Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-1995/1322-3F		

4. Title and Subtitle	5. Report Date
AN EVALUATION OF THE STATUS, EFFECTIVENESS, AND THE FUTURE OF TOLL ROADS IN TEXAS: REMAINING ISSUES AND EXECUTIVE SUMMARY	October 1995
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Mark A. Euritt, Robert Harrison, Randy B. Machemehl, and Chungwon Lee	Research Report 1322-3F
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, Texas 78705-2650	11. Contract or Grant No. Research Study 0-1322
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Research and Technology Transfer Office P. O. Box 5080 Austin, Texas 78763-5080	Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Research study title: "An Evaluation of the Status, Effectiveness, and Future of Toll Roads in Texas"

16. Abstract

This project has investigated the future of toll road development in Texas. As indicated in two previous reports, our research has determined that, while toll roads represent a potentially vital component of the Texas transportation network, the future of such toll roads in the state will depend ultimately on the public's willingness to support them. This report, the final report of this study, discusses several remaining issues that are important in developing a state toll road policy. The final chapter summarizes important study findings, including those of an earlier, related project.

17. Key Words	18. Distribution Statement
Toll roads, electronic toll collection (ETC), Dallas North Tollway, demand estimation, tollway elasticities, toll schedules and pricing, commercial carriers	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	59	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

AN EVALUATION OF THE STATUS, EFFECTIVENESS, AND FUTURE OF TOLL ROADS IN TEXAS: REMAINING ISSUES AND EXECUTIVE SUMMARY

Mark A. Euritt
Robert Harrison
Randy B. Machemehl
Chungwon Lee

Research Report Number 1322-3F

Research Project 0-1322
An Evaluation of the Status, Effectiveness, and Future of Toll Roads in Texas

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

October 1995

IMPLEMENTATION STATEMENT

This report is the final of three reports evaluating the future and effectiveness of toll roads for the state. It introduces and discusses remaining issues associated with toll roads in Texas, and concludes with an executive summary. In terms of implementation, the findings reported herein could prove useful to state transportation planners and policymakers involved in the Texas Transportation Plan.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

TABLE OF CONTENTS

SUMMARY

This project has investigated the future of toll road development in Texas. As indicated in two previous reports, our research has determined that, while toll roads represent a potentially vital component of the Texas transportation network, the future of such toll roads in the state will depend ultimately on the public's willingness to support them. This report, the final report of this study, discusses several remaining issues that are important in developing a state toll road policy. The final chapter will then summarize important study findings, including those of an earlier, related project.

CHAPTER 1. OVERVIEW OF REPORT

INTRODUCTION

This project has investigated the future of toll road development in Texas. As indicated in two previous reports (Refs 1, 2), our research has determined that, while toll roads represent a potentially vital component of the Texas transportation network, the future of such toll roads in the state will depend ultimately on the public's willingness to support them. This report, the final report of this study, discusses several remaining issues that are important in developing a state toll road policy. The final chapter will then summarize important study findings, including those of an earlier, related project.

TEXAS TRANSPORTATION TODAY

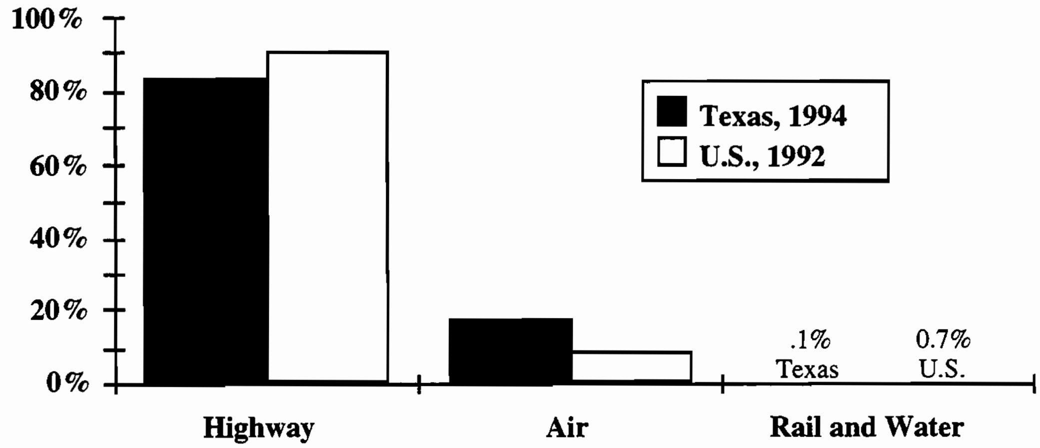
Clearly, Texas and the rest of the U.S. are dependent on highways for the movement of goods and travelers (see Figure 1.1). Nationwide, U.S. roads and highways accommodate over 90 percent of all passenger miles. Within Texas, our roads and highways accommodate around 82 percent of all state passenger miles. Overall, Texas chalked up 247.6 billion passenger miles on its network of highways and roads in 1994 (Ref 3). Although the freight sector is more balanced among the modes (see Figure 1.2), highways remain the largest single conduit for freight transportation. Forty-three percent of Texas' freight ton-miles, compared with 32 percent for the nation, travel over paved surfaces. In 1994, there were a total of 137.6 billion ton-miles of freight moved on Texas roads (Ref 3).

Texas Road Conditions and Associated Costs

In Texas, motor vehicles travel over 474,535 km of the state's roadway system, of which the state is responsible for only 26 percent (123,730 km) (Ref 4). Importantly, however, the state's share of the system accommodates over 69 percent of the average daily traffic (Ref 4). This growth in vehicular traffic requires sufficient resources for maintaining and expanding the system. Failure to provide a steady stream of revenue for the maintenance and operation of the highway system can result in a more rapid deterioration of the highway infrastructure.

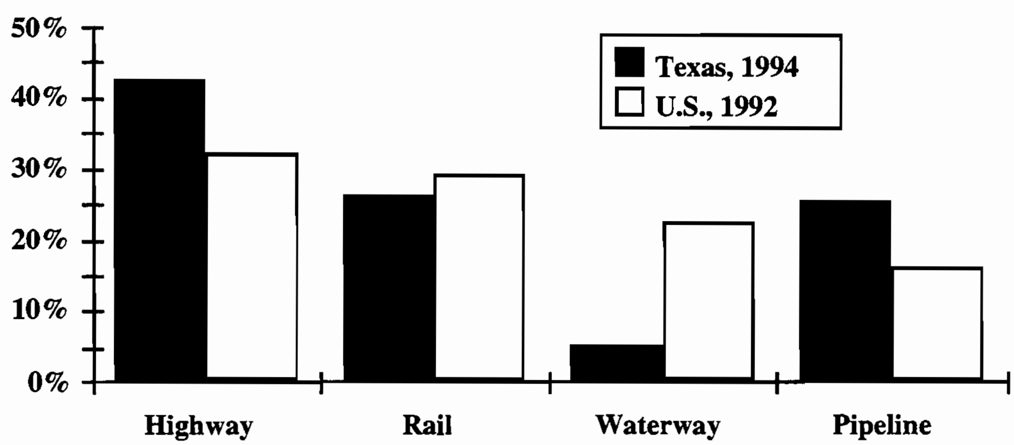
As illustrated in Figure 1.3, much of the Texas highway system already has a rating of fair or lower on the Present Serviceability Rating index. Among the implications of these rougher roads are higher motor vehicle operating costs. The Congressional Budget Office has estimated that variable vehicle operating costs are 11 percent higher on fair roads and 29 percent higher on poor roads, compared with roads in good condition (Ref 5). Unquestionably, poor pavement conditions have serious consequences for personal and freight transportation costs.

The impact of the growing traffic volumes (as illustrated in Figure 1.4) has led to another cost impact on Texas motorists, namely, congestion. In 1991 the state estimated that motorists in the major Texas metropolitan areas paid an additional $3.9 billion in delay and fuel costs (Ref 6). In addition to these higher direct costs, there are a number of other, indirect costs that are affecting surface transportation, namely, the cost to the environment. In the past, these costs were largely ignored. Implementation of the Clean Air Act Amendments of 1990, however, has effectively changed the situation. Metropolitan areas in violation of National Ambient Air Quality Standards face severe restrictions on their urban mobility. Currently, Texas has four metropolitan areas that are in non-attainment of the ozone standard, and an additional three cities that are marginally below the standard (Ref 7). Cities in violation of the national standards are required to make major adjustments to their transportation system.



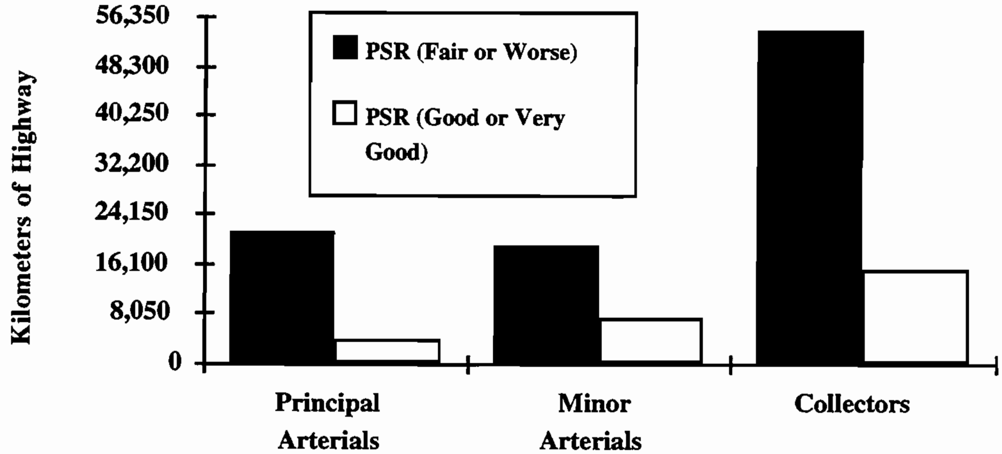
Source: Refs 3, 8

Figure 1.1 Modal distribution of passenger kilometers of travel



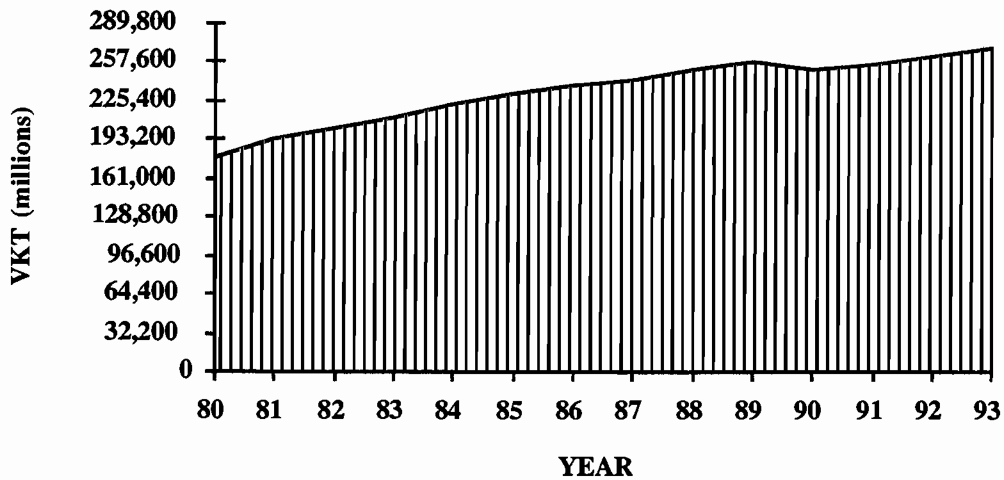
Source: Refs 3, 8

Figure 1.2 Modal distribution of freight ton-kilometers



PSR = Present Serviceability Rating
Source: Ref 4

Figure 1.3 Pavement condition of Texas highways, 1993



Source: *Highway Statistics* (various years)

Figure 1.4 Texas vehicle miles of travel

The Texas Transportation Challenge

A safe, efficient, and effective transportation system is crucial to maintaining a healthy economy, promoting economic development, and sustaining an acceptable standard of living for the people of Texas. As the state's primary transportation agency, the Texas Department of Transportation (TxDOT) is charged with providing a transportation system that satisfies the state's transportation needs in a cost-effective manner.

But increasingly, Texas is facing a burgeoning mobility problem. *The Texas Transportation Plan* forecasts a 45 percent increase in vehicle miles of travel (VMT) over the state highway system between 1995 and 2014 (Ref 9). At the same, the state will receive revenues sufficient to fund only 44 percent of the projects necessary to address this growth in VMT. Failure to respond adequately to this problem will result in higher congestion costs, greater productivity losses, higher vehicle operating costs, and ever-worsening air quality. *The Texas Transportation Plan* outlines the basic issues facing Texas' efforts to finance its transportation needs:

> ... the analysis of the existing funding structure has shown that resources are insufficient to meet the goals of the Plan. Current funding mechanisms do not always lead to the most efficient and effective use of scarce resources. This is in part because users do not pay for the full costs they impose on the system, and because current funding mechanisms are not flexible enough to allow for the best use of scarce resources. In addition, funding sources are declining in value over time because they do not account for inflation and other factors, like increases in fuel efficiency, which reduce available funding.... The challenge is to provide Texas with maximum flexibility to meet transportation needs for the next twenty years (Ref 9).

Transportation Funding Alternatives

During the 1980s, transportation planners nationwide generated a multitude of innovative approaches to fund transportation infrastructure. In some instances, states and municipalities developed new strategies to capture a greater share of revenues from the private sector. These innovations included special financing districts, impact fees, tax increment financing, toll financing, and other forms of private-sector financing. A number of these innovations were used in Texas, with the state adopting several legislative initiatives aimed at increasing private-sector participation in funding transportation improvements. Likewise, TxDOT commissioned numerous studies to assist in evaluating funding alternatives. Some of the major research projects (including this one) related to these efforts are illustrated in Figure 1.5.

REPORT OBJECTIVE

The basic objective of Project 1322 was to evaluate the future of toll roads in Texas. This project was preceded by related Project 1281, which more specifically examined the issue of highway privatization. Together, the two studies have examined in some detail present and future issues associated with toll roads in Texas. This report, the final for this project, introduces remaining issues and provides an executive summary of both projects' relevant findings.

REPORT ORGANIZATION

Chapter 2 examines demand estimation issues and methods, reviewing in particular four case studies that illustrate methods of toll usage forecasting. Chapter 3, which focuses on the Dallas North Tollway elasticities, identifies a correlation between toll traffic and toll charges. This discussion leads naturally to a discussion of toll schedules and pricing, the subject of Chapter 4. Chapter 5, which examines toll road development from the perspective of the commercial carrier, suggests that successful implementation of toll roads will require the support of the motor carrier industry. They bring a different set of issues and concerns that must be adequately addressed in a toll roads policy. Finally, Chapter 6 provides general conclusions for future toll road development in Texas.

