume v can be written as $c(v)/\alpha + fs(v) + p/\alpha$.

The relationship between the demand, value of time, and various cost elements are depicted in Figure 2. The figure clearly illustrates that if the value of time, α , is large enough, it is possible to lower the travel cost (and increase consumer surplus) by imposing a toll. This is because the time savings from the toll, IJ, is constant across the market while the toll has different effects on individual's utilities, which are assumed to be the time equivalent of the generalized travel cost (i.e. toll/ α).

The distance between the demand and cost curves at the equilibrium volume with a toll, HJ, is the optimal toll divided by the average value of time across the market (α_{AVG}). Therefore, for someone whose value of time is higher than the average, the toll's impact, toll/ α , is less than HJ. Furthermore, note that this analysis can be applied to an imposition of a flat(non-varying) or congestion toll. Any kind of toll essentially improves the service quality of the facility by eliminating some of the traffic in exchange for the increase in the out-of-pocket cost. Whether the improvement is worth the extra cost depends on the valuation of the improvement by each user.

Based on the analysis presented, it is evident that if the demand and supply curves and value of time are known, then welfare analysis can be performed to identify the distributional impact of congestion pricing. The change in the consumer surplus can be calculated by integrating the demand function between the values of H and I. To determine the net benefit to society, consumer surplus, toll revenue, and reduction in social cost must be added together. In Figure 1, the net social benefit is:

$$\begin{aligned} \text{Net Social Benefit} &= \text{Toll Revenue} + \text{Change in Cost} + \text{Change in Consumer Surplus} \\ &= \text{HJFB} + \text{ABCD} - \text{HIEB} . \end{aligned}$$

To calculate the second term, the social cost curve must be identified. The social cost function relates the traffic volume to the generalized cost to society, which should include marginal changes in travel time, pollution, and maintenance cost.

3. EVALUATION FRAMEWORK

In this section, the results from the analysis in the previous section will be tailored toward the objective of this study, which is to assess the impact of congestion pricing on commercial vehicles.

3.1 Demand and Supply Curves

The supply curve (i.e. private cost curve in Figure 2) describes the relationship between generalized travel cost and traffic volume. Mohring argues that the operating cost for automobile is approximately independent of traffic volume (or at least insignificant compared with time cost). Then, the supply curve can be specified using one of many formulas that approximate the volume-travel time relationship.

One of such functions is the Bureau of Public Road (BPR) formula.

$$T = T_F [1 + 0.15(V/C)^4]$$

Where,

T = Average travel time on a facility

T_F = Travel time under free flow condition

V = Traffic Volume

C = Capacity of link

Mohring used following function:

$$T = 2c/[1 \pm (1-v/c)^{1/2}]$$

Where c is a parameter that is adjusted according to the ratio of free-flow travel time and travel time at capacity. In Mohring's paper, it is assumed to be 1 for freeways and 2.4 for city streets.

In a recent study by Evans, following formula was used:

$$T = [(1 - V/C)^{-1} - 1]$$

In order to standardize units, heavy vehicles in traffic flow must be converted into passenger car equivalent. The Highway Capacity Manual recommends appropriate factor for converting the number of truck into passenger car equivalents under various road conditions.

In defining the supply and demand functions, it is advantageous to normalize the volume by converting it to the volume-capacity ratio or volume to population ratio. The latter approach enables us to use probability estimates, which are outputs from demand functions based on discrete choice models, as opposed to the actual number of trips. Taking advantage of this fact, Daganzo used a highly flexible approach, in which he broadly defined the demand function as a multivariate random variable with some unknown distribution.

Suppose that, in our example, there is an alternative route, which connects the same origin and destination pair as the tolled facility. Also, assume that there are only two groups of users, passenger cars and trucks. Under uncongested conditions, the travel time and vehicle operating cost on the alternative route are greater than on the tolled facility. The

travelers will choose the alternative route if and only if the generalized cost (i.e. the sum of the opportunity cost of travel time and the vehicle operating cost) of travel is less than that for taking the tolled facility. Taking the utility maximization approach, the probability of choosing the tolled facility can be expressed as:

$$\Pr\{\text{choosing facility 1}\} = \Pr\{\text{Toll} + \alpha T_1 + OP_1 < \alpha T_2 + OP_2\} \quad [1a]$$

$$= \Pr\{\text{Toll} + \alpha (T_1 - T_2) + OP_1 - OP_2 < 0\} \quad [1b]$$

Where, T and OP are travel time and vehicle operating cost, and the subscripts 1 and 2 indicate the tolled facility and the alternative route, respectively. This relationship can be used to define the demand functions for both passenger cars and trucks with some adjustments. While the travel time, T, is the same for both passenger cars and trucks, there should be a considerable difference in the operating cost, OP. The operating cost of trucks is a function of the efficiency of the vehicle and gross weight, and is often assumed to be independent of the congestion level. This is a valid assumption in most cases because the magnitude of the time cost under congested conditions should be enormous compared with the increase in vehicle operating cost. The value of time, α , can be considered as a random variable that follows some distribution specific to each group of users.

