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16. Abstract

A methodology for identification and evaluation of proposed or existing highway toll facilities is presented. This report presents an operational typology, the development of a route-share computer model, a method for economic evaluation, and guidelines for benefit-cost analysis. The material presented in these sections is intended to support the identification of candidate locations for toll financing as well as the evaluation of existing facilities.

The typology, a classification mechanism, provides a framework for identifying the legal, institutional, economic, financial, and operational issues associated with various tolling concepts for a given set of local conditions. An illustration of this framework's usefulness is provided through its application to the Texas context and its use to organize the results of a national survey of toll facilities operators.

The route-share model is a random utility maximization model of the logit form that is used to predict a toll facility's traffic share for a given set of local conditions. Limited sensitivity analysis and application to an example scenario is presented.

The chapter on economic analysis presents a method of revenue-expenditure analysis. The components that can be expected at a toll facility are detailed along with example data for five toll agencies.

The final chapter of the study presents guidelines and recommendations for benefit-cost analysis including application of the route-share model to examine the impact of various toll pricing schemes on user-equity and traffic diversion.

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# IDENTIFICATION OF CANDIDATE TOLL ROADS IN CURRENT AND FUTURE HIGHWAY DEVELOPMENT

by

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and
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Research Report Number 413-1F

Research Project 3-10-85-413

conducted for

Texas State Department of Highways and Public Transportation

by the

**CENTER FOR TRANSPORTATION RESEARCH**
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**THE UNIVERSITY OF TEXAS AT AUSTIN**

August 1986

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. This report does not constitute a standard, specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design, or composition of matter, or any new and useful improvement thereof, or any variety of plant which is useful or may be patentable under the patent laws of the United States of America or any foreign country.

## PREFACE

Declining tax revenues, higher highway construction and maintenance costs, and a call for more equitable allocation of costs to highway users has prompted the Texas State Department of Highways and Public Transportation (SDHPT) to consider tolling as an alternative financing mechanism.

Presently, agencies, municipalities, or other groups advocating the use of tolling to finance a highway project within the state of Texas must petition the Texas Turnpike Authority for a preliminary study (with the exception of Gulf Coastal counties, which are permitted by legislation to create independent Toll Authorities). However, little or no emphasis has been placed on the evaluation of toll financing on a system wide level. Additionally, no effort has been made in the development of an analytical and objective means for identifying and evaluating likely candidate locations for toll highways.

This is the first and final report for project 3-10-85-413, "Identification of Candidate Toll Roads in Current and Future Highway Development," a two-year study conducted at the Center for Transportation Research, The University of Texas at Austin, sponsored by the Texas State Department of Highways and Public Transportation. The study was supervised by University of Texas Professor C. Michael Walton and Associate Professor Hani S. Mahmassani.

Special Recognition is extended to Mr. Bob Cueller of D-10 of SDHPT for his assistance during this project. Appreciation is also extended to the International Bridge, Tunnel, and Turnpike Authority (IBTTA) and to the many toll authorities that participated in this project by providing invaluable information and data.

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August 1986

## ABSTRACT


A methodology for identification and evaluation of proposed or existing highway toll facilities is presented. This report presents an operational typology, the development of a route-share computer model, a method for economic evaluation, and guidelines for benefit-cost analysis. The material presented in these sections is intended to support the identification of candidate locations for toll financing as well as the evaluation of existing facilities.

The typology, a classification mechanism, provides a frame work for identifying the legal, institutional, economic, financial, and operational issues associated with various tolling concepts for a given set of local conditions. An illustration of this framework's usefulness is provided through its application to the Texas context and its use to organize the results of a national survey of toll facilities operators.

The route-share model is a random utility maximization model of the logit form that is used to predict a toll facility's traffic share for a given set of local conditions. Limited sensitivity analysis and application to an example scenario is presented.

The chapter on economic analysis presents a method of revenue-expenditure analysis. The components that can be expected at a toll facility are detailed along with example data for five toll agencies.

The final chapter of the study presents guidelines and recommendations for benefit-cost analysis including application of the route-share model to examine the impact of various toll pricing schemes on user-equity and traffic diversion.

## SUMMARY

Traditionally, tolls have been used to finance highway construction on a case by case basis with system-wide application receiving little emphasis. Expensive, detailed feasibility studies have been conducted for each of these facilities. The objective of this study is the development of a systematic procedure to support the identification and evaluation of candidate locations for toll financing prior to the execution of more extensive feasibility studies. The report provides an analyst with a methodology for screening and ranking of a number of candidate toll facilities, thereby reducing costs by eliminating studies for infeasible or undesirable candidate projects, and improving efficiency of site selection.