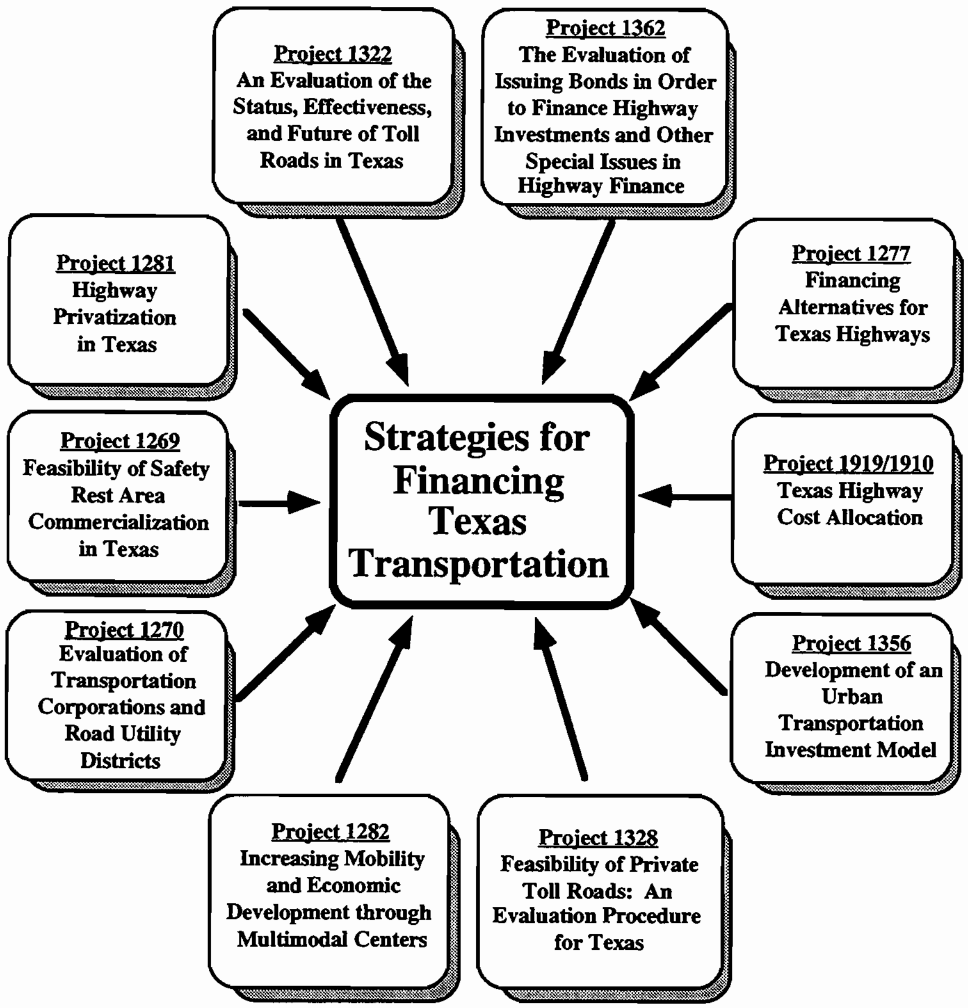


Figure 1.5 TxDOT research on transportation finance

CHAPTER 2. DEMAND ESTIMATION ISSUES

INTRODUCTION

The revenue generation and corresponding profitability of toll facilities are of critical importance to toll road developers and operators. The revenue generated by a toll facility is directly proportional to the amount of traffic utilizing the toll facility, and to the prices levied on the various vehicle categories. Thus, in general, the financial feasibility of a toll project is dependent on both the usage level and the toll rates.

In spite of the importance of toll usage estimation, no efficient procedure for such estimation has been established; nor is there abundant literature on comprehensive treatments of toll usage estimation. As with traditional demand forecasting methods, though, many hybrid methods have been devised. Practically speaking, the selection of a method depends on data availability and time/budget constraints. Since traffic forecasting depends on accurate predictions of traveler decisions, two factors must be addressed: (1) traveler decision-making processes, and (2) system equilibration (Ref 10).

Figure 2.1 shows a generic sequential demand forecasting method and the relationship between usage estimation and revenue forecasting.

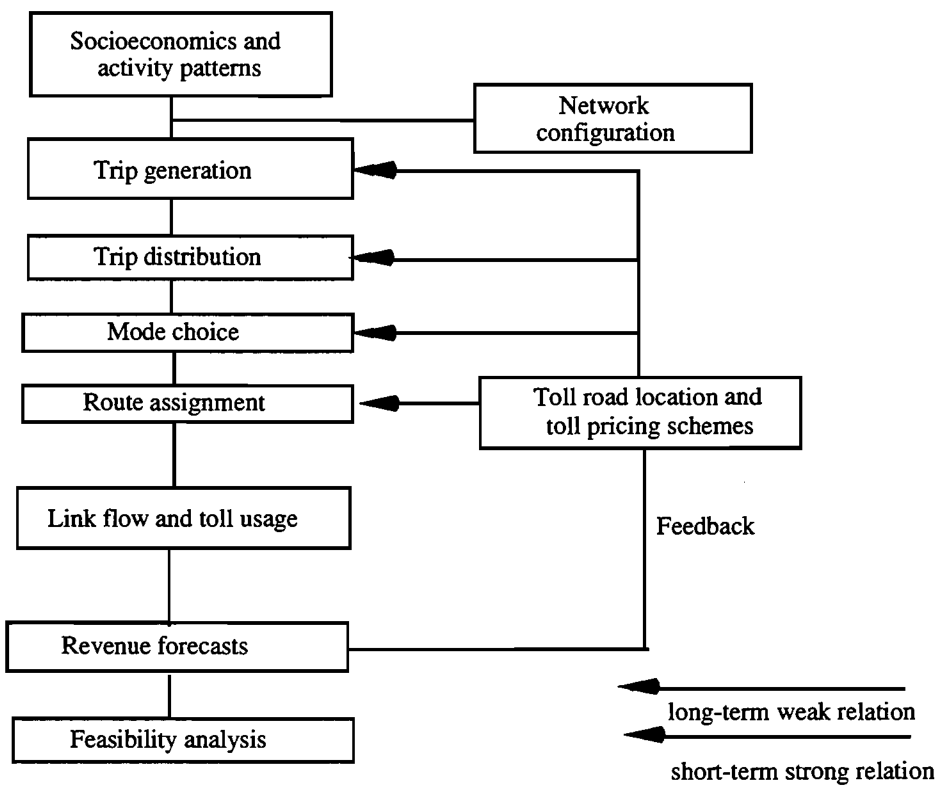


Figure 2.1 Toll road usage and revenue forecasting

When a toll is introduced on a network, motorists may or may not divert to the new tolled route. Some motorists may even increase trip frequency and distance as a result of the new route — an example of latent demand stimulated by new network options and level of service associated with trip choice. Although long-term impacts suggested in Figure 2.1 are difficult to capture (and are sometimes ignored), they are important for a full feasibility study.

The following section discusses several approaches to estimating the usage of toll facilities in a network; a few case studies are also presented and examined.

TRADITIONAL AGGREGATE APPROACH

The traditional aggregate approach to estimating toll facility usage, based on the conventional four-step modeling process, is as follows (Ref 11):

1. Code a computer network with the generalized cost of travel, and identify the present link flows by this computer network.
2. Incorporate toll facilities as links in the network.
3. Calculate the equivalent time penalty of the toll price by an average value of travel time, and allocate this additional time penalty to the toll facility link(s).
4. Using a selected assignment algorithm, assign an origin and destination (O-D) table to the network.

This traditional aggregate approach has several shortcomings. First, the time penalty on toll links is a rough approximation only of user perceptions of tolling and travel time interaction. Second, the model produces overly sensitive assignment patterns, in that any route with toll road segments changes from the shortest route to the "second-best" route, and vice versa, due to toll level or trip time changes. In other words, a small difference between two routes for an O-D pair could elicit totally different assignment results. This problem stems from the use of an aggregate assignment tool to model complex route choice phenomena. A potential alternative is the use of discrete choice models based on consumer choice theory.

ASSIGNMENT TECHNIQUES BASED ON DISCRETE CHOICE MODELS

Discrete choice models have been used for the mode choice modeling step. Application in the assignment step has not been performed widely, as there are several problems to the full application of discrete assignment models. The following discussions briefly review typical discrete choice models — logit and probit; they are followed by a discussion on the difficulty of using a discrete choice approach in modeling the route assignment step.

Logit Model

Random utility models are widely used to predict mode choice in both urban and intercity applications. These models are based on the assumption that an individual's preferences among the various alternatives can be represented by a utility function. The utility of an alternative depends on attributes of the alternative and characteristics of the individual who is assumed to choose the alternative with the highest utility.

Since choice virtually always depends on attributes of alternatives and characteristics of individuals not included in data sets available to analysts, the utility function is represented as the sum of two components (Ref 12). A systematic component depends on observed attributes of alternatives and characteristics of individuals. A random component represents the effects of unobserved attributes that influence choice. Thus, the utility of an alternative "i" for an individual decision maker "n" has the following form:

$$U_{in} = V_{in} + e_{in} \tag{1}$$

where

U_{in} = the utility of an alternative i for an individual decision maker n;

V_{in} = the systematic component of the utility of alternative i viewed by decision maker n; and

e_{in} = the random component of the utility of alternative i for decision maker n.

Since utility depends on unobserved attributes of alternatives and characteristics of individuals, it is not possible to predict with certainty which alternative an individual will choose. Instead, a random utility model gives the probability that any specified alternative is chosen. The probability that alternative i is chosen (P_{in}) is the probability that the utility of alternative i exceeds the utility of all other available alternatives. Thus,

$$\begin{aligned} P_{in} &= \Pr\,[U_{in} > U_{jn} \text{ for all available alternatives j other than i}] \\ &= \Pr\,[V_{in}+e_{in} > V_{jn}+e_{jn} \text{ for all alternatives j other than i}] \end{aligned}$$

Random utility models are often classified according to the probability distribution of the random component of the utility function. The multinomial logit model, which is the simplest and most frequently used random utility model, is based on the assumption that the random components of the utilities of different alternatives are independently and identically distributed (IID) with the Gumbel distribution. In this model, the probability that alternative i is chosen is

$$P_{in} = \exp(V_{in}) / \Sigma \exp(V_{jn}) \tag{2}$$

It has long been recognized that the multinomial logit model is unsuitable for use with applications in which the random components of utility are not IID across alternatives and observations of choices. For example, the multinomial logit model is not applicable when alternatives have common unobserved attributes that influence choice. This is because common unobserved attributes cause the random components of utility to be correlated across alternatives.

The red bus/blue bus problem is a famous example of the inability of the multinomial logit model to describe choices among alternatives having common unobserved attributes. The weakness of the logit model in route assignment modeling can be explained within the same context of the IID assumption; this will be discussed later.

Probit Model

An alternative and more flexible way of relaxing the IID assumption of multinomial logit is to assume that the random components of utility have a multivariate normal distribution. This leads to the multinomial probit model. By suitably specifying the covariance matrix of the random utility components, a probit model can be made to accommodate common unobserved attributes and random taste variation (Ref 13). This makes the multinomial probit model a highly flexible demand forecasting tool.

Unfortunately, the flexibility of the multinomial probit model comes at a high cost. There is no closed analytic form for the integrals of the multivariate normal density function, and they must be evaluated numerically. This presents severe computational difficulties if there are more than three or four alternatives in a choice set. As a result, the multinomial probit model has rarely been used in applications. Given the progress of super computing, however, the method based on Monte Carlo simulation to evaluate the probit integrals promises to become much more attractive. Indeed, Lam recently coded a multinomial probit model in a parallel computer environment (Ref 14). Thus, it seems possible that the computational barriers to the use of multinomial probit in applications will soon be greatly reduced. Daganzo (Ref 15) provides a more detailed explanation of the theory of multinomial probit.

Difficulty of Applying the Logit Model in Route Choices

A route choice proposed by Dial has subsequently become known as Dial's Model, or the STOCH method (Ref 16). Computationally, the model is termed a two-pass Markov model. It assigns trips simultaneously to an entire set of reasonable paths without explicitly examining a path.

Dial's model is a multinomial logit model (though it was not explicitly identified as such). The model's algorithm inherently maintains the IIA (the independence of irrelevant alternatives) axiom; that is, it employs a logit-type formula to estimate the path utilization probability. At the same time, the algorithm generates "reasonable" paths that cannot avoid overlapping with each other. Because of the overlapping routes, the model risks violating the IID assumption. This problem is demonstrated in the following example taken from Sheffi (Ref 17).

A simplified three-route example (Figure 2.2) includes different network configurations in which Dial's method generates the same probability (i.e., a third of total traffic) for each of the three routes in the network. As shown in part (a) of Figure 2.2, each of the three routes from O to D is assumed to be of equal length. Each route is expected to carry a third of the total traffic, as Dial's method will verify.

Now, move to Figure 2.2 (b). The small segment (BD) is overlapping, but is of negligible length compared with OB. Dial's method will assign a third of the total volume to each of the three routes. This assignment seems reasonable, unless the overlapping segment (BD) is large.

In Figure 2.2 (c), the overlapping segment (BD) is increased and consists of a major portion of the two lower routes. Thus, the upper route (OAD) should handle around half the total traffic, and the two lower routes should carry a quarter, respectively. Dial's model, however, still assigns a third of the total traffic to each route, resulting in two-thirds of the total on the overlapping segment, BD. Hence, the model loses the ability to forecast reasonable traffic patterns.

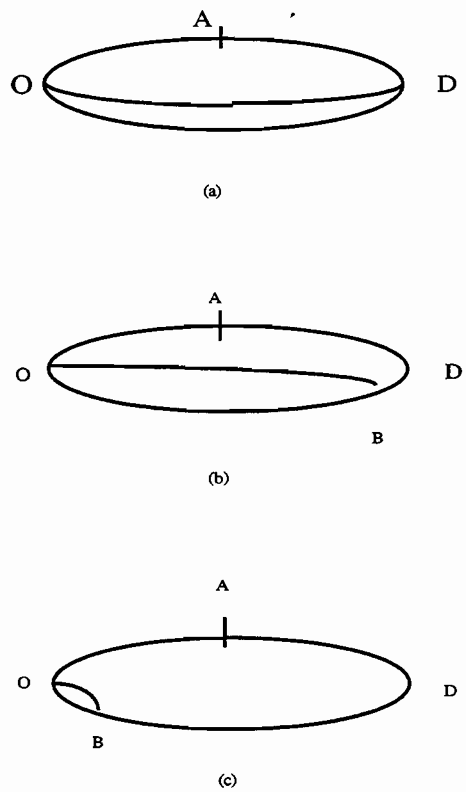


Figure 2.2 Example network to illustrate the inability of logit-based assignment

This inability stems from the independence assumption in the random component in the logit model. The (perceived) travel times on the two lower routes are correlated for the overlapping segment. Theoretically, logit-based models cannot overcome this problem and therefore cannot properly reflect the network topology (Ref 17).

Consequently, route-based assignment models such as the logit model should be used carefully to avoid the assumption violation by generating heavily overlapping routes as shown in this example. For a dense and/or large network, the use of a link-based probit model, instead of a route-based logit model, resolves this problem.

Elasticity-Based Quick Method

Travel demand elasticity is defined as the percentage change in ridership or traffic volume that results from a 1-percent change in a given independent variable (e.g., travel time or cost). If only a single variable in the system (such as the toll) is changed, elasticity-based usage estimation becomes attractive because it is quick and inexpensive. In this method, a small change of one system variable may not generate large changes in the O-D pattern, an effect that, in turn, minimizes changes to such traffic-related variables as volumes and travel times. Thus, if the network demand structure can be assumed unaltered or slightly altered, an elasticity-based method can be used for identifying the usage change. The limitation of this method is that it is not appropriate for large network analyses.

Brand and Benham recommend the following criteria when using elasticities in forecasting (Ref 18).

1. Elasticities should be derived from travel models that are consistent with travel behavior theory.
2. Long-run elasticities should be used when future year travel forecasts are required. Long-run elasticities can be estimated from cross-sectional (or some time-series) models that include a large set of relevant variables.
3. Elasticities should reflect the travel patterns of the study population to the extent possible by developing composite elasticities estimated for specific trip types. For example, the observed trip purpose distribution can be used to combine work and nonwork trip elasticities to develop the appropriate peak-period or all-day study area elasticity.
4. Socioeconomic characteristics of the population and the base level of service can have an effect on the elasticity value. Therefore, elasticities appropriate for the study population and level of service should be used.