Since assumptions regarding the values of time are often the determinants of capital investment decisions, a number of studies have been conducted in the past. The factors that affect the value of time should be quite different between passenger cars and trucks. In his study of the incidence of congestion tolls (Small, 1983), Small used wage rate as a proxy for the value of time for passenger car drivers, thus assuming the distribution of the value of time follows the income distribution. This approach has been used widely in other studies. Even though most studies focus on passenger vehicles, there have been several projects that evaluated the value of time for commercial vehicles. The paper by

Waters, et al, summarizes the results from six studies conducted in the U.S. The methodologies to identify the value of time can be divided into two categories. One is based on observing the behavior of the motor carriers. The other drives value of time by calculating the opportunity cost: the cost of operating a truck for a unit time is calculated by summing maintenance, fuel, depreciation, licensing and labor costs (note that in this method, the vehicle operating cost is included in the value of time calculation). The two methods usually produce different values of time since the first method measures perceived value while the second method measures actual cost savings. The results from the six studies indicate that the value of time varies between \$13 and \$30 in 1993 dollars. In comparison, for passenger vehicles, Small found the value of in-vehicle time to be 66% of marginal post-tax wage. For a person making \$30,000 a year in post-tax wage, this translates to about \$9.5 per hour(assuming 2080 working hours per year).

The studies also indicate that the value of time increases with the size of the trucks. However, for this study, more detailed results are needed since the distribution of values of time must be identified to derive the demand function as shown below.

Equation 1b can be modified to:

$$\begin{aligned} \Pr\{\text{choosing facility 1}\} &= \Pr\{\alpha (T_1 - T_2) < \text{Toll} + OP_2 - OP_1\} \\ &= \Pr\{\alpha < [OP_2 - OP_1 - \text{Toll}] (T_1 - T_2)^{-1}\} \end{aligned}$$

If we let F_α be the cumulative distribution function of α , then

$$D(\text{facility 1}) = \Pr(\text{choosing facility 1}) = F_\alpha [(OP_2 - OP_1 - \text{Toll}) (T_1 - T_2)^{-1}]$$

Therefore, if the cumulative distribution of the value of time is known, the demand can be defined as a function of the toll, and the differences in the operating costs and travel times between the two facilities.

As mentioned before, there are two distinct approaches to measuring the value of time for commercial vehicles. If the opportunity cost approach is used, then F_{α} becomes a joint distribution of the components of the opportunity cost such as labor, vehicle operating cost, inventory cost, and so on. There are several commercially available software packages for forecasting truck costs [TRB, 1997]. These software packages take shipment and operating characteristics as inputs to forecast shipment costs. Some can actually include transfer and delivery costs. In the other approach using behavioral studies, $F_{\alpha i}$ can be identified by taking a random sample of the value of time across the user group. Of course, in order to rely on revealed preference, data on the observed choices under the time-money trade-off situation must be observed and recorded. 1989 Nationwide Truck Activity and Commodity Survey conducted by the U.S. Bureau of Census collected detailed truck activity characteristics and other information at individual truck level through mail-in survey of over 44,000 truck owners. The data contains routing and stopping records, and may be sufficient to impute value of time information [TRB, 1997]. Another method of collecting activity choice data is to conduct a stated preference survey. In stated reference surveys, respondents are faced with hypothetical situations that are designed to reveal their preferences. For example, value of time can be imputed from the choices made under hypothetical situations in which respondents must make a trade-off between time and money.

3.2 Generalized Framework

The above example can be easily modified to analyze the situation in which the alternative choice is to use a different mode or departure time. Under such a scenario, it seems appropriate to include a fixed cost in the utility formula to account for the intrinsic

characteristics associated with each choice as well as the inconvenience and the transaction cost of switching the choice. For example, it has been shown that for some individuals, the automobile has an inherent advantage over transit. Also, if a mode or departure time is changed, a fixed cost will result from adapting to the new procedures or schedule. For commercial vehicles, changing the mode, schedule or shipment size can incur considerable transaction costs.