The starting point for the methodology is a typology for toll financing, presented in the second chapter of the report. It provides a classification and identification mechanism (typology) for various methods and characteristics for toll operation is developed. This typology helps the analyst organize the many issues and components of toll financing. The dimensions and levels of operating characteristics are combined to form 9 typology cells which represent possible schemes of toll road operation. To illustrate the typology's usefulness as a classification mechanism, a survey of U.S. toll road operators was conducted. In addition, a section presents an application to the tolling scene in Texas.

The third chapter of the report presents a model developed to estimate traffic volumes and revenues for a given corridor. Sensitivity analysis results showed that some model inputs could be derived from secondary data, while other data must be specified by the analyst. The model, when applied to approximate conditions at the Dallas North Tollway for 1981 produced reasonable estimations. The model is used in subsequent chapters to estimate volumes and revenues for additional analysis.

The fourth chapter of the report, "Revenue/Expenditure Analysis", provides the analyst with a tool for screening potentially economically infeasible candidate locations. Components of revenues and expenditures that may be expected at a toll facility are identified and described in the first section. The second section of Chapter 4 presents minimum requirements of R/E ratios for each of the nine typology cells of operation. Those candidate facilities that fail to meet these criteria can be screened from further consideration. Finally, the third section of this chapter presents example revenue and expenditure data for five toll agencies.

The fifth chapter of the report, "Benefit-Cost Analysis", provides the analyst with a method for evaluating or ranking candidate facilities that meet the requirements presented in the previous chapter. Sections present qualitative discussions of benefits and costs associated with toll financing. In two other sections, the route-share model is used to estimate effects of toll financing on cost based equity and traffic diversion. With the information presented in this chapter, an analyst may develop benefit-cost ratios for each of the candidate locations, there by facilitating comparison and selection of the most viable sites.

## IMPLEMENTATION STATEMENT

An objective of the Texas State Department of Highways and Public Transportation is "to implement procedures to encourage public and private cooperation to improve transportation facilities and alleviate congestion. "Developing certain projects as toll facilities is proposed as one mechanism which may assist in meeting this objective. In summary, the overall study objectives of this project, "Identification of Candidate Toll Roads in Current and Future Highway Development," is to incorporate the economic, operational, legal, institutional, and social considerations summarizing tolling into a systematic procedure for identifying, designing, and evaluating toll road proposals in Texas.

The above identification/design/evaluation methodology provides guidelines to highway administrators and other concerned decision-makers and officials as to the feasibility of toll financing in meeting the highway needs of the State. In addition, the study produced general recommendations for projects that could be implemented, along with quantification of costs and benefits of such projects, and a discussion of their broader implications. Difficulties and hindrances that may be encountered in the implementation of toll road projects have been identified, along with suggestions for their mitigation, based on experience in other states and discussion with appropriate state officials in Texas.

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# CHAPTER 1 - INTRODUCTION

## CURRENT HIGHWAY FUNDING CONSIDERATIONS

The Federal Aid Road Acts of the 1920s, which allocated the first federal funding for highway construction, generated an attitude among both federal and state legislative bodies that highway construction should be toll free. While a number of toll roads have been constructed post World War II, toll free road systems prevail in the United States.

In 1958, the Comptroller General of the United States barred federal funding of toll roads without congressional approval. Few toll roads have been built since that time. However, current legislative and financial considerations may foster a change in this policy. (1)

Currently, seven states are utilizing toll financing for selected major roads, nine states toll one major highway or sections thereof, and four states use tolls to a very limited extent. There are no toll roads in the remaining 30 states. The demand for available resources coupled with the aging roadway infrastructure have promoted the issue of equitable allocation of costs to user categories. Lack of revenue for highway construction will be the main thrust behind tolling since the majority of states are experiencing dwindling road budget allocations. In 1965, Texas allocated one third of its budget to highways; by 1985, allocations had declined to less than twelve percent.