Thus, with less effort than that required for full network models, carefully estimated elasticities based on appropriate historical data or survey data are applicable for demand and revenue forecasting (where the analyzed network is not too complex).

TOLL USAGE ESTIMATION CASE STUDIES

Four case studies were chosen to demonstrate the variety and complexity of toll road usage and revenue modeling. It is interesting to note that those groups nationally recognized as acceptable to Wall Street bond analysts are generally conservative (and somewhat secretive) about their models and inputs. The four case studies are presented below.

Estimating Toll Diversion for Beltways in Denver

In the late 1980's, Heisler, Imhoff, and Schumm analyzed usage for the proposed E-470 beltway, a 77-km circumferential highway in Denver, Colorado, using a logit-based assignment model (Ref 19). They adopted the following procedure:

1. Using data collected during ten small group sessions in selected communities, they estimated utility functions for logit models for four trip types: home-based work, home-based nonwork, nonhome-based, and air passenger trips.
2. The utility-function-independent variables were travel time savings using E-470, number of toll stops, distance traveled on E-470, toll cost, and number of stops saved.

3. The logit-based probability of using E-470 for each trip purpose, i.e., E-470 share for the routes containing E-470, was modeled by the above utility function.
4. Before the assignment step, toll diversion equations were applied to all O-D pairs with an E-470 travel time savings. The resulting E-470 and non-E-470 trip tables were assigned to the roadway network to obtain final average daily traffic projections on all links.

Theoretically, the above procedure contains a critical mistake. Step (4) suggests that toll usage was calculated between two routes for each O-D pair, a route with a toll road segment and a route without a toll road segment. If the two routes are overlapping, as previously explained, the IIA property of the logit model is violated. Considering the network size analyzed in this study, overlapping is assumed to exist in many O-D pairs. Therefore, it is doubtful that trip-making behavior is correctly modeled, and as long as a logit model is used in a large network, this problem will not be resolved; consequently, either changing to a probit model or reducing the network until the overlapping problem disappears becomes preferable.

Estimation of Usage and Revenue for the Logan Motorway in Australia

Johnston and Patterson tried to establish a toll level to maximize revenue of the Logan Motorway in Australia, which opened in 1988 (Ref 11). Usage curves for various trip purposes were estimated using before-and-after survey data (i.e., before and after opening the toll road). They also used a binary logit model of the type employed by Heisler, Imhoff, and Schumm. Trips were divided into home-based work, nonwork, employers business, commercial vehicles, and external trips. Independent variables were time savings, distance difference between the toll road and the existing free road, vehicle operating cost, and market segment toll charge.

In addition to conducting a stated preference survey before the opening of the toll road, Johnston and Patterson conducted a revealed preference survey after opening the toll road. Thus, usage estimation could be adjusted one step closer to the actual usage level. They also compared the value of travel time between the stated and the revealed data. In the logit-based route assignment, however, the theoretical problem that weakened the E-470 beltway study similarly weakens this study. Johnston and Patterson gave no comment on this matter.

Dallas North Tollway Route Share Model

Souleyrette conducted a usage estimation analysis employing a logit-based user equilibrium formulation (Ref 20). O-Ds were assumed to be fixed and known to the analyst. His route share model combined a Bureau of Public Records (BPR) type link performance function with the successive average method to obtain equilibrium flows. Values of user group travel time were used for a Dallas North Tollway application.

His work was based on a logit model in the assignment step, which means the model was a route-based (not a path-based) assignment. Thus, the model is not appropriate for large, dense networks for the reasons already given.

Dallas North Tollway Usage Estimation

Wilbur Smith Associates studied the impact of the proposed extension of the Dallas North Tollway in 1990 (Ref 21). Using a mailback survey, travel characteristics and patterns were investigated. In terms of modeling, the method adopted was a capacity restrained diversion assignment technique having the following characteristics:

1. For travel from 25 randomly selected traffic zones, two travel paths were determined: one via the tollway, if reasonable, and the other via nontolled roads.
2. For each of the two travel paths, the time and mileage involved were calculated based on network link information. All toll costs were also included.
3. The cost of the tollway route was divided by the cost of the alternative route to develop a diversion cost ratio for each of the movements. Trips were assigned to each of the two paths based on a function of this ratio.
4. A volume/capacity ratio was then established with the assigned volume. A function of this ratio was used to estimate reduction in travel speeds for each link.
5. Finally, the procedure was repeated for the next random group of 25 zones among the total of 800 traffic zones until all trips were assigned.

Since the diversion assignment process utilizes total cost ratios of travel for alternate routes, it is important to identify a reasonable average perceived travel time value. According to their report, the median household income was weighted based on the number of households to estimate the regional household income. The regional household income was weighted based on observed trip purpose distributions.

The model is a typical conventional aggregate assignment. Because of the aggregate nature of the assignment step, the model contains the weakness of aggregate models already identified. In addition, the assignment procedure is arbitrary and gives different usage estimates depending on the order selection of each 25 traffic zones.

CONCLUSION

This section examined the basic principles underlying toll usage forecasting. Discrete models, along with conventional aggregate methods in the route assignment step, were discussed and selected examples were presented. Surprisingly, most logit-based examples violate the IID assumption, which could elicit unreasonable results in spite of the logit model advantages. Thus, more careful application and possibly a probit-based approach are needed. Clearly, there is a need to develop a thoroughly sound and applicable forecasting model that addresses the central issues of toll road forecasting.

We also noted that most work, as evidenced by all the case studies, are for urban toll roads, where business trips — mostly undertaken by single occupancy autos — dominate. The revenue models for an intercity toll system must be accurately estimated because they relate to systems with higher total toll rates and involve users (like truckers) who are cost conscious. Forecasting accuracy is therefore essential if intercity toll networks are to be a feature of highway travel in the next century.

CHAPTER 3. A CASE STUDY OF DALLAS NORTH TOLLWAY ELASTICITIES

INTRODUCTION

Demand elasticity is the term used to describe the relationship between toll road traffic demand and toll charges. In looking at this relationship, this chapter uses the Dallas North Tollway to illustrate how toll traffic features from past experiences can be used to make better toll revenue predictions. The study includes two phases: a time-series analysis, which captures monthly and seasonal traffic variations, and a toll elasticity analysis, which uses monthly and seasonally-adjusted data.

DESCRIPTION OF THE DALLAS NORTH TOLLWAY

The Dallas North Tollway is located in a fast-developing suburban area, directly linking the Dallas central business district with the north central section of the city, including the separately incorporated municipalities of Highland Park and University Park. As existing roads in the urban area became heavily congested, the toll road was built to provide higher levels of service and was opened in 1968. It was originally constructed as a 15.8-km, four-to-six-lane controlled access facility. The 7.7-km Phase 1 northward extension of the Tollway was opened fully to traffic in December 1987. Another 10.9-km Phase 2 northward extension is now under construction (Ref 22).

The Tollway is owned, developed, operated, and maintained by the Texas Turnpike Authority, an agency of the State of Texas. The only funding source for this toll project has been revenue bonds. Since the economics of toll road financing have changed greatly over the past few decades, it can be considered as possibly the last major Texas toll road successfully financed with revenue bonds, where toll revenues are the sole source of both bond interest payments and bond retirement. Upon retirement of the bonds, the facility will become a toll-free segment of the state highway system operated and maintained by state highway funds.

Figures 3.1 and 3.2, which are based on survey results, represent present travel patterns and characteristics. Data for July 1989 were used to study the daily traffic variations shown in Figure 3.1. The daily trip pattern is similar Monday through Friday, indicating the impact of commuter traffic.

Figure 3.2 shows the trip purpose distribution (Ref 23). The trip purpose distribution was obtained from 1987 surveys, which indicated 53 percent of all persons interviewed were traveling to or from work. Company business comprised 20 percent of the travel, while personal business accounted for another 14 percent. Shopping trips were 5 percent of the total, while school, recreational, social, and other trips accounted for 8 percent. As the survey data indicate, most trips are weekday commuter trips, which are not expected to be sensitive to toll changes.

METHODOLOGY

In order to study the effects of toll changes on tollway traffic, we undertook the analysis in two phases:

1. A time-series study was performed to capture monthly and seasonal variations within each year. A moving average method was then used to calculate monthly and seasonal toll traffic indexes.
2. After adjusting toll traffic by these indexes, toll elasticity values were calculated for both short- and long-term (monthly and seasonal) variations for each vehicle category.

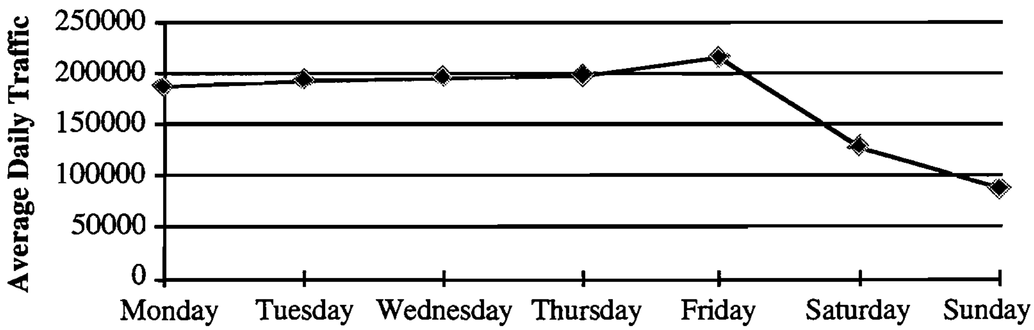


Figure 3.1 Daily traffic variations at Dallas North Tollway (1989 data)

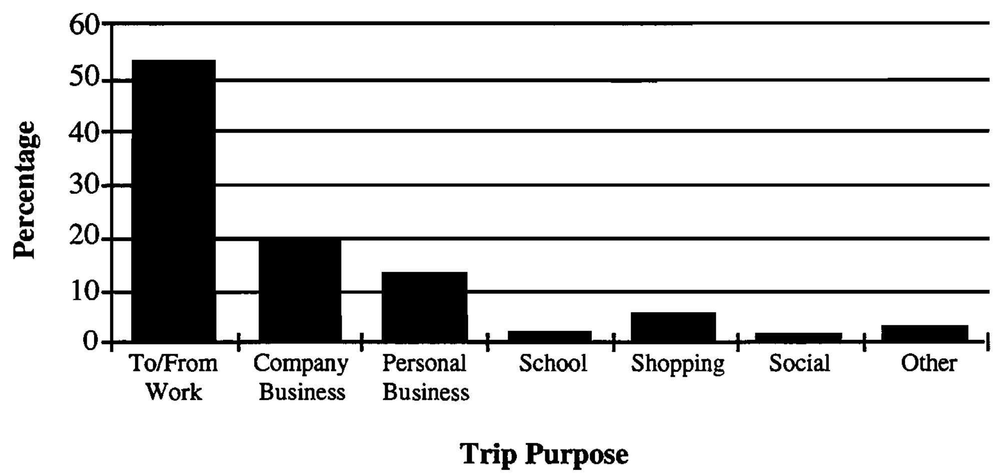


Figure 3.2 Trip purpose distribution in Dallas North Tollway corridor (1987 data)

Since there are many different types of road users with dissimilar elasticity values, the vehicle market is segmented into two aggregate levels, passenger cars and commercial vehicles, where commercial vehicles are defined as vehicles having more than two axles.

MONTHLY TRAFFIC VARIATIONS

The moving average method compares each individual observation with a moving average encompassing the period of observations. Monthly indices are calculated as arithmetic means of two or more differences of the same month. The analysis is based on the data sets between 1968-1974 and 1987-1993.

Monthly traffic indices were calculated separately for the 1968-74 and 1987-93 data sets, (both sets have similar patterns). There is no evidence of changes in this pattern, except those caused by external forces (e.g., toll changes or service improvements). Comparing results from the data sets, the adjusted monthly traffic indices are very similar. Thus, the monthly toll traffic patterns for all years comparing the two six-year periods are stable. Monthly indices are presented in Table 3.1 for passenger cars and commercial vehicles. Numerical values of less than 100 for January and February indicate these months typically have less traffic than the long-term monthly average. Values greater than 100 for May through August indicate these months have more than average traffic and are, therefore, high demand periods. These index values can be used to adjust counted traffic for any month or to forecast specific monthly values using a long-term trend.

Table 3.1 Monthly toll traffic indexes for passenger cars and commercial vehicles at Dallas North Tollway (1987-1993)

	Monthly Toll Traffic Indexes	
Month	**Passenger Car**	**Commercial Vehicles**
January	96.90	82.09
February	92.29	80.40
March	103.09	101.34
April	99.65	107.67
May	103.44	115.95
June	102.39	107.11
July	100.17	107.62
August	102.80	106.70
September	97.47	99.42
October	104.21	111.21
November	97.24	94.36
December	100.34	86.14

Source (Ref 23)

SEASONAL TRAFFIC VARIATIONS

Using similar procedures, we analyzed the seasonal traffic variations to produce seasonal traffic indices. Again, calculations were performed for the two vehicle groups. Seasonal indices presented in Table 3.2 indicate that the higher volume seasons are spring and summer.

Table 3.2 Seasonal toll traffic indexes for passenger cars and commercial vehicles on Dallas North Tollway (1987-1993)

	Seasonal Toll Traffic Indexes	
Season	**Passenger Car**	**Commercial Vehicle**
Spring	102.15	106.15
Summer	101.79	108.73
Fall	99.70	102.07
Winter	96.36	83.04

Source (Ref 2)

TOLL ELASTICITY

Toll Schedule Changes

There have been three toll changes in the history of the Dallas North Tollway. The toll change percentage each time was calculated by vehicle category and by each toll plaza. The averages of all percentages by the two vehicle categories — passenger cars and commercial vehicles — were then calculated. The results are shown in Table 3.3.

Table 3.3 Toll change percentage, Dallas North Tollway

	YEAR		
Vehicle Type	**1970**	**1975**	**1982**
Passenger Car	16.7	36.1	100.0
Commercial Vehicle	30.4	16.4	135.7

Monthly Toll Elasticity

The monthly indexes, calculated as described in the previous section, were used to adjust observed traffic volumes for monthly variation. Original traffic was divided by the appropriate monthly index and then multiplied by 100 to restore the original units. Thus, the monthly traffic variation was isolated from other external factors that might affect toll traffic volume. The monthly toll elasticity was then calculated, based on the adjusted traffic data.

The monthly toll elasticity was used to measure the short-term effect of a toll increase (i.e., to indicate the direct impact of a toll change in the first month). The calculation is based on the following arc elasticity formula:

$$Arc\ Elasticity = {}^{Traffic\ Change\ Percentage}\!\big/_{Toll\ Change\ Percentage}$$

Seasonal Toll Elasticity

Calculations similar to those for monthly based elasticity were made for seasonal values. These values capture the effects of toll change over arbitrarily selected three-month "seasons."

RESULTS AND DISCUSSION

Table 3.4 presents the results of the toll elasticity analysis. As expected, toll elasticity, both monthly and seasonally, was found to be somewhat inelastic. This might be because most vehicle trips made using this tollway were commuter-oriented, where time-sensitive users seem to be relatively price insensitive. Also, the toll rate for the Dallas North Tollway was relatively low (compared with the market price at that time).