In defining the demand function, it is necessary to specify the current choice since transaction costs only result when the choice is changed. Therefore, the generic form of the demand function can be written as:

$$\begin{aligned} \Pr\{\text{choosing A}\} &= \Pr\{\text{Toll} + \alpha T_A + OP_A + G_A + N_A < \alpha T_B + OP_B + G_B + N_B\} \\ &= \Pr\{\text{Toll} + \alpha (T_A - T_B) + OP_A - OP_B + G_A - G_B + N_A - N_B < 0\} \end{aligned}$$

$$D(A) = \Pr(\text{choosing A}) = F_\alpha [(\text{OP}_B - \text{OP}_A - \text{Toll} - G_A + G_B - N_A + N_B) (T_A - T_B)^{-1}]$$

Where G_A and G_B are transaction cost, and

$$G_A = 0 \text{ if currently using facility A}$$

$$G_B = 0 \text{ if currently using facility B.}$$

N_A and N_B are the constants that represent the inherent attractiveness of the choices A and B, respectively.

Finally, under some conditions, this framework may not be sufficient to fully account for the distributional consequences of imposing a toll on commercial vehicles. Since tolls are part of the production cost for commercial vehicles, they will be able to recover the additional expenditure by charging higher price for shipments. If the customer's demand is

perfectly inelastic, then trucking firms will be able to recover the full amount of the toll. In general, the amount of incidence from the toll born by trucking firms and customers is determined by the elasticity of supply and demand, and consequently the competitiveness of the market. Privately owned and operated trucks are mainly used to transport materials and goods to be sold in a market. Therefore, the toll incidence depends on the elasticities of the supply and demand for the goods transported. Then, the eventual impact of a congestion toll on trucks, especially private trucks, is not transparent. When such transfer of cost occurs, it might result in seemingly irrational choice behavior under the framework developed in this report.

4. CONCLUSION

In this report, the theoretical analyses of congestion pricing conducted in the past were used to develop a versatile model that can be applied to assess the social welfare and distributional impacts to different user groups including commercial vehicles. The essential data required to use the model are the demand and supply curves as well as the cumulative distribution for the value of time. Also, the marginal social cost function with respect to traffic volume must be known to analyze the overall impact on society.

Essentially, the ultimate goal of policy analysis is to determine whether if a policy is good for the society. Therefore, for this study, the impending question is: "Is congestion pricing good or bad for society and for various groups within society"? Obviously, it depends on how one defines the "good" and "bad". In many policy studies, consumer surplus is used to evaluate the change in the welfare of the consumers. In more ambitious studies, weight is assigned to losses and gains for different segments of consumers by defining social welfare functions. Sometimes, a different criterion, such as "not making anyone worse off" or Pareto Optimum improvement is used to evaluate a policy change

(Daganzo, 1995). Even though congestion pricing always makes someone worse off, appropriate use of the toll revenue can achieve a Pareto Optimum improvement. Although the framework presented in this report uses consumer surplus as a measure of distributional effects, it is flexible enough to be used under different evaluation criteria.

REFERENCES

Daganzo, Carlos F., A Pareto Optimum Congestion Reduction Scheme, *Transportation Research - B*, Vol. 29, No. 2, pp. 139 - 154, 1995

Evans, Andrew W., Road congestion Pricing: When Is It a Good Policy?, *Journal of Transport Economics and Policy*, pp. 213 - 243, September 1992

Hau, Timothy D., Economic Fundamentals of Road Pricing - A Diagrammatic Analysis, Working Paper, Infrastructure and Urban Development Department, The World Bank, 1992

Kulash, Damien J., Income Distributional Consequences of Roadway Pricing, *Transportation Research Forum*, 15(1), pp. 153-159, 1974

Lo, Hong K., Mark Hickman, and Maura Walstead, An Evaluation Taxonomy for Congestion Pricing, Research Report, California PATH, 1996

Mohring, Herbert D., Pricing and Transportation Capacity, Special Report 153, Transportation Research Board, National Research Council, Washington, D.C., pp. 183 - 195, 1975

Small, Kenneth A., The Incidence of Congestion Tolls on Urban Highways, *Journal of Urban Economics* 13, pp. 90 - 111, 1983

Small, Kenneth A. And Clifford Winston, Welfare Effects of Marginal Cost Taxation of Motor Freight Transportation: A Study of Infrastructure Pricing, Institute of Transportation Studies, 1984.