## CURRENT ISSUES IN TOLL FINANCING

In the current debate surrounding toll financing of highway facilities, the following issues have been identified:

### CONVERSION OF EXISTING OR PREVIOUSLY PLANNED HIGHWAYS TO TOLL FACILITIES

With few exceptions, which can only be granted by Congressional approval, roads financed (even partially) by federal funds are not eligible for such operation. This also affects the feasibility of the advocated use of tolling as the principal (and according to some, the only practical) means of completing the remaining four percent of the interstate system, which involves very costly construction of urban links.

### FINANCIAL CONSIDERATIONS

The user pay structure of tolling allows an increase in the user share of support for transportation as "it is estimated that non-users contributed 24 percent of the expenditures for highway purposes, yet were responsible for only 7 percent of the costs" in 1977 (2).

Tolling relative to general taxation is argued to be less progressive than the income tax, but it seems less regressive than a motor fuel tax (1).

Flexible toll pricing could allow a more equitable allocation of costs to various user groups; in this regard, pricing on the basis of cost seems to be easier to implement (technologically and politically) than some other schemes.

## PUBLIC ACCEPTANCE:

Toll free travel is taken for granted in most states. The public is generally not well informed about toll financing for highways. Attitudes of a public accustomed to driving on exclusively tax financed roads are therefore likely to present an obstacle, at least initially, to the expansion of road financing by tolls.

The potential impact on tourist trade and the accessibility to business may lead to objection to toll roads from the affected business community. This has to be compared with the potential low service levels offered by improperly maintained or severely congested roads.

Safety: The IBTTA (International Bridge, Tunnel, and Turnpike Association) and other organizations have compiled statistics that seem to indicate that toll parkways are safer than other major freeways.

## THE POTENTIAL OF TOLLS TO ACHIEVE OTHER OBJECTIVES:

Besides revenue generation, tolls might achieve other objectives, such as congestion relief and efficient pricing especially when coupled with operating concepts such as exclusive truck facilities and high occupancy vehicle lanes.

Recommendations have been made regarding a few of these issues in recent times, including those by the TRB (3):

-new federally constructed roads should be allowed to be tolled
-revenues should be used on a facility specific basis
-tolls should be removed after bond retirement
-no tolls should be allowed on existing federal projects
by the Institute of Transportation Engineers (4):

> "Transportation agencies should be permitted to develop toll highways in conjunction with use of federal funds on federally aided projects. Tolls should be allowed on federal aid highways and bridges where high maintenance, construction, or reconstruction costs exists. There should be no obligation to repay federal aid highway funds that have been expended on the facility."

and by the Federal Highway Administration (5):

1982 - tolls should be used to fund federal construction
- toll free facility after bond retirement
- no 4R funds appropriated during bond life

1983 - supported Senate bill 524 (similar to 1982 recommendations, specifically for Illinois)

However, no such legislation has been enacted.

## SCOPE AND OBJECTIVES

Because tolling is considered by many to be a viable method for alternative financing, some states may consider its implementation on existing or proposed facilities. The objective of this report is to develop a methodology whereby an agency may identify and screen likely candidate locations for this implementation and assess the relative desirability of alternate tolling strategies. This objective is accomplished in two steps. The first step is economic assessment of a candidate location. This step is facilitated by a typology which organizes the many complex tolling issues and methods of operation, and by a route share model which estimates facility traffic shares and revenues. The second step involves quantitative as well as qualitative evaluation of benefits and costs associated with toll financing. The objective of this procedure is the development of a B/C ratio that will facilitate comparison and choice among candidate toll facilities.

This methodology is not an alternative to the more traditional, detailed feasibility study. Such studies of potential toll roads done by consultants for toll authorities and financial institutions are intended to satisfy the extensive requirements for bonding. Rather, the methodology developed in this study is one level removed, with preliminary assessment being the primary objective. (See figure 1.)

## OVERVIEW

To organize tolling issues in a systematic manner for analysis, and to document the status of toll financing across the nation, a typology is developed. This typology provides a useful approach for organizing and presenting toll financing concepts. A comprehensive survey of toll operators across the United States is presented, providing documentation of toll practices as organized by the typology. The status of current toll operations in Texas is analyzed within the context presented in the typology.