Table 3.4 One-month toll elasticity values for Dallas North Tollway

Elasticity	Passenger Car		Commercial Vehicle	
Year of Toll Changes	Monthly	Seasonal	Monthly	Seasonal
1970	-0.77	-0.41	1.30	0.74
1975	-0.27	-0.17	1.37	1.17
1982	-0.16	-0.13	-0.32	-0.19
Average	-0.4	-0.24	0.78	0.57

The average toll elasticity based on monthly data for passenger cars is about -0.4. In other words, a 1-percent toll increase for passenger cars was associated with approximately a 0.4-percent traffic decrease in the first month after the new toll schedule became effective. This was not true for commercial vehicles, which indicated a mean monthly toll elasticity across three toll changes of about 0.78; that is, every 1-percent toll increase was related to approximately a 0.78-percent increase in commercial vehicle traffic in the first month after the toll increase. Only the 1982 toll increase produced a commercial traffic decrease. One must note, however, that according to Figure 3.3, commercial vehicles average only about three-tenths of one percent of the total traffic.

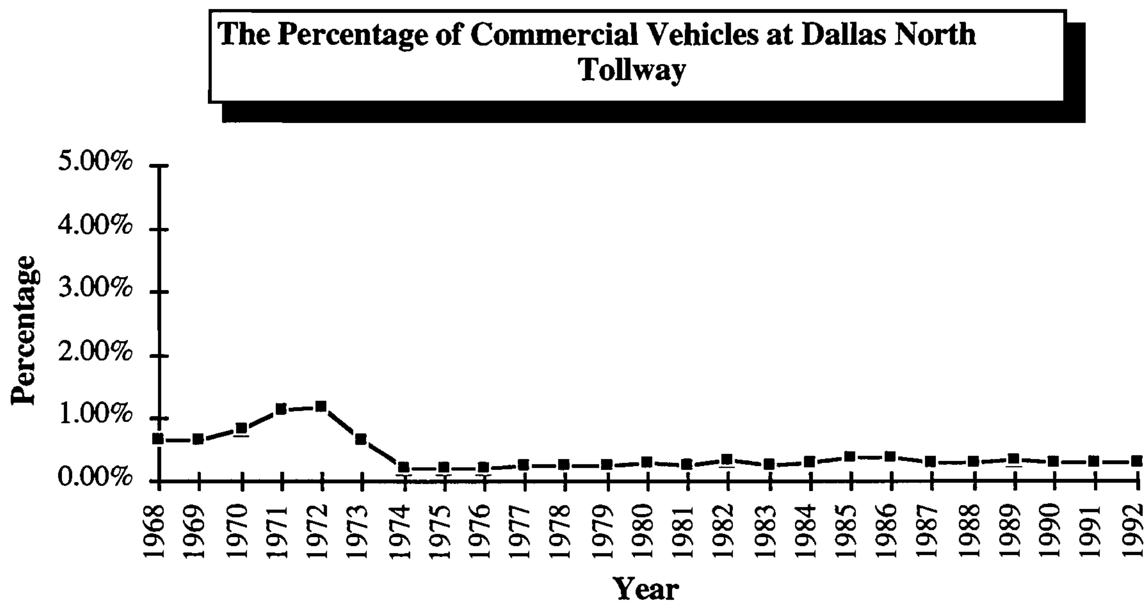


Figure 3.3 Commercial vehicles proportion on Dallas North Tollway

Elasticity values based on adjusted seasonal data averaged -0.24 and +0.57 for passenger and commercial vehicles, respectively. As expected, variability across the three observed toll changes was less for seasonal impacts as compared with the monthly base. The positive average value for commercial vehicles might be interpreted as indicating no price sensitivity. However, the 1982 percentage toll change, which was large for passenger cars but even larger for commercial vehicles (see Table 3.3), did produce a negative elasticity (-0.19 seasonal and -0.32 monthly). The 1982 data seem to indicate even commercial traffic has a price sensitivity threshold.

Seasonally based elasticity indicates less sensitivity to toll increases than monthly based data. One might extrapolate this result to conclude that the longer the measurement period, the less the observed impact of a toll change. As mentioned earlier, most trips through the Tollway are work trips, which are relatively inelastic. However, commercial vehicle traffic was less sensitive to toll changes than passenger cars. Survey results, described in Table 3.5, show that commercial vehicle drivers value travel time significantly more than drivers of other vehicles (Ref 24).

*Table 3.5 Estimated value of travel time (cents/minute)**

	Australian Tollway		
Trip Purpose	Sunshine Motorway	Logan Motorway	Sydney
Journey to work	6.3	9.7	9.6
Employer business	NA**	11.9	16.2
Commercial vehicle travel	15.0	19.3	20.8
Non-work travel	6.3	7.0	5.9
Recreational travel	3.3	7.5	NA**

* All values adjusted to represent November 1988 values
** Not collected

As the Tollway provided great time-savings, these time-sensitive users were relatively insensitive to toll increases. This is explained by Ramsey in his discriminatory temporal pricing and rate structure theory. He predicts that demand will be small in the initial road-use period, and that therefore price elasticity will be high. Hence, the tollway agency tends to charge the marginal or incremental cost for driving during initial years, and distributes capital cost to each year in inverse proportion to the demand price elasticity for that year. In early stages of the Tollway's operation, substantial time-savings were possible because of low demand. Benefits to commercial traffic using the Tollway outweighed the cost of the tolls, and, as a consequence, commercial vehicle traffic demand increased despite later toll increases. However, because of the magnitude of increases in demand, ultimately economic benefits became smaller and commercial demand became more sensitive to toll increases, much more so than passenger cars. The magnitude of the 1982 toll increases relative to previous ones may also indicate significant non-linearity in the demand-versus-price relationship.

COMPARISON WITH OTHER PRICE ELASTICITIES

Using figures obtained from the literature, Table 3.6 presents elasticity values for downtown-bound travel and for general urban travel. The average value of toll elasticity developed for Dallas North Tollway passenger car traffic is very close to the values for downtown-Boston auto travel. Both have similar downtown-commuting travel characteristics, and parking demand elasticities are less than other auto travel price elasticities.

Table 3.6 Elasticity for auto travel demand (Ref 25)

Elasticity for auto commute trips to downtown Boston	
Charles River Associates model	-2.00
Cambridge Systematic Inc. model	-0.36
McFadden/Train model	-0.32
Elasticity for parking demand	
Mid-Wilshire, Los Angeles	-0.23
Warner Center, Los Angeles	-0.18
Century City, Los Angeles	-0.08
Civic Center, Los Angeles	-0.22
Downtown Ottawa, Canada	-0.10
Average	-0.16

Generally speaking, auto travelers are not travel-cost sensitive; that is, they appear to be more sensitive to travel time than to travel cost, unless travel costs reach their response thresholds.

The elasticity values discussed above were developed under observed base social and economic background conditions. Spatial transferability is of special concern, as the conditions in which the parameters have been calibrated may be unique. In order to apply the elasticities obtained in one city to another, the cities might be grouped according to socioeconomic characteristics and travel patterns, which can then be collectively referred to as base conditions.

CONCLUSIONS

Travel demand forecasts are prominent in any toll road risk assessment, especially for those using toll revenue as the sole source for revenue-bond retirement. Through this case study, a significant correlation is recognized between toll traffic and toll charges; therefore, it is important to understand traffic demand elasticity. The better the understanding of elasticities, the more accurate the travel demand forecasts.

CHAPTER 4. TOLL SCHEDULE AND PRICING

INTRODUCTION

The schedules of most toll agencies in the U.S. are proportional to the mileage of tolled links adjusted for vehicle types (typically defined by number of axles). Vehicle classes are limited in number and generally include a passenger car and four truck types comprising two, three, four and five or more axles. These truck categories poorly correlate with actual pavement consumption, and few vehicle toll schedules capture the congestion effect through variable prices. Such crude systems make it impossible to effect demand management principles and equitable pricing mechanisms.

Table 4.1 and Figure 4.1 show nationwide average tolls (cents per kilometer) for 1987 and 1992 (Refs 26, 27). Weighted average tolls by distance operated are lower than simple average tolls, due to the fact that rural toll roads are longer and cheaper than urban toll roads and, hence, occupy larger weights. For all vehicle categories, tolls have risen by about a third from 1987 to 1992. The rates increase linearly with axle numbers in both average and weighted average cases. These current toll schedules fall short of efficient cost allocation mechanisms (though researchers still dispute the form and structure of an efficient system); it can also be said that the average cost pricing nature of static tolls fails to insure that the price paid equals the social cost occasioned.

Table 4.1 Average toll rates in U.S. ¢/km (¢/mile)[a]

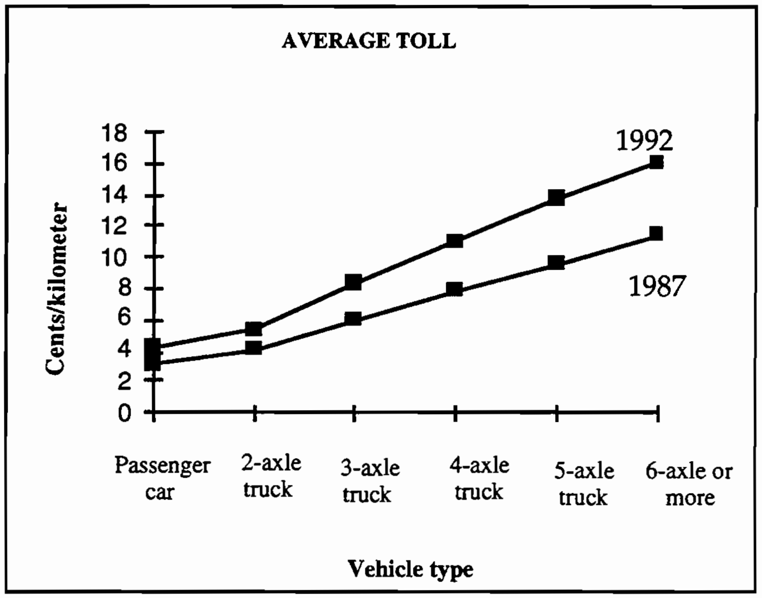
Year	Number of toll roads[b]	Passenger car	2-axle truck	3-axle truck	4-axle truck	5-axle truck	6 or more axle truck
1987	49	2.0 (3.2) 1.6 (2.5)[c]	2.6 (4.1) 2.2 (3.5)[c]	3.7 (6.0) 3.2 (5.1)[c]	4.9 (7.8) 4.0 (6.5)[c]	5.9 (9.5) 4.8 (7.7)[c]	7.2 (11.5) 6.0 (9.7)[c]
1992	49	2.7 (4.3) 2.0 (3.2)[c]	3.4 (5.4) 2.8 (4.5)[c]	5.2 (8.4) 4.2 (6.8)[c]	6.8 (11.0) 5.5 (8.8)[c]	8.6 (13.8) 6.6 (10.6)[c]	10.0 (16.1) 7.3 (11.8)[c]

[a] Tunnels and bridges are excluded. Buses are excluded for charging inconsistency. Some agencies charge buses the same as trucks depending on number of axles. Others charge different rates or flat tolls.

[b] A few agencies are excluded for their non-axle based charge.

[c] Values adjusted for distances operated.

The literature on toll schedule decisions is relatively sparse, though recent peak period road pricing and cost allocation studies show the potential for improvements over current practices. There are two major components in cost allocation: travel times (or delay) and pavement consumption costs. Axle loads were found to be critical in pavement performance in the American Association of State Highway Officials (AASHO) road test in the late 1950s, and the concept of equivalent standard axle loads (ESALs) was developed to assist in pavement design and performance. Toll agencies use axle number as an implicit index for loads and consumption, but this clearly penalizes lightly loaded or empty vehicles. If toll prices and schedules are based on equitable and efficient principles, then they can be a component of a full demand management system, an important planning option for agencies facing rising congestion levels.



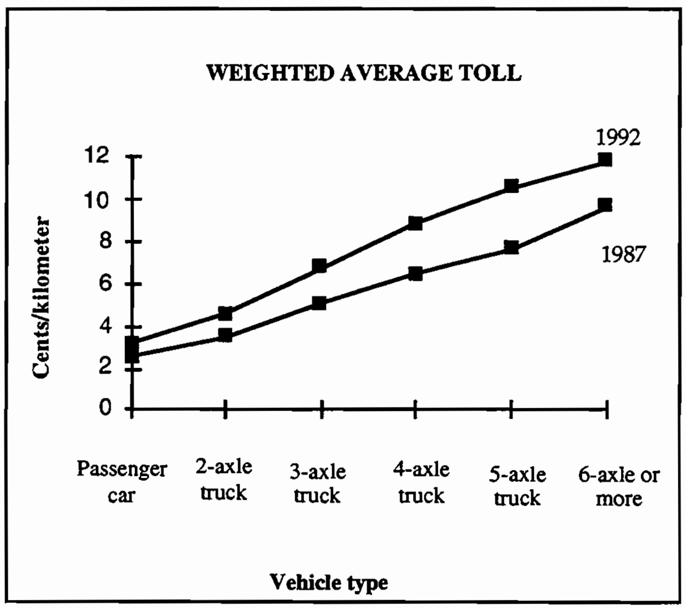


Figure 4.1 Average and weighted average toll rates in U.S. (Note: For 49 toll roads in the U.S., the average rate per kilometer and weighted average rate per kilometer by kilometer operated were calculated) Sources: Refs 26, 27

CLASSICAL SHORT-RUN OPTIMAL PRICING

The purpose of optimal or efficient pricing is to maximize net benefits to society. Many researchers have argued that current average cost pricing should be changed to marginal cost pricing to maximize social benefits. A cost allocation study (Ref 28) stresses the need for efficient charging and enumerates the conditions for efficient highway-user charges, which are typically that:

1. each vehicle pays the marginal cost of its usage, on each occasion of use;
2. the benefits from usage accrue directly to the user, whether or not they are eventually passed on to others (e.g., consumers of products shipped by highway); and
3. the user accurately perceives both the benefit and the price of each occasion of use, including the benefits and prices of substitute alternatives.

Figure 4.2 shows the classical short-run pricing toll mechanism. The standard definition of short-run is a situation in which some productive inputs are regarded as fixed and, hence, certain costs are fixed. In the context of the short-run road pricing, construction cost and cost recovery are generally regarded as sunk costs and are not incorporated. As traffic grows, average travel time increases nonlinearly. Then, marginal travel times can be shown as in Figure 4.2, where demand decreases with increases in travel time. Here, the demand curve indicates "the marginal willingness-to-pay" of each additional user, and the benefit of each trip to the user. Point A in Figure 4.2 is the equilibrium point of demand (flow) and supply (travel time) in the average cost charging scheme. Then, all trips above volume Q_0 create marginal costs that exceed the marginal benefit. The shaded area is the loss of net benefits (opportunity cost, welfare loss) from the inefficient average cost charging. Thus, demand should be reduced to Q_0, which can be achieved by tolling the amount of P_0D. This optimal toll is frequently recommended in reports addressing peak period pricing. Notice that this toll is a static optimal toll on a link in terms of the short-run marginal pricing based on the travel time each additional user imposes on other users.

Next, two important elements associated with optimal pricing — marginal users and the welfare impact of optimal pricing — are explained.