Transportation Research Board, NCHRP Report 388: A Guidebook for Forecasting Freight Transportation Demand, National Research Council, Washington, D.C., 1997

Transportation Research Board, Highway Capacity Manual, National Research council, Washington, D.C., 1985

Waters, W.G., Carey Wong, and Kevin Megale, The Value of Commercial Vehicle Time Savings for The Evaluation of Highway Investments: A Resource Saving Approach, *Journal of Transportation Research Forum*, Vol. 35, No. 1, 1995

Zlatoper, Thomas J. And Ziona Austrian, Freight Transportation Demand: A Survey of Recent Econometric Studies, *Transportation* 16, pp. 27 - 46, 1989

Figure 1: Graphical Analysis of Congestion Pricing

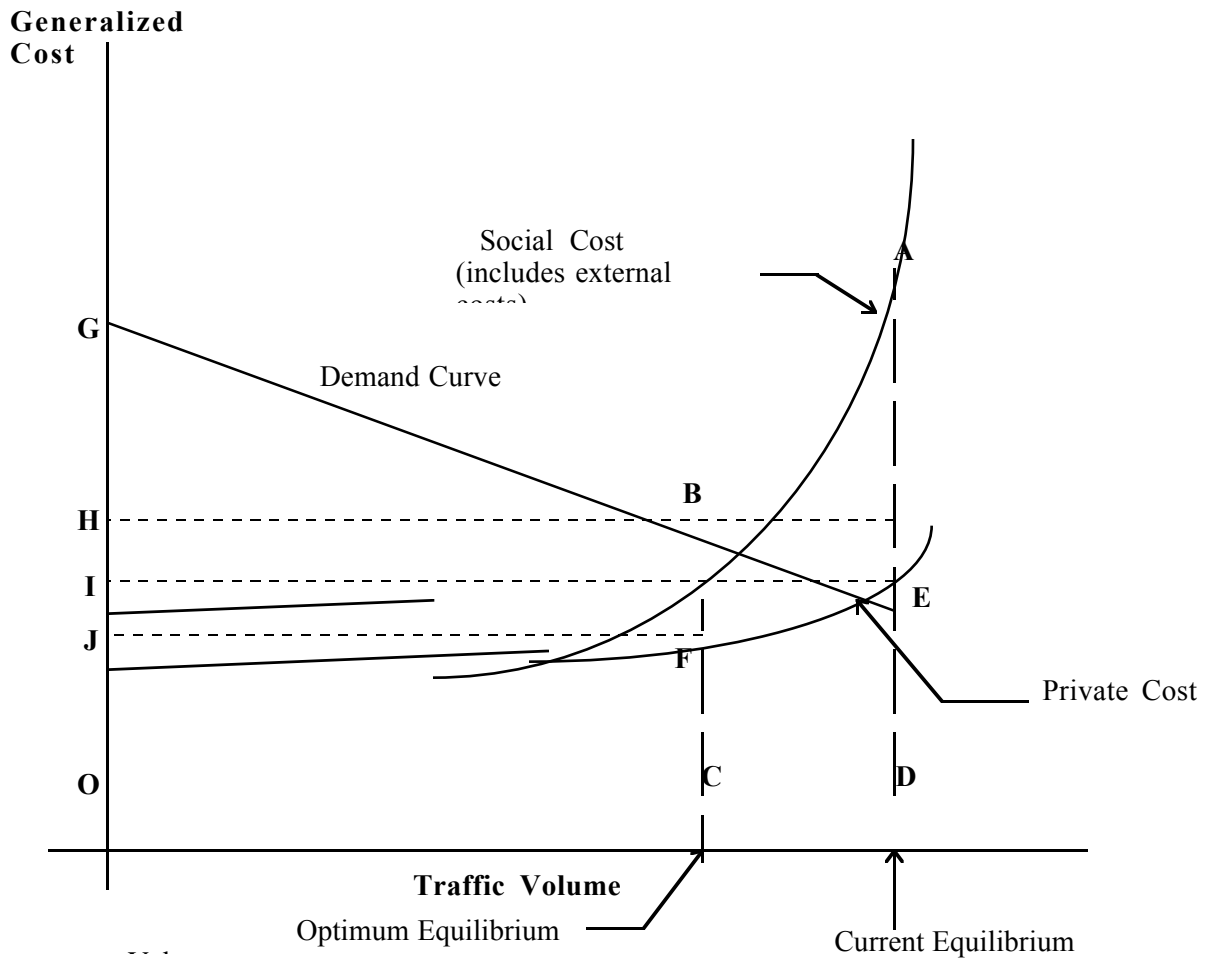


Figure 2: Supply - Demand Relationships for Congestion Pricing