Beyond the use of the typology to determine type of facility and method for toll operation, is economic assessment of a candidate location. This assessment is addressed in Chapter 3. A revenue generation and route-share model is developed to aid the assessment. This model is of the logit form and requires certain site specific data for input; however, it does not require extensive data collection and preparation so as to make prohibitive its use in considering a sufficient number of candidate sites. A sensitivity analysis was performed using secondary data for two automobile user groups (work trips and non-work trips). The next section of the report develops required levels of funding (revenue/expenditure or R/E ratios) for the methods (cells) of operation described in the typology. In this section, the required R/E ratio is introduced as a concept that would facilitate screening of a candidate location. Within this chapter, components of revenues and expenditures for toll operations are identified. Values for these components are documented through a survey of toll facility operators. Finally, required R/E ratios are presented for a number of possible toll operating schemes. Candidate locations that fail to meet these criteria would be eliminated from further consideration, leaving only economically feasible projects for consideration.

The final section of the report presents guidelines for development of benefit to cost (B/C) ratios. B/C ratios can be developed for each of the candidate corridors in question. This ratio depends not only on site specific characteristics but on the objective of the toll financing, the type of facility (whether new or existing), the involvement and attitudes of the business and political community, and the conditions of the existing transportation network. There are many components to consider for both the benefits and the costs. This chapter outlines these components and provides the decision maker with guidelines for assessing a benefit-cost ratio to facilitate comparison of the candidate sites. In addition, the benefits and costs associated with various pricing strategies are analyzed. The route-share model is used to predict the effects of such strategies. Finally, guidelines are presented to show that the benefit/cost ratios can be compared to rank candidate locations for the implementation of toll facilities.

## TOLL ROADS CANDIDATE IDENTIFICATION PROCESS

ESTIMATE REVENUES
(ROUTE-SHARE MODEL - CHAPTER3)

ESTIMATE EXPENDITURES
(R/E ANALYSIS - CHAPTER 4)

IDENTIFY POSSIBLE TOLLING MECHANISM(S)
(TYPOLOGY - CHAPTER 2)

SCREEN INFEASIBLE CANDIDATE LOCATIONS
(R/E METHOD - CHAPTER 4)

EVALUATE BENEFITS AND COSTS
ASSOCIATED WITH EACH CANDIDATE
(B/C ANALYSIS - CHAPTER 5)

RANK FEASIBLE CANDIDATE LOCATIONS
ACCORDING TO B/C RATIO

PERFORM DETAILED FEASIBILITY STUDY
ON MOST PROMISING CANDIDATES

IMPLEMENT TOLL FINANCING AT
MOST VIABLE LOCATIONS

FIGURE 1

# CHAPTER 2 - TYPOLOGY FOR TOLL FINANCING

## INTRODUCTION

The discussion of issues in the preceding chapter reveals a multitude of complex considerations in assessing the desirability of tolling as a viable financing mechanism. This is further complicated by the existence of a confusing array of tolling concepts, or approaches to implementing and operating a toll facility. The principal objective of this chapter is to present an operational typology of tolling concepts in order to provide a framework for assessing a variety of concepts and examination of related policy issues in a systematic manner.

A second objective is to document and characterize existing toll operations in the United States. This was accomplished through a survey of operators, the results of which are presented with the above typology. Note that the scope of this study is limited to toll collection for the principal purpose of road financing, therefore, tolls on urban bridges and tunnels are excluded.

The dimensions of the typology and their corresponding levels, presented in the next section, are examined by investigating the cells of the typology and potential inconsistencies. The results of the survey of operating agencies are discussed, highlighting cells of the typology which correspond to existing and proposed tolling concepts (6).

In addition, the intention is to show the typology's usefulness as a classification tool by its application to the Texas case. Issues surrounding the present and increasing use of toll financing in the state are identified by the typology, and promising institutionally feasible tolling schemes for Texas are presented. The typology is utilized to analyze tolling on a statewide basis in the section entitled "Application to the Texas Context".

The typology also helps identify tolling approaches that may not currently be in use but may nevertheless be worthy of further consideration, as discussed in the concluding section.

## TYPOLOGY

The typology consists of three dimensions of operating characteristics, with dimensions comprised of a number of mutually exclusive levels. Each combination of possible facility operating characteristics defines a "cell", which represents a particular method of toll road operation. Of the total number of possibilities, many of the cells are found to be internally inconsistent, while others are not found in current practice. However, the typology allows us to highlight some tolling concepts which, while not found in current practice, seem to exhibit good potential for applicability in a variety of contexts.