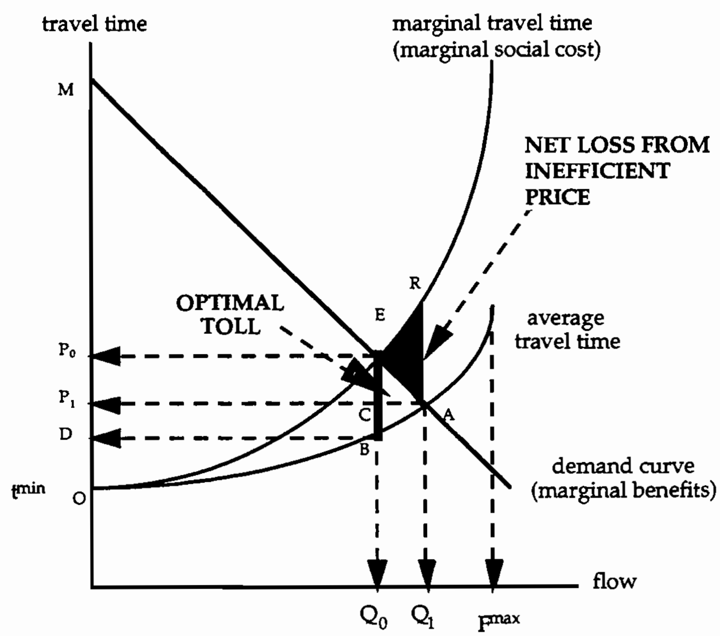


Figure 4.2 Short-run optimal pricing

Marginal Users

Marginal pricing does not mean that only the last vehicle pays the price of P_0 in Figure 4.2. Every vehicle is a marginal vehicle in the sense that every vehicle pays the same price. First arrivals do not get lower prices (Ref 28). In terms of traffic, vehicles forming a steady state flow on a link maintain the same speeds and hence pay the same travel times or costs; accordingly, all vehicles are marginal users.

Welfare Impact of Short-Run Optimal Pricing

Hau (Ref 29) discussed the effects of short-run pricing on the tolled, the "tolled off," and the untolled users. Table 4.2 shows the welfare impact on short-run marginal cost pricing (refer to Figure 4.2). The conclusions are:

1. Society receives increased benefits by the shaded area in Figure 4.2.
2. All three user groups are worse off by pricing (see Table 4.2).
3. The toll revenue collected by the agency may have a greater value than the dollar amount itself if it replaces other revenue sources with an excess burden.

Notice the relationship between (2) and (3). Channeling toll revenues back to road users or road improvements is important in compensating all three user groups for being worse off. If toll revenues are invested in capacity improvement, user groups may become better off.

Table 4.2 The welfare impact of road pricing (see Figure 4.2)

Society	• Total society benefit before pricing		ΔMOE-ΔEAR
	• Total society benefit after pricing		ΔMOE
	• Net society benefit change		Increased by ΔEAR
	• Net revenue by toll charge		P_0DBE
Users	Tolled users (Q_0)	• Consumer surplus before pricing	MP_1CE
		• Consumer surplus after pricing	ΔMP_0E
		• Net consumer surplus change[a]	Reduced by P_0P_1CE
	Tolled-off users (Q_1-Q_0)	• Consumer surplus before pricing	ΔECA
		• Consumer surplus after pricing	0
		• Net consumer surplus change	Reduced by ΔECA
	Users on other roads	• Reduced benefits due to additional congestion caused by diverted tolled-off users	

[a] In a different way, time saving benefit is P_1DBC (+) and the amount of charged toll is P_0DBE (-).

In the case of "hypercongestion," where density is beyond the point of maximum flow, all user groups are better off. As can be seen in Figure 4.3, traffic density is so high that both traffic flows and speed diminish. Demand is oversaturated and flow is much lower than the capacity, in spite of high travel costs. Introducing an optimal toll (EB) reduces both demand and travel time because the implementation of a marginal cost toll would result in travelers reverting to the normal undersaturated speed-flow curve. Here, society gets revenue (P_0DBE) and consumer surplus of users increases from ΔMP_1A to ΔMP_0E.

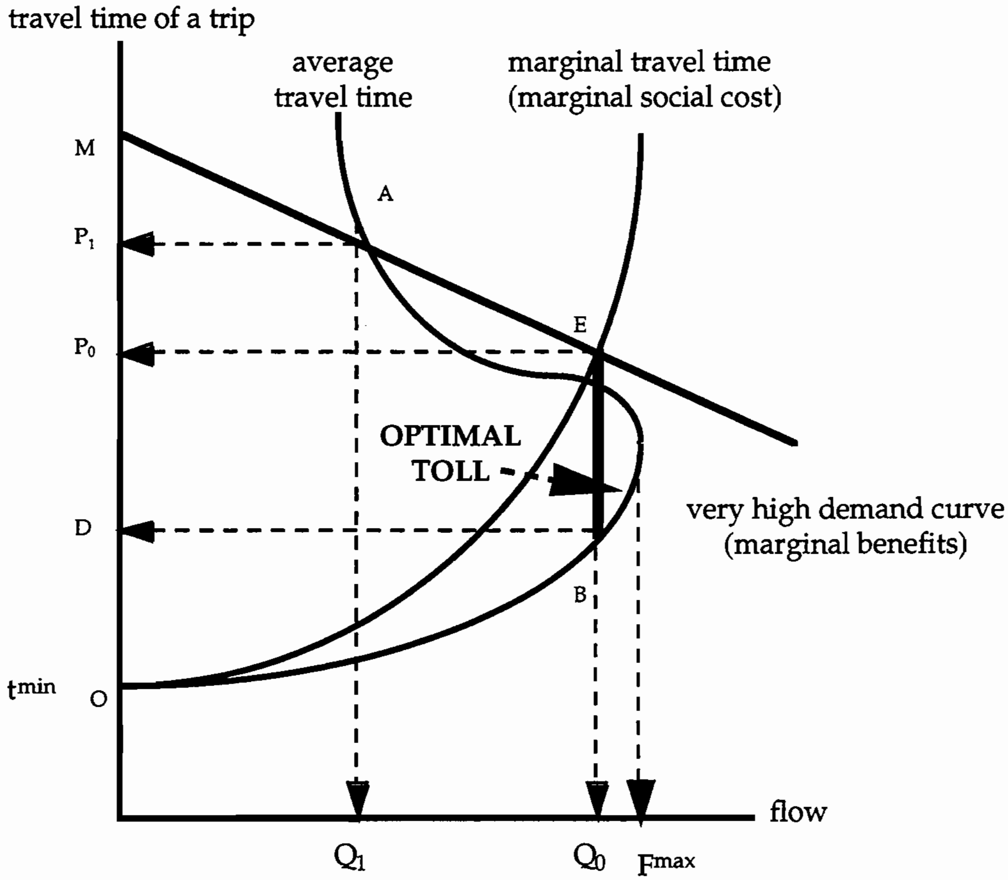


Figure 4.3 Short-run optimal pricing in hypercongestion realm

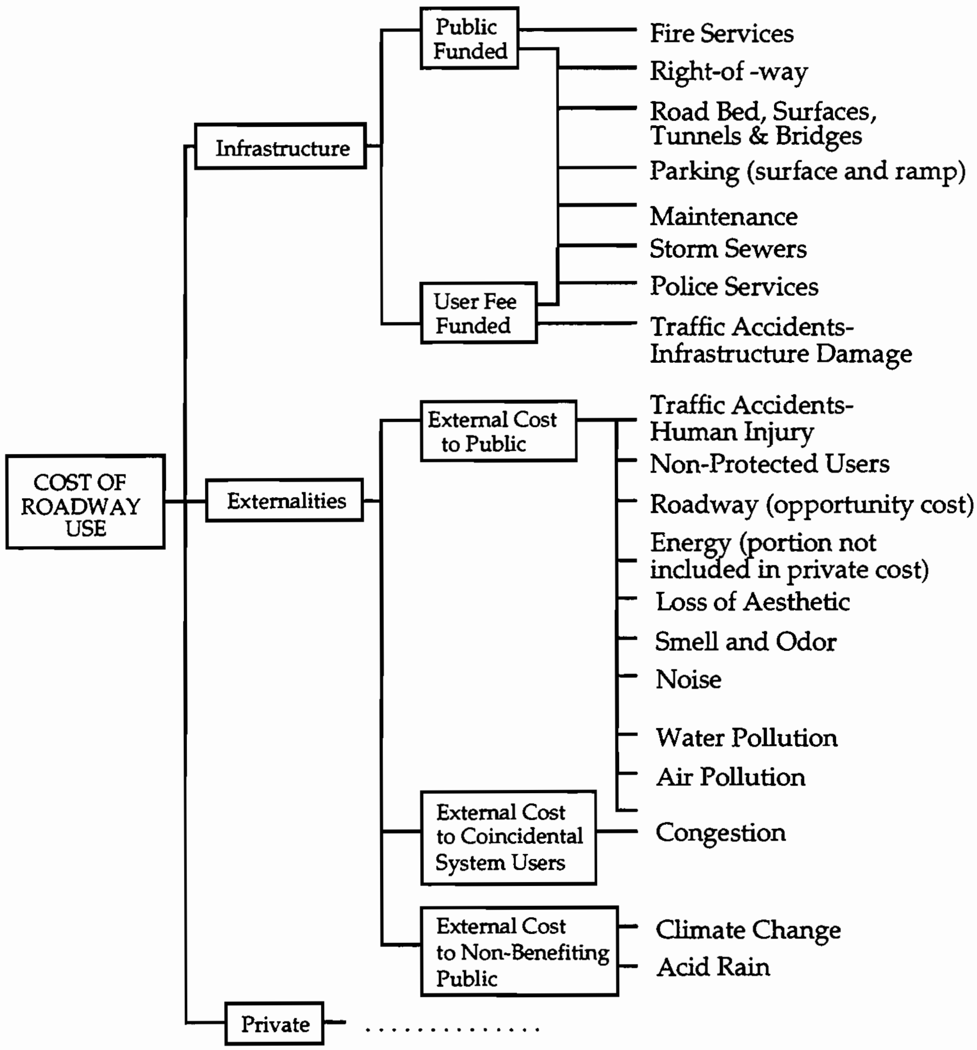
FULL COST ALLOCATION STUDY

So far, the travel time externality in short-run marginal cost pricing has been considered a major component of peak-period pricing studies. However, from the highway agency's planning perspective, attention should also be paid to the capital cost of highway operations. Thus, long-run cost allocation studies are desirable. The duration of the long-run depends on the rate at which, say, the size of a road — and hence the basic capacity — can be varied.

In considering volume dimensions, the passenger car equivalent (PCE) of trucks is the preferred unit of measure. In weight movement dimension, the unit of measure is an equivalent single 815-kg axle load (ESAL). Pavement damage on a given flexible pavement increases exponentially to the fourth power of the weight on the axle. Even though each ESAL does less damage to a thicker pavement (because pavement strength increases with roughly the seventh power of thickness), heavy vehicle consumption on pavements is around 9,000 times more than that caused by the average vehicle (automobile). Thus, analysis regarding heavy vehicle loading is a major component in any long-run full cost allocation study. Current toll schedules in the U.S.

are generally not correctly calculated, as they are based on axle numbers, instead of on actual axle weights, as discussed earlier in this chapter.

Figure 4.4 contains a more complete list of the social costs of urban roadway use. According to a recent study (Ref 30), there are few systematic economic treatments of the overall social costs of highway use and uneven treatment of the specific aspects. As can be seen in Figure 4.4, some elements, such as climate change due to air pollution associated with transportation, are rather vague and difficult to compute.



Source: Ref 30

Figure 4.4 Taxonomy of costs of roadway use

Therefore, Hau (Ref 29) recommends that short-run marginal cost pricing be used for economic efficiency, since the concept of long-run marginal cost cannot be unambiguously defined whenever cyclical variations in demand are involved. This not-too-surprising recommendation mirrors recommendations made by Vickrey and Walters in the 1950s and 1960s. Translating these into workable toll pricing mechanisms is more challenging and problematic.

DYNAMIC PRICING AND INFORMATION SYSTEM

Congestion costs and optimal tolls have long been analyzed from static (single period or multiple static periods) models. Only recently have efforts been made to derive congestion prices from models having time-varying flows. Carey and Srinivasan (Ref 31) derive system marginal costs, user perceived costs, and user externality costs for each arc and path. The study obtains a set of optimal congestion tolls and flow controls which may be used to shift the user-determined flows toward a socially preferred pattern. In the dynamic context, static tolls based on static analysis may be inappropriate for accomplishing pricing goals that maximize social benefits.

Two aspects of dynamic pricing make it particularly challenging. One is the complexity of modeling interactions among traffic variables (flow, density and speed), pricing, and related driver behaviors. The other is the lack of techniques to solve dynamic pricing formulations for large-scale dynamic networks.

Information systems connecting drivers and controllers (or tolling agencies) may play a large role in dynamic pricing. Hau suggested 20 criteria for a good road pricing system. Among them, the following two are related to dynamic pricing and information systems:

1. User-friendliness (simplicity) — The tolling system should be simple to understand and convenient to motorists. Extremely complex and continuous pricing gradations should best be avoided because of "bounded rationality" on the part of drivers' cognitive limitations. For safety reason, drivers' attention should not be diverted for more than a very short time in the process of using the system.
2. Transparency (via *ex ante* pricing) — The tolling system should inform the motorist of the prices to be charged ahead of time and place, so that the trip decision can be rationally made and rerouted if necessary. At the time when the trip decision is undertaken, a user ought to be made aware of *when* and *how much* the charges will be. This is to be contrasted with *ex post* pricing, where users are charged only *after* the fact (Ref 30).

While the above criteria might be useful, in some situations, they would conflict with the pricing goal of correct cost charging. For example, "simplicity" would keep toll agencies from using comprehensive charging schemes to realize efficient tolls. "Transparency" can be provided only when toll agencies have a high degree of system control to accurately detect current flow patterns, to precisely anticipate future flow patterns, and to quickly inform drivers of analyzed tolling schemes before they make trips.

CONCLUSIONS

In spite of these challenges, dynamic pricing is desirable for several reasons:

1. Traffic is changing dynamically. Thus, travel time savings will change over time, and the benefits from pricing will be dependent on traffic patterns. Therefore, an optimum scheme with dynamic prices should be developed at the network level, not at the local link level (as in past research).

2. It has been verified by several researchers using computer simulations that dynamic pricing is possible and is plausible if communication devices between toll agencies and individual vehicles are established (Ref 32). The existing and emerging information system under the intelligent transportation system (ITS) umbrella can be used as a communication device for that purpose.
3. Ever-increasing congestion in the U.S. needs demand management strategies in addition to transportation performance improvements. Efforts to develop ITS technologies have largely been justified on the grounds that they will increase the efficiency/capacity of the existing transportation network and, hence, reduce congestion, fuel consumption, and environmental impacts. However, there is increasing concern that the benefits of various components of ITS may not be as large as had originally been anticipated, because of latent demand due to the capacity improvements. Now, many researchers believe that demand management techniques should be incorporated with ITS technologies. Then, dynamic pricing rather than static pricing would be necessary to deal effectively with the demand management.

CHAPTER 5. COMMERCIAL CARRIER ISSUES

INTRODUCTION

U.S. trucks and truck-tractors number around 45 million units, 2 million of which are registered as farm vehicles and do not operate extensively on public roads. Thirty-eight million vehicles are classified as "light," defined as lighter than 4,536 kg (gross weight) and dominated by "pick-ups" that essentially substitute for auto use. Another 1.3 million units are truck-tractors that carry the greatest loads and pull the 3.8 million commercial trailers registered in private use and the 200,000 that are publicly owned (Ref 33). This is the market that comprises the commercial carrier industry, which is the subject of this section. The greatest growth in truck numbers, both nationwide and statewide, has been occurring in the small vehicle category. In Texas, light trucks are numerous and pay a substantial cross-subsidy, via motor fuel taxes and registration fees, to the larger trucks, typically the 18-wheel tractor semi-trailer.

Motor carrier services include freight, bus passengers, public service and utility vehicles, taxicabs, and vans. Some serve passengers while others serve freight demands; a few provide joint services. Overall, it is calculated that over 75 percent of the value of all goods and services produced in the U.S. is carried by truck. The industry employs over 2.1 million truck drivers and delivery personnel and has a network of 1.6 million truck terminals in the continental U.S.

The Interstate Commerce Commission reports more than 50,000 for-hire motor carriers of property, of which around 48,000 are small carriers having less than $1 million in annual sales. Thus, major transport markets contain many motor carriers, though some specialize in certain types of hauls and markets. For example, the average size of less-than-truck-load (LTL) carriers, which specialize in smaller shipments, is greater than the size of truck load (TL) carriers. Both TL and LTL carriers travel extensively over the U.S. highway network, with the average freight haul having increased from around 451 km in 1960 to 644 km in 1991. This has had an impact on labor relations in the industry, and it is currently characterized by high turnover among drivers. In fact, J. B. Hunt reported that driver turnover reached almost 100 percent in 1992, a situation that is forcing it to change its strategy to include rail intermodal to assist in securing over-the-highway business.

LTL carriers have sought to develop distribution networks that can take advantage of productivity gains through truck size and weight. These networks (or terminals) are used to gather, distribute, or transfer freight (including intermodal shipments). While such terminals are capital intensive, they do demonstrate the diversity and extent of the nation's trucking terminal networks. In terms of modal tonnage, ton-kilometer, and revenue shares, trucking has shown continuous gains since around 1950. Overall shares reached 20 percent by 1960 and 25 percent by the mid-1980's; present shares are approaching 30 percent. Accordingly, such growth has generated substantial revenue, with national gains for local truck operations exceeding $110 billion in 1990, and interstate truck operations amounting to $160 billion.

Clearly then, the trucking industry is important to the national economy: it generates substantial employment and has important influences in the determination of both federal and state legislation concerning its operations. The partial deregulation of the motor carrier industry through the Motor Carrier Act of 1980 has made the industry more efficient and effective. It has also led to industry fragmentation, with a few large but powerful companies setting policy and standards, operating in an environment that is characterized by many smaller companies ranging from mid-size operations to owner-drivers. This makes for a very competitive environment, with resulting battles over costs of inputs and pricing of services.

In the last three decades, truck freight operators have been successful in linking increases in size and weight dimension to changes in federal motor fuel taxes and other transport fees. This policy of linking (or ratcheting) size and weight increases to changes in federal taxation has resulted in more productive tractor semi-trailer configurations operating over the nation's system. And while repeated efforts have been made to introduce long combination vehicles, these were "frozen" out in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. However, with the passage of the North American Free Trade Agreement (NAFTA), the issue is reemerging, and truck freight operators may seek additional gains in productivity to maintain costs and profitability. Toll road systems could be configured to allow trucks to run larger and heavier, though this option needs to be explored with the motor carrier industry.

Importantly, truck freight operators and their industry associations have been successful in resisting changes at both the federal and state level — changes that would more equitably charge trucks for the use of the highway system. In many states, Texas included, large trucks are subsidized by other vehicle classes (Ref 39). The contemporary view of planners is that tolls are essentially considered cost burdens by the truck freight industry, unless the level of service offered through use of the toll road is reflected in speed and other salient industrial practices.

Because toll roads have not been extensively built in the U.S., little research has been conducted on the impacts they have had on the trucking industry. Contacts made with staff at the American Trucking Association (ATA) revealed that they had not commissioned any studies on toll roads in recent years; nor was it an important issue on their political agenda at the current time. However, the view commonly expressed by ATA is to oppose using tolls to provide facilities that should be provided as part of the U.S. highway trust fund. In this regard, truck freight operators are suspicious of tolling as a policy and regard it as double taxation.

Figure 5.1 shows the operating expense breakdown in the for-hire trucking industry for 1991 (Ref 40). (This breakdown does not appear to have substantially changed by the mid-1990s.) First, it can be seen that there are substantial cost categories that the truck freight operator must control to remain competitive, and a number of these are speed related, including fuel, repairs, and tire consumption. In other words, if a toll road can offer guarantees of higher speeds and time reliability, then over 60 percent of a truck operator's cost will be affected, particularly those relating to payroll productivity and benefits. It would therefore seem that, suitably packaged, a toll program that actually resulted in higher levels of highway service (service that could be translated into real vehicle productivity gains) would be attractive to the trucking industry, or at least a sufficient portion of them, to make some toll projects viable.

However, the literature review carried out by the study team on commercial carrier *acceptance* of toll roads revealed that little has been done on this subject; moreover, any such study would be hard-pressed to obtain a representative and statistically valid sample of common carriers, due to the heterogeneity in carrier attributes on which the toll facility attitudes depend. Therefore, instead of a random sample, a stratified sample is recommended to effectively investigate carrier attitudes.

This study recommends that the economic importance of the trucking industry combined with the increasing congestion and falling levels of service along the primary U.S. freight arteries will ultimately (and possibly rapidly) reach a point where tolling alternatives to supplement the system will be acceptable to common carriers. However, careful research needs to be done to identify industry concerns so that these can be built into the design, implementation, and operation of these facilities.

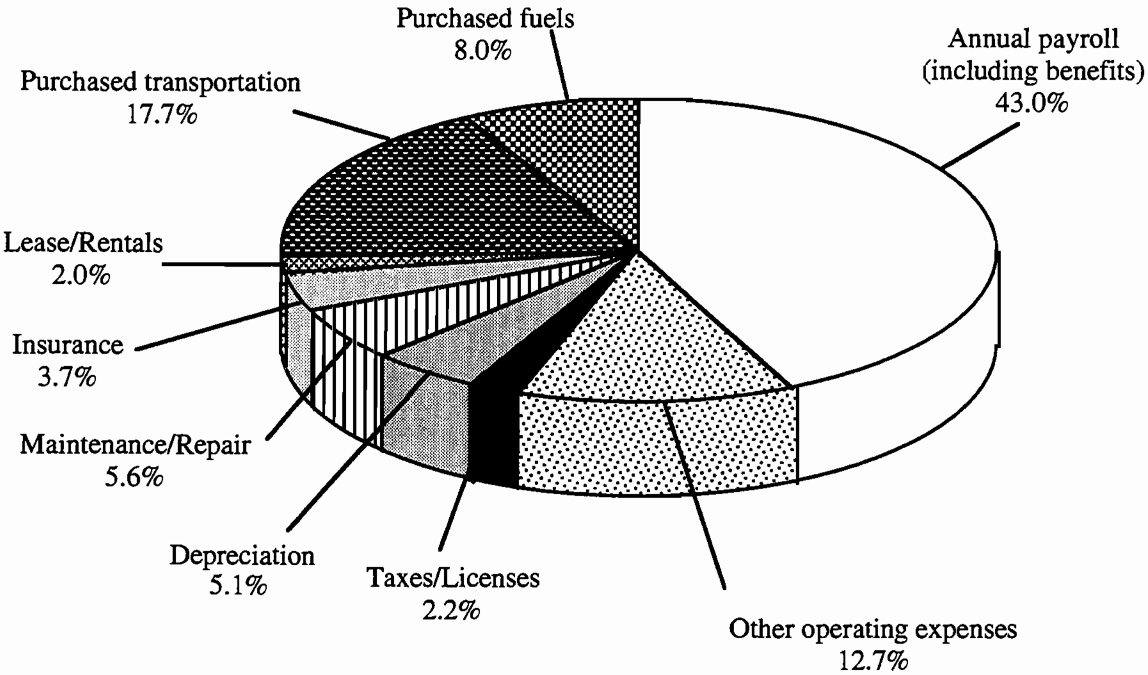


Figure 5.1. U.S. for-hire trucking industry operating expenses — 1991

LITERATURE REVIEW ON COMMERCIAL CARRIER ATTITUDES TO TOLLING

A review of research reported in this area revealed only a few, but nevertheless interesting, studies. The results, treated as individual case studies, comprise, first, road pricing in London, second, a freight flow and attitudinal survey in Arizona, and, finally, the U.S. Crescent project.

Commercial Vehicle Reactions to Road Pricing in London (Ref 34)

The United Kingdom (UK) Department of Transport (DoT) undertook an extensive research program of road pricing in London in the early 1990's, with commercial carrier reactions to the road pricing study forming part of that research. The overall objective of the study was to provide commercial carrier inputs to the Assessment of Pricing of Roads in London (APRIL) forecasting model, which was then a new strategic model developed by the DoT to assess road pricing impacts in London for seven daily time periods, representing peak, peak shoulder, and inter-peak periods. The study included two important assessments regarding the scope and objectives of this TxDOT project: (a) an assessment of the impact of road pricing on commercial vehicle operations; and (b) a limited number of interviews with operators to assess their likely reaction.

For purposes of the operator survey, assumptions were made regarding the type of road pricing scheme, road pricing charges, and associated levels of congestion relief. Travel time saving is a core benefit for paying tolls. The following conditions were given to respondents in a stated preference survey:

1. pricing type: distance-and cordon-based charging options;
2. charge: a maximum of 12 pence/km (19¢/km or 31¢/mile in U.S. dollars) for 2 axle vehicles, and a maximum 25 pence/km (39¢/km or 62¢/mile in U.S. dollars) for larger vehicles; and
3. benefit: a 20 percent travel time saving during priced periods.

Fifty interviews were carried out with chosen operators of commercial vehicles in the London area. The chosen operators were key decision makers who would be able to trade off changes in transport costs against other aspects of their distribution or service operation in London. The sample covered major food retailers, the licensed trade, consumer goods retailers, manufacturing, petrol/oil, building/construction, express parcels, service providers, food wholesalers, and distribution contractors. The sample size in each category was dependent on its relative importance and homogeneity.

The study reported that reactions to the road pricing scenarios given in the questionnaire were broadly consistent; the majority of respondents felt that they would make few changes based on the given scenarios. The only significant changes would occur in the areas of time of operation; night and weekend working appeared likely to increase.

Distance charging was reported to be felt more punitive than cordon charging. Over half the respondents stated that they would pass all or most of the costs of road pricing on to customers. Extending charging to off-peak times, including weekends, made little additional impact. Post-payment of charges was preferred to pre-payment by the commercial carriers. In many cases the respondents indicated that they were simply unable to modify either their vehicle sizes or time of operation, because of customer constraints. In view of the above responses, the report concluded that

> It is safe that the type of road pricing considered in the study will have no significant overall effects on the demand for commercial vehicles operating (CVO) in London. (Ref 34)

Even though commercial carriers are believed to be sensitive to their cost structure, they indicated that much of their demand schedules were inelastic. This might occur on account of: (a) commercial carriers higher time resource values than passenger cars; (b) customer constraints (for example, some customers may prefer a daytime, or a specific-time, delivery); and (c) commercial carriers' ability to pass the charged tolls on to customers.

Road pricing, however, would have a greater effect on businesses where transport costs are a major element of total costs (e.g., express parcel operators) and where trip demand is a function more of carrier choice than of client needs.

The results of this study, though conducted in the UK, are relevant to Texas carriers. First, many operators feel their schedules to be relatively inelastic with respect to substantial changes in the work day. This may be especially true of urban operations. However, attitudes towards congestion management — using prices to alter demand — are different from tolling where added value in terms of improved levels of service are achieved through payment of a fee or a user charge. The study clearly shows the importance of separating out, and then isolating, any issues that relate to congestion pricing in Texas.

Arizona Freight Flow and Attitudinal Survey (Ref 35)

In 1987, a mail survey of carriers was used to collect data about freight flows on Arizona's primary and secondary highways and carriers' perceptions of certain freight-related problems. This survey became part of the Heavy Vehicle Electronic License Plate (HELP) program, which is described more fully in the following case study.

A random stratified sampling technique was applied to the total population of 12,900 carriers, ranked by total annual kilometers driven in Arizona. The stratified sampling plan used in the survey was:

1. top 1,200 carriers (1,200 sampled — 100 percent),
2. carriers from 1,201 to 1,900 (350 sampled — 50 percent), and
3. carriers from 1,901 to 12,900 (550 sampled — 5 percent).

Thus, the overall sample size (2,100) represented 16 percent of the total carriers in Arizona.

The study used a mail-back survey instrument, with multiple follow-up procedures which consisted of sending the second and third questionnaires to those who did not respond, and calling after mailing the third. The questionnaire included two main sets — a freight movement survey and a carrier attitudes survey.

The freight movement survey (FMS) encompassed the following items:

- carrier code,
- contact person,
- date,
- carrier type,
- shipping date,
- commodity shipped,
- gross weight,
- shipment's origin city and state,
- shipment's destination city and state,
- Arizona routes taken in travel, and
- comments.

The carrier attitudes survey (CAS) encompassed:

- issues that adversely affect the operation and safety of the carriers (e.g., geometric design, pavement condition, etc.),
- seasonal variations in carrier operations,
- current and future concerns in the transportation industry (e.g., insurance, labor issues, public safety, etc.),
- primary carrier markets (e.g., farms, manufacturing, wholesale and retail trade, etc.), and
- competition with other carrier modes (rail, air, pipeline, or water).

Response rates by mail were:

- first wave: 7.5 percent (FMS), 7.3 percent (CAS),
- second wave: 5.5 percent (FMS), 7.5 percent (CAS),
- third wave: 11.6 percent (FMS), 13.0 percent (CAS), and
- total: 24.6 percent (FMS), 27.8 percent (CAS).

This is considered an acceptable response and should result in reliable data for policy planning purposes.

Within the scope of tolling attitudes, the CAS is more important than the FMS. The following conclusions were drawn from the CAS:

- poor pavement condition was the greatest concern of carriers.
- insurance, economic conditions, tax collection, bad drivers, government control, and public safety (in order of importance) are the current and future industry concerns.
- wholesale and retail trade commodities were the most frequently carried goods and rated most important.
- delays at intermodal facilities were reported by a majority of respondents.

The survey results suggest that providing well-maintained toll facilities and reducing delays may be attractive incentives. It is interesting to note that roadway congestion is not cited as a key concern — a response that would probably change given the lower service levels now being reported on the nation's highways (a decade after the Arizona study was undertaken). Nevertheless, there are clear signals that toll roads provide good pavements, safe travel, and greater reliability, all of which are attractive to truck freight operators.

The Crescent Project (Ref 36)

The Crescent Project element of the HELP Program is a binational (U.S. and Canada), multi-jurisdictional cooperative research and demonstration initiative involving the public and private sectors. It applies to the creation of an integrated heavy vehicle management system and is a leading example of the commercial vehicle operation (CVO) aspect of the Intelligent Transportation Systems (ITS) concept.

After initial freight studies by the Arizona Department of Transportation (AzDOT) and Oregon Department of Transportation (ODOT) in 1983, FHWA provided grants to AzDOT to undertake a feasibility study and to ODOT to perform a proof-of-concept demonstration. The HELP program was then started as part of a multistate development and testing program. This study includes motor carrier views on HELP systems, which provide information regarding potential carrier attitudes toward tolling.

The objectives of the Crescent demonstration and evaluation project were to understand (1) which HELP CVO services provide benefits and should be deployed, and (2) what obstacles had to be overcome in order to deploy CVO services.

The Crescent Project evaluation process encompasses several dimensions that need to be defined to understand how they fit together, including CVO service evaluated, HELP technologies applied, measures of effectiveness, and evaluation areas. The study includes four principal technologies:

1. automatic vehicle identification (AVI),
2. weigh-in motion (WIM),
3. automatic vehicle classification (AVC), and
4. data communication networks and systems integration.

These technologies might enhance the performance of toll roads and, consequently, attract more commercial vehicles to toll roads. Thus, toll operators should consider implementation of these technologies to maximize toll road user incentives. For heavy vehicles, WIM technology would be expected to play a significant role in comprehensive road pricing.

Each of the CVO services evaluated were rated according to measures of potential effectiveness; these services can be grouped as follows:

- benefits to the states,
- benefits to motor carriers,
- institutional situation,
- industrial situation, and
- technical situation.