Those characteristics shared by all facilities have been omitted from the typology. For example, since all toll facilities, with the exception of those contributing all revenues to a state's general budget, fund administration and toll collection with gate receipts, this common attribute is not listed as a level within the third dimension of the typology. The dimensions and levels of the typology have been identified as the following:

Dimension 1 is road status when tolls were introduced and contains three levels:

1.1 Placement of tolls at a new facility
1.2 Tolls placed on an existing facility with payback of original financing
1.3 Tolling on an existing facility with no payback of original financing

Dimension 2 captures the administrative arrangement for the flow and use of toll revenues from a given facility, coupled with the contribution of these revenues to the facility's overall financing. This dimension also has three levels:

2.1 All revenues contribute to a general budget
2.2 The facility is completely self supporting
2.3 The facility requires or is provided with some subsidy

Dimension 3 describes the functional use for revenues at the facility level:

3.1 No toll revenues support purchase or development of right of way (ROW) , construction, or maintenance
3.2 Tolls support ROW and construction only
3.3 Revenues support maintenance only
3.4 Gate receipts fund ROW, construction and maintenance

A fourth dimension can be used in conjunction with the typology's feasible cells to examine the compatibility of these cells with tolling objectives under consideration. This dimension consists of five levels which, however, are not mutually exclusive:

4.1 Road funding
4.2 Revenue generation
4.3 Perpetual funds
4.4 Congestion relief
4.5 Truck or authorized vehicle lane tolling

The above characteristics are summarized in Figure 2 and are explained in turn hereafter, along with a brief discussion of related issues and trends.

## DIMENSION 1: TYPE OF FACILITY

### LEVEL 1.1 NEW FACILITY

Most toll roads in the United States today were conceived, designed, and built as toll facilities. Federal law and many state regulations prohibit the implementation of tolls on any publicly constructed facility that was funded by taxes. Exceptions to these laws are occasionally granted, but by far the most common use of tolls for road financing has been on new facilities.

### LEVEL 1.2 EXISTING FACILITY WITH FUNDING REPAYMENT

In 1954, Connecticut repaid to the federal government the funds provided for construction of some of the present Connecticut Turnpike. After repayment was agreed upon, Connecticut was allowed to charge a toll. Similar cases include federal repayment by Maryland and Delaware for conversion of I-95 in 1960, by Indiana and New Jersey in 1979, and Maine in 1981 (1). At the present time, Congressional approval must be obtained before any repayment and conversion may be undertaken. Current trends indicate increasing acceptability of this procedure, and new legislation may be introduced which could facilitate future conversion.

### LEVEL 1.3 EXISTING FACILITY WITHOUT REPAYMENT OF FUNDING

Finally, and most controversially, tolls could be placed on an existing road. This might be perceived by the public as double taxation. This perception is reinforced by the knowledge that the road has already been paid for, even if tolls are charged only for maintenance and reconstruction.