The study included five evaluation areas: (1) on-site evaluation of HELP technologies and operations; (2) surveys and interviews with key state agencies; (3) surveys and interviews with participating motor carriers; (4) review of the crescent computer system components; and (5) review of the crescent demonstration office.

The surveys and interviews with participating motor carriers provide information applicable to carrier attitudes toward tolling. The survey procedure used a stratified method having the following characteristics:

- Stratification of carriers: for-hire (37.5 percent) and private (62.5 percent).
- 19 carriers were selected for the case-study.

- Evaluation procedures:
  a) preliminary telephone interview
  b) pre-test for the 19 selected case-study carriers
  c) pre-test for the all carriers including non-case-study carriers (60 total)
  d) visiting and interviewing the case-study carriers
  e) an all carrier survey through mailing and telephone follow-up
  f) case-study monitoring
  g) analysis
- Methodological considerations: Two statistics were given for each response. One represents the percent of respondents, e.g., "26 out of 52 carriers or 50 percent think..." The other considers weighting in terms of the size of a motor carrier as measured by number of trucks, i.e., "percent of participating carrier power units."
- Quality of data: The report states that the collected data are problematic. They include:
  a) Changes over time. For example, fleet size is constantly changing with the recorded number as of September 1992 for some carriers and May 1993 for other carriers.
  b) Different information from different people. In one company, two different people may have two different views for the same issue.
  c) The qualitative nature of open-end responses. In many cases, there is a qualitative aspect of responses to the open-ended questions, which is difficult to capture in a database. For example, "Yes, we might use it" to the question: "Would you use HELP's AVI data?" It is not clear that this response really indicates much interest in use of the Crescent database for fleet management purposes.
  d) Missing or "Unknown" values.
- Routing: In some companies, the choice of routes is entirely up to the driver, but in other companies, managers prefer — and sometimes insist — that drivers use a particular highway. The related statistics are not given.

Results indicate that motor carriers perceive a by-passing service (for roadside dimension and weight compliance and document preclearance) is a key to providing them significant time saving benefits. Motor carriers' perceptions of CVO services appeared to be dependent on their operating characteristics, as defined by one or more dimensions, such as class of carriage (for-hire, private), commodity carried, jurisdiction (intrastate, interstate, international), length of haul, and nature of routes (primarily regular, primarily irregular, mixture). The sample size for each particular set of characteristics is small, and statistical conclusions are not given in the report.

Like the Arizona study, this study provides some useful information regarding tolling attitudes. Time saving is an important factor in attracting commercial vehicle support for new initiatives like tolling. However, a key issue in the HELP study was the clear demonstration that truck freight operators must be involved in the planning and implementation of new initiatives that raise both productivity and operator costs. Too often in the past, decisions have been made on infrastructure provision without due regard to the users. When the users become the market, as in the case of tolled facilities, all parties must be included in the planning process.

Proposed Texas Commercial Carrier Tolling Attitude Survey

Based on the literature review, the following recommendations are made regarding a future commercial carrier tolling attitudes survey for Texas.

1. Sampling should be carefully designed. The industry is divided into too many segments. Eliciting homogeneous segments would play a key role in a successful survey.
2. Interviewing is more desirable than a mail survey. The literature has shown face-to-face interviews to be the most effective method for obtaining carrier acceptance data.
3. In addition to direct survey information, using secondary data sources (literature, interest group policy statements, etc.) would be useful in developing a questionnaire and in drawing general conclusions.
4. An issue/incentive oriented approach to commercial carrier analysis is desirable. It is important to identify what kinds of incentives are preferred by commercial carriers. Such incentives include, but are not limited to, time savings, increased weight/size limits, truck exclusive highways, paperless/stopless regulation stations, and more direct routing options.
5. It is highly desirable to seek assistance from trucking industry groups like the Texas Motor Transportation Association.

SUMMARY AND CONCLUSIONS

Although the literature on research into commercial vehicle operator attitudes to tolling is sparse, the three case studies provide telling evidence of the problems associated with tolling in the minds of commercial vehicle operators. The key issues can be summarized as follows.

1. The U.S. trucking industry is highly competitive and therefore extremely cost conscious. It is dynamic in the sense that alliances, mergers, and failures are altering the structure of the industry in dramatic ways. Also, a portion of the profits from operations must be retained to reinvest in the new operating technologies — for example, intermodal equipment — that are important to remain competitive. In all this, tolling does not play a strong part in determining current policy. First, toll facilities are a rarity compared with the extensive network of federal and state highways that are supported through motor fuel excise and other taxes. In this regard, most operators have little experience with tolled facilities and regard them as a financial imposition and possible threat if they are extensively used to supplement the national system. These attitudes need to be carefully examined and reviewed to appropriately address future toll road evaluations.
2. In addition to toll roads being relatively rare, those that do actually operate frequently do so without close cooperation from their users. In 1992, the Florida Turnpike doubled its rates overnight for the largest vehicles permitted on the system, causing anger and distrust among truck freight operators who retaliated by diverting much of their traffic to other alternative routes. Recently, tolls on the Ohio Turnpike increased nearly 80 percent on June 1, 1995. The charge for the average truck traveling the 388-km length of the highway will increase from $18 to $33. Prices for the largest trucks will rise from $49 to $88. Trucking associations in the state said they were not notified of these

increases and regard the decision as a breach of public trust granted to the Turnpike Commission (Ref 37). This demonstrates the poor relationship between existing tolling agencies and their markets. Understandably, if truck freight operators view this approach as the standard for toll roads, they will have great misgivings about supporting future toll road development, even when there may be direct productivity gains.

3. Many truck freight operators are becoming aware of the problem of declining service levels over the national highway system, and in that regard tolling may be a viable infrastructure alternative for certain sectors of the industry, particularly those associated with just-in-time and time-dependent deliveries. Since financing and construction of a toll road takes considerable time, the industry should be included in the planning process. Forging such an attitude is best done through cooperating with the industry and conducting surveys of the sort recommended by this study.
4. In working more closely with the industry, specific issues may be addressed including those associated with productivity, which relate to the industry's profitability and financial strength, safety, and the problems of jointly sharing crowded highway facilities. It is appropriate to identify those sectors where tolling may be a viable option and the conditions that make the toll roads attractive to truck freight operators while retaining financial viability for the appropriate state transportation agency.

Working with industry is the only way toll facilities will move from those associated with urban automobile planning to the development of a state and federal freight transportation perspective. Not only is this consistent with the broad objectives of the 1991 ISTEA legislation, but it also accords with the development of a full and effective Texas State Multimodal Transportation Plan (Ref 38).

CHAPTER 6. SUMMARY OF STUDY FINDINGS

The *Texas Transportation Plan* predicts that vehicle miles of travel within the state will increase by 45 percent between 1995 and 2014. At the same time, the Texas Department of Transportation forecasts that revenues required to fund the improvements necessary to accommodate this increase will make up only 44 percent of the total needed. This funding gap has prompted state transportation experts to explore a variety of approaches to fund highways efficiently and economically. The result of this exploration has been a renewed interest in toll roads, not only as a source of new funds, but also as a method of promoting greater efficiency within the highway system.

Accordingly, the basic objective of Project 1322 was to evaluate the future of toll roads for Texas. This project was preceded by Project 1281, which more specifically examined the potential for private-sector participation in highway construction. Together, the two studies have produced six reports that, individually, address the important issues that challenge toll road development within the state. This chapter highlights, in summary brevity, the relevant findings from both studies.

PROJECT 1281: SUMMARY OF FINDINGS

Report 1281-1

An Overview of Highway Privatization, by Mark A. Euritt, Randy B. Machemehl, Robert Harrison, and James E. Jarrett, Center for Transportation Research, The University of Texas at Austin, February 1994.

This report concludes that the opportunities for greater private involvement in highway improvements are extensive and available in a number of forms. While the U.S. has a history of private participation in highways, current policies and procedures of state agencies may require modifications for such participation and may necessitate changes in state laws and/or local ordinances to become legally viable.

Given that the opportunities for public/private ventures are noteworthy, it must be remembered that these are not reliable, predictable, or stable sources of funding. The objective of state highway agencies is to seek a stable, reliable, and predictable funding base in order to perpetuate the extensive highway system. These joint techniques alone are not adequate, but can be viewed as an attractive option worthy of careful consideration. It has been estimated that private financial support could, nationwide, provide $770 million annually for highway improvements, approximately 6 percent of the annual budget requirements for state and local expenditures (Orski, 1986). A very recent example of a successful private venture is the Dulles Greenway, a 22.5-km highway in northern Virginia that connects a Washington, D.C., suburb with the Dulles International Airport. Construction on the $326 million private toll road was completed in September 1995, 6 months ahead of schedule (*New York Times,* September 29, 1995).

Finally, the challenge of meeting the mobility needs of the U.S. is tied to emerging technologies, innovation, and persistence — persistence in searching for opportunities while maintaining a perspective on the future. Therefore, every notion of resource capture must be carefully analyzed. Private and public partnerships are fundamental to the success of future mobility and economic achievement.

Report 1281-2

Reliability of Toll Road Revenue Forecasts for Selected Toll Roads in the United States, by Borivoje P. Dideitch, Randy B. Machemehl, Mark A. Euritt, Robert Harrison, and C. Michael Walton, Center for Transportation Research, The University of Texas at Austin, July 1993.

This report analyzes forecast and actual revenues and costs of several public toll roads in the U.S. Forecasts and actual values are compared on an aggregate level to determine the reliability of the toll road forecasts. Using the relationship between elasticity of demand and the elements of revenue, traffic, and toll rates, the report suggests that the establishment of an error prediction model is viable. The development of an error forecast model is an important step toward establishing some semblance of standardization in the forecasting process. This standardization is important because it provides private investment in highways a feasible basis for road project comparisons.

Report 1281-3F

Strategic and Implementation Issues in Texas' Public-Private Transportation Projects, by James E. Jarrett, Mark A. Euritt, Randy B. Machemehl, and Robert Harrison, Center for Transportation Research, The University of Texas at Austin, February 1994.

Faced with shrinking resources, the Texas Department of Transportation, like many other state transportation agencies, continues to seek innovative ways of financing highway improvements. And a potential solution to the problem — one endorsed by the U.S. Department of Transportation — may well be the involvement of private sector entities in the building and rehabilitation of state transportation infrastructure. What many transportation planners are now focusing on is the implementation of a public-private program (as against a purely public toll road). As they see it, the private sector, in partnership with state and local transportation offices, can potentially bring about additional transportation capacity more quickly than efforts that are wholly financed by the public. Private firms and institutions thus represent a major — and virtually untapped — source of much-needed highway funding.

Thus, this report explores privatization strategies appropriate to TxDOT's mission. In addition, the report documents and assesses the privatization experiences of other states (e.g., Georgia, California, Arizona, Florida, and Washington). The overall objective of this project was to identify for TxDOT policymakers the potential risks and benefits associated with the implementation of a privatization program.

After reviewing public-private initiatives in other states, the researchers found that there is "almost no experience with private sector involvement in the selection, design, and operation of transportation facilities in the United States." Nonetheless, the CTR team formulated four models by which TxDOT might proceed. These models include:

1. *A Perpetual Franchise:* In this model, the facility is privately owned, financed, and operated (much like a utility). The government's role usually is restricted to regulation of health and safety, and, if deemed a monopoly, to regulation of fares or rates of return. This arrangement is not commonly found in transportation (outside of railroad and some ferry applications).
2. *Build-Operate-Transfer (BOT) model.* Under this scheme, the private firm or entity constructs and operates the facility during a franchise period (usually 20-40 years), after which ownership is transferred to a governmental agency. The selected franchise period and fees are assumed to provide sufficient time to recover all costs, pay off debt, and generate an acceptable rate of return for the private group. Worldwide, BOT is considered the most common transportation privatization model.
3. *Build-Transfer-Operate (BTO) model.* In this model, the title is transferred to a governmental entity once facility construction has been completed. A private entity then operates the facility under a franchise agreement.
4. *Lease-Purchase model.* Under this arrangement, a private entity finances and builds the facility, then leases it to a governmental entity that pays installments. The facility may be operated by either party, with or without a toll. This approach, commonly used for the construction of local government waste treatment facilities and for purchases of large equipment, has not been much used for transportation.

In addition to the selection of an appropriate public-private program model, the reports suggests that TxDOT must address four key policy issues and one procedural issue. First, because a transportation facility that is investor-owned will in some cases have monopolistic characteristics, its finances and charges must be regulated by an appropriate agency. Second, TxDOT must decide how it will invoke eminent domain for public-private projects. Third, the state agency must define the nature and extent of its financial contributions to approved projects. Fourth, TxDOT must determine the extent to which it will become actively involved in a public-private partnership program: For example, it could participate actively, or it could choose an approach similar to that used in Minnesota, where local road authorities will have the primary responsibility for establishing new infrastructure. Finally, TxDOT must define the submission process for new projects. (Interestingly, these same issues were raised by participants at the August 1995 Toll Symposium held in San Antonio, Texas.)

The report concludes that pubic-private transportation partnerships have the potential to provide supplemental financing of highway improvement projects, and therefore "deserve very serious consideration by TxDOT." While many such initiatives in other states have failed because of either inadequate financing or lack of community support, the researchers believe that there are, nevertheless, "few risks in undertaking cautiously a public-private Texas transportation partnership." There are, in fact, several reasons why such a partnership *will* work in Texas: First, present and projected economic, demographic, and transportation trends in Texas indicate that there may be more potential projects in Texas than in any other state. Moreover, Texas can learn from the mistakes of other states in undertaking a privatization effort.

Finally, the researchers suggest that there are many benefits over the long term to a public-private program. "With development of appropriate policies and controls, through legal and financial analyses, and adequate program resources during the first 2 years of the plan, a public-private transportation partnership would have an opportunity to succeed in Texas. A partnership with private entities for meeting the transportation needs of Texas citizens deserves serious consideration."

PROJECT 1322: SUMMARY OF FINDINGS

Report 1322-1

Texas Public Opinion of Toll Roads, by Christopher J. Oswald, Chungwon Lee, Mark A. Euritt, Randy B. Machemehl, Robert Harrison, and C. Michael Walton, Center for Transportation Research, The University of Texas at Austin, March 1995.

As this report makes clear, *The Texas Transportation Plan* has identified a number of action items related to the development of a statewide system of toll roads. As Texas moves in this direction, it is important to realize that Texas' experience with toll roads has been limited primarily to urban areas, where comparable alternate routes are available. Thus, rural areas and existing non-tolled highways have no experience with such systems. As a result, it is difficult to determine how Texans would respond to the development of a toll road network. This report presents the results of a statewide survey on Texas attitudes towards tolling. This information should assist policy makers and planners in developing effective strategies for toll road development. The survey clearly indicates that it is possible to develop support for tolling when clear transportation needs and benefits are identified.

The Center for Transportation Research conducted a comprehensive statewide survey of public attitudes towards tolling. The questionnaire presented the Texas funding dilemma to the respondents and asked whether the funding gap should be addressed by using toll roads or increasing motor fuel taxes. Additionally, the survey explored in great detail the factors leading to this decision. The results are somewhat surprising.

Nearly 40 percent of the 6,011 surveyed households responded, a figure that enhances the statistical validity of the results. The researchers were able to adjust results to account for geographical and gender bias. With great confidence, the researchers are able to present the findings of the survey. Importantly, however, the survey method is a stated preference, which does not always accurately measure how persons will actually respond. Nevertheless, the survey results do gauge how the public feels about tolling, which is essential to the development of an effective toll road policy.