# DIMENSIONS AND LEVELS FOR TOLL ROADS TYPOLOGY

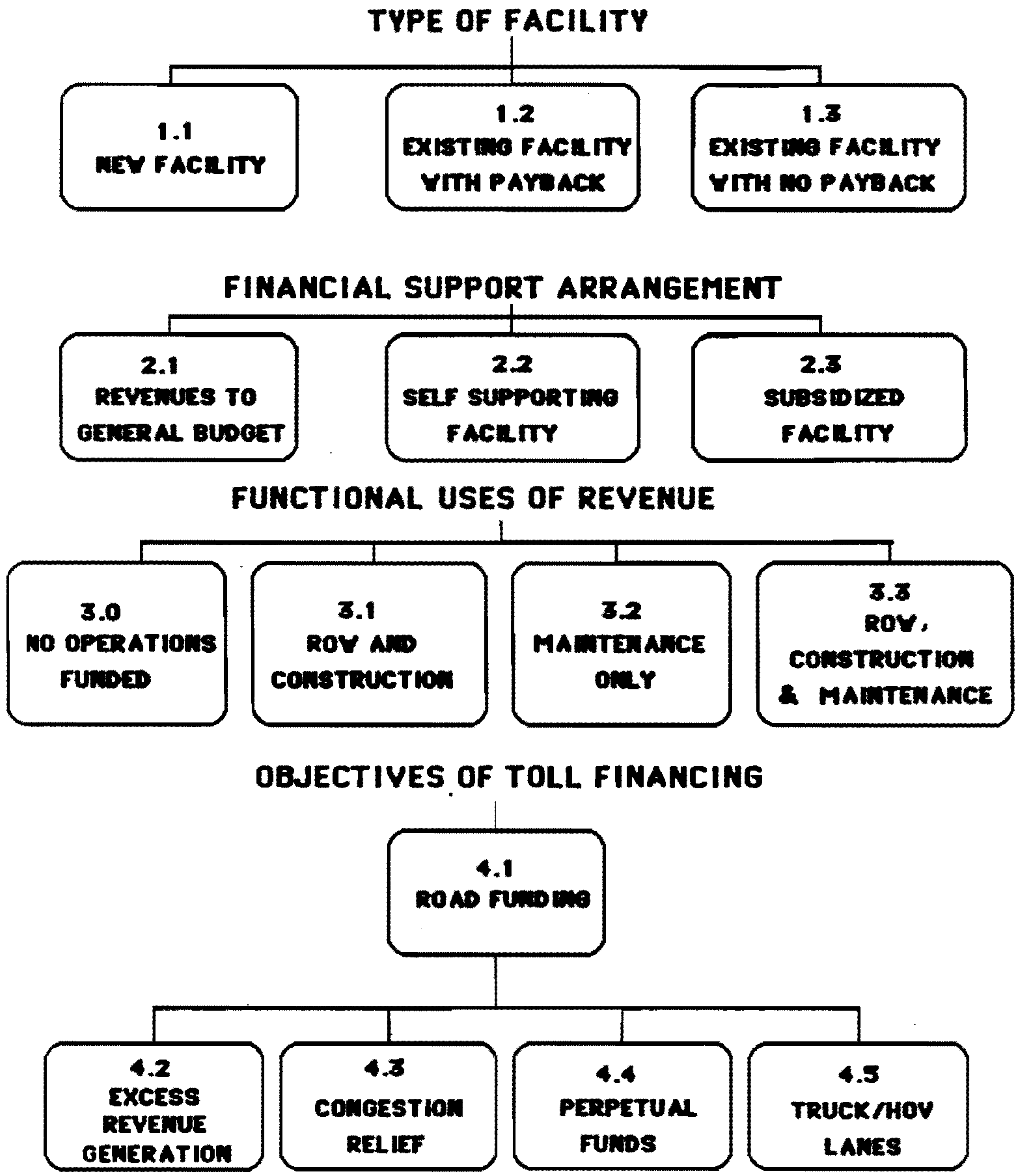



FIGURE 2

## DIMENSION 2: FINANCIAL SUPPORT ARRANGEMENT

### LEVEL 2.1 REVENUES FLOW DIRECTLY TO A GENERAL BUDGET

Revenues may be used on a general government (local, state, or federal) level either for specific projects or for the general budget. However, prevailing attitudes suggest a reluctance of the public to accept any cross-subsidy not closely related to transportation (1). Because revenues from the facility are channeled to a broader administrative level before eventually returning to support the facility, the typology will classify this type of operation as not directly funding any of its own financial requirements (see Dimension 3 Level 0).

### LEVEL 2.2 SELF SUPPORTING FACILITY

In the next two levels, priority for use of toll revenues is given to support and finance the toll generating facility itself. Levels 2.2 and 2.3 differ in terms of the relative contribution of these revenues to the toll facility's overall financing. Under level 2.2, the facility is self supporting and excess revenues may be generated. Further distinction can be made on the basis of the disposition of these excess funds. These might be limited to future spending on the generating facility only, or be used to support the operating toll authority's other projects, thereby remaining within the bounds of that agency's budget. Other restrictions may stipulate that excess revenues be spent on roads in the immediate geographic or administrative area (e.g. the Texas Turnpike Authority). Broader uses would allow the extra revenue to go into a general state fund, a local level roads fund, or the state highway trust fund.

### LEVEL 2.3 SUBSIDIZED FACILITY

When a toll facility cannot fully support itself, some toll authorities have the flexibility of alternate support, such as through tax subsidy, whereby a facility's deficit may be met by allocating general fund revenues or the like. On the positive side, the support of a toll facility by a tax base assures bond investors of a secured return, thereby enhancing the bond rating and keeping interest payments lower. This funding would also allow for more income for maintenance and operations in the event of low gate receipts caused by unforeseen circumstances. However, this extra security may have a negative impact, particularly if the project's economic feasibility is dubious or otherwise poorly planned or managed.

## DIMENSION 3: FUNCTIONAL USES FOR REVENUES

### LEVEL 3.0 NO OPERATIONS DIRECTLY FUNDED

This level applies to those facilities that contribute all revenues