Adjusting for gender bias, overall, 61.7 percent of Texans favor toll roads over increases in motor fuel taxes. This support holds for both urban and rural areas. However, urban areas tend to support toll roads because they more accurately relate transportation costs to transportation use. Rural areas, on the other hand, tend to support toll roads over motor fuel tax increases because residents oppose "any" increases in motor fuel taxes. The rural perspective represents more of a protest vote, rather than an affirmative statement in support of a statewide system of toll roads.

Report 1322-2

Electronic Toll Collection Systems, by Diane L. Venable, Randy B. Machemehl, and Mark A. Euritt, Center for Transportation Research, The University of Texas at Austin, May 1995.

An in-state survey of attitudes towards tolling revealed that a large percentage of the respondents were concerned with delays at toll collection booths. (See Report 1322-1 for a complete discussion of the survey.) Traditional toll collection booths require a number of operations — stopping the vehicle, lowering the window, finding the correct coinage or valid card — before travelers can continue their journey. These labor-intensive, land-intensive, and time-consuming toll booths impede traffic flows on and off a toll road, resulting in congestion, higher vehicle operating costs, and increased pollutant emissions. To address these concerns, electronic toll collection (ETC) systems have been developed.

ETC systems are comprised of three functional elements: a vehicle-mounted transponder or tag; a roadside communication unit (RCU); and a computer system. Four different ETC technologies are used, including optical/infrared, inductive loop, radio frequency/microwave, and surface acoustic wave/complimentary metal oxide semiconductor systems, with radio frequency (RF) systems being the most popular. There are a number of technical and design issues to address when evaluating ETC technologies. Important technical issues include environmental conditions, recording accuracy, payment systems, and audit control. Design issues include security, communication between vehicle and roadside, equipment reliability, compatibility with other systems, system flexibility, and safety. In addition to these issues, the implementing agency must be aware of emerging standards for ETC, toll booth capacity or throughputs, user privacy issues, enforcement, maintenance, and staffing requirements.

ETC systems have been used successfully nationally and internationally. In addition to reducing bottlenecks at the toll booth, ETC systems also significantly reduce the cost of toll collection. Finally, because ETC systems can reduce the number of required lanes and booths to support throughput, they can significantly reduce labor costs.

ETC opens up the possibility of setting virtually any toll-pricing scheme. If desired, the tolls can be distinguished by time of day, type of vehicle, laden weight, speed of travel, distance traveled, and traveler types entitled to a discount.

Implementation of an ETC system, however, represents a major investment. With the rapid emergence of new technologies, and the need for integration with conventional toll systems and other regional ETC systems, agencies must carefully evaluate their needs and determine optimum system configurations. Some agencies are delaying ETC implementation to take advantage of emerging technologies. Nevertheless, the possibilities for ETC system uses are endless, requiring only good planning, funding, and demand use.

Report 1322-3F

In discussing issues tangential to toll road development, this final report provided the following findings:

Chapter 2 — Demand estimation issues: The revenue generation and corresponding profitability of toll facilities are of critical importance to toll road developers and operators. The revenue generated by a toll facility is directly proportional to the amount of traffic utilizing the toll facility, and to the prices levied on the various vehicle categories. Thus, in general, the financial feasibility of a toll project is dependent on both the usage level and the toll rates.

In spite of the importance of toll usage estimation, no efficient procedure for such estimation has been established; nor is there abundant literature on comprehensive treatments of toll usage estimation. As with traditional demand forecasting methods, though, many hybrid methods have been devised. Practically speaking, the selection of a method depends on data availability and time/budget constraints. Since traffic forecasting depends on accurate predictions of traveler decisions, two factors must be addressed: (1) traveler decision-making processes, and (2) system equilibration.

When a toll is introduced on a network, motorists may or may not divert to the new tolled route. Some motorists may even increase trip frequency and distance as a result of the new route — an example of latent demand stimulated by new network options and level of service associated with trip choice. Although long-term impacts are difficult to capture (and are sometimes ignored), they are important for a full feasibility study.

We concluded that the traditional aggregate approach to demand estimation has several shortcomings. First, the time penalty on toll links is a rough approximation only of user perceptions of tolling and travel time interaction. Second, the model produces overly sensitive assignment patterns, in that any route with toll road segments changes from the shortest route to the "second-best" route, and vice versa, due to toll level or trip time changes. In other words, a small difference between two routes for an origin-destination pair could elicit totally different assignment results. This problem stems from the use of an aggregate assignment tool to model complex route choice phenomena. A potential alternative is the use of discrete choice models based on consumer choice theory.

We also noted that most work, as evidenced by all the case studies, are for urban toll roads, where business trips — mostly undertaken by single occupancy autos — dominate. The revenue models for an intercity toll system must be accurately estimated because they relate to systems having higher total toll rates and involve users (like motor carriers) who are cost conscious. Forecasting accuracy is therefore essential if intercity toll networks are to be a feature of highway travel in the next century.

Chapter 3 — Demand elasticity is-the term used to describe the relationship between toll road traffic demand and toll charges. In looking at this relationship, we used the Dallas North Tollway to illustrate how toll traffic features from past experiences can be used to make better toll revenue predictions. Through this example, we recognized a significant correlation between toll traffic and toll charges. Accordingly, we recommend efforts to better understand demand elasticities as a way of more accurately forecasting travel demand.

Chapter 4 — Toll scheduling and pricing: We concluded that, despite certain inherent challenges, dynamic pricing is desirable for several reasons:

1. Traffic is changing dynamically. Thus, travel time savings will change over time, and the benefits from pricing will be dependent on traffic patterns. Therefore, an optimum scheme with dynamic prices should be developed at the network level, not at the local link level (as in past research).
2. It has been verified by several researchers using computer simulations that dynamic pricing is possible and is plausible if communication devices between toll agencies and individual vehicles are established. The existing and emerging information system under the intelligent transportation system (ITS) umbrella can be used as a communication device for that purpose.
3. Ever-increasing congestion in the U.S. needs demand management strategies in addition to transportation performance improvements. Efforts to develop ITS technologies have largely been justified on the grounds that they will increase the efficiency/capacity of the existing transportation network and, hence, reduce congestion, fuel consumption, and environmental impacts. However, there is increasing concern that the benefits of various components of ITS may not be as large as had originally been anticipated, because of latent demand due to the capacity improvements. Now, many researchers believe that demand management techniques should be incorporated with ITS technologies. Then, dynamic pricing rather than static pricing would be necessary to deal effectively with the demand management.

Chapter 5 — Commercial carrier issues: Although the literature on commercial vehicle operator attitudes to tolling is sparse, the three case studies presented provide telling evidence of the problems associated with tolling. The key issues can be summarized as follows:

1. The U.S. trucking industry is highly competitive and therefore extremely cost conscious. It is dynamic in the sense that alliances, mergers and failures are altering the structure of the industry in dramatic ways. Also, a portion of the profits from operations must be retained to reinvest in the new operating technologies — for example, intermodal equipment — that are important to remain competitive. In all this, tolling does not play a strong part in determining current policy. First, toll facilities are a rarity compared with the extensive network of federal and state highways that are supported through motor fuel excise and other taxes. In this regard, most operators

have little experience with tolled facilities and regard them as a financial imposition and possible threat if they are extensively used to supplement the national system. These attitudes need to be carefully examined and reviewed to appropriately address future toll road evaluations.

2. In addition to toll roads being relatively rare, those that do actually operate frequently do so without close cooperation from their users. In 1992, the Florida Turnpike doubled its rates overnight for the largest vehicles permitted on the system, causing anger and distrust among truck freight operators who retaliated by diverting much of their traffic to other alternative routes. Recently, tolls on the Ohio Turnpike increased nearly 80 percent on June 1, 1995. The charge for the average truck traveling the 388-km length of the highway will increase from $18 to $33. Prices for the largest trucks will rise from $49 to $88. Trucking associations in the state said they were not notified of these increases and regard the decision as a breach of public trust granted to the Turnpike Commission. This demonstrates the poor relationship between existing tolling agencies and their markets. Understandably, if truck freight operators view this approach as the standard for toll roads, they will have great misgivings about supporting future toll road development, even when there may be direct productivity gains.
3. Many truck freight operators are becoming aware of the problem of declining service levels over the national highway system, and in that regard tolling may be a viable infrastructure alternative for certain sectors of the industry, particularly those associated with just-in-time and time-dependent deliveries. Since financing and construction of a toll road takes considerable time, the industry should be included in the planning process. Forging such an attitude is best done through cooperating with the industry and conducting surveys of the sort recommended by this study.
4. In working more closely with the industry, specific issues may be addressed including those associated with productivity, which relate to the industry's profitability and financial strength, safety, and the problems of jointly sharing crowded highway facilities. It is appropriate to identify those sectors where tolling may be a viable option and the conditions that make the toll roads attractive to truck freight operators while retaining financial viability for the appropriate state transportation agency.

Working with industry is the only way toll facilities will move from those associated with urban automobile planning to the development of a state and federal freight transportation perspective. Not only is this consistent with the broad objectives of the 1991 ISTEA legislation, but it also accords with the development of a full and effective Texas State Multimodal Transportation Plan.

REFERENCES

1. Oswald, Christopher J., Chungwon Lee, Mark A. Euritt, Randy B. Machemehl, Robert Harrison, and C. Michael Walton, "Texas Public Opinion for Toll Roads," Research Report 1322-1, Center for Transportation Research, The University of Texas at Austin, March 1995.

2. Venable, Diane L., Randy B. Machemehl, and Mark A. Euritt, "Electronic Toll Collection Systems," Research Report 1322-2, Center for Transportation Research, The University of Texas at Austin, May 1995.

3. Center for Transportation Research and The Tellus Institute, "Strategies for Reducing Energy Consumption in the Texas Transportation Sector," CTR Report SEDC-2, The University of Texas at Austin, June 1995.

4. Federal Highway Administration, U.S. Department of Transportation. 1993 Highway Statistics (U.S. Government Printing Office: Washington, D.C.) October 1994.

5. The Road Information Program, 1993 State Highway Funding Methods. (Washington, D.C.) June 1993.

6. Shrank, David L., Shawn M. Turner, and Timothy J. Lomax, "Trends in Urban Roadway Congestion —1982 to 1991: Volume 1: Annual Report," Research Report 1131-6, Texas Transportation Institute, Texas A&M University, September 1994.

7. Texas Air Control Board, Air Quality in Texas 1992 and Beyond. Austin, Texas.

8. John A. Volpe National Transportation Systems Center, National Transportation Statistics: Annual Report, September 1993: Historical Compendium, 1960-1992. (U.S. Government Printing Office: Washington, D.C.) Bureau of Transportation Statistics, U.S. Department of Transportation, 1993.

9. Texas Department of Transportation, *The Texas Transportation Plan: Partnerships into the 21st Century.* 1994 edition.

10. Mannering, F. L., and W. P. Kilareski, *Principles of Highway Engineering and Traffic Analysis*, John Wiley & Sons, New York, 1990, pp. 205-246.

11. Johnston, D. K., and N. Patterson, "Toll Roads — A Method for Estimating Usage and Revenue," *Transportation Planning Proceedings*. Conference of the Australian Road Research Board, Part 4, 1990, pp. 191-210.

12. Ben-Akiva, M., and S. R. Lerman, *Discrete Choice Analysis: Theory and Application to Travel Demand*, The MIT Press, Cambridge, MA, 1987, pp. 60-79.

13. Horowitz, J., "Reconsidering the Multinomial Probit Model," *Trans. Res. B*, Vol. 25B, No. 6, 1991, pp. 433-438.

14. Lam, S. H., *Multinomial Probit Model Estimation: Computational Procedures and Applications*, doctoral dissertation, The University of Texas, Austin, 1991.

15. Daganzo, C., *Multinomial Probit: The Theory and Its Application to Demand Forecasting*, Academic Press, New York, 1979.

16. Dial, R., "A Probabilistic Multipath Traffic Assignment Model Which Obviates Path Enumeration," *Trans. Res.* Vol. 5, 1971, pp. 83-111.

17. Sheffi, Y., *Urban Transportation Network: Equilibrium Analysis with Mathematical Programming Methods,* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1985, pp. 294-297.

18. Brand, D., and J. L. Benham, "Elasticity-Based Method for Forecasting Travel on Current Urban Transportation Alternatives," *Transportation Research Record 895*, TRB, National Research Council, Washington, D.C., 1982, pp. 32-37.

19. Heisler, J., M. Imhoff, and E. Schumm, "Estimating Toll Diversion," *Microcomputer in Transportation*. 1990, pp. 995-1010.

20. Souleyrette, R., *A Method for Identification and Evaluation of Proposed Highway Toll Facilities*, Master's thesis, The University of Texas, Austin, 1986.

21. Wilbur Smith Associates, *Traffic and Revenue — Dallas North Tollway and Proposed Extension, Phase 2*, 1990.

22. Texas Turnpike Authority, *Fortieth Annual Report*, Dallas, Texas, 1993.

23. Wilbur Smith Associates, *Traffic and Revenue — Dallas North Tollway and Proposed Extension — Phase 2*, 1990.

24. Johnston, D., and N. Patterson, "Toll Roads — A Method for Estimating Usage and Revenue," *Transportation Planning Proceedings: Conference of the Australian Road Research Board part 4*, p.191-210, 1990.

25. Decorla-Souza, P., and A. Kane, "Peak Period Tolls: Precepts and Prospects," *Transportation*, Vol 19, No. 4, 1992, p.293-311.

26. International Bridge, Tunnel and Turnpike Association, *Toll Rates Survey*, April, 1987.

27. International Bridge, Tunnel and Turnpike Association, *Toll Rates Survey*, April, 1992.

28. U.S. Department of Transportation, *Final Report on the Federal Highway Cost Allocation Study*, 1982.

29. Hau, T., *Economic Fundamentals of Road Pricing: A Diagrammatic Analysis*, The World Bank, Washington D.C., 1992.

30. Resource Management Associates, *Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use*, Madison, WI, 1992.

31. Carey, M., and A. Srinivasan, "Externalities, Average and Marginal Costs. and Tolls on Congested Networks with Time-Varying Flows," *Operation Research,*. Vol. 41, No. 1, 1993. pp. 217-231.

32. Sanhouri, I. El, and D. Bernstein, *Integrated Driver Information and Congestion Pricing Systems*, Transportation Research Board 73rd Annual Meeting, Washington D.C., 1994.

33. *Transportation Statistics*, Annual Report 1994, Bureau of Transportation Statistics, U.S. Department of Transportation, Washington D.C., 1995.

34. The John Fearon Consultancy with & Touche Ross, *Commercial Vehicle Reactions to Road Pricing-Final Report*, 1993.

35. Radwan, A. E., M. Rahman, and S. A. Kalevela, *Arizona Freight Network Analysis, Volume 1, Freight flow Information,* Final report, Center for Advanced Research in Transportation, Arizona State University, Tempe, 1987.

36. American Trucking Associations, "The CRESCENT Evaluation Team," *The Crescent Project: An Evaluation of an Element of the HELP Program — Executive Summary*. American Trucking Associations, 1994.

37. American Trucking Associations, "Major Toll Hike for Ohio Turnpike," Transport Topics, American Trucking Associations, Alexandria, Virginia, May 1, 1995, p. 5.

38. Dye Management Group, *The Texas Transportation Plan — Partnerships into the 21st Century,* Texas, November 1994.

39. Euritt, Mark A., C. Michael Walton, Zane A. Goff, and Dock Burke, "Texas Highway Cost Allocation Analysis and Estimates, 1993-1995," Research Report 1919-3F/1910-4F, Center for Transportation Research, The University of Texas at Austin, November 1994.

40. Eno Transportation Foundation, Inc., *Transportation in America, 1991,* Eno, Washington, D.C., 1992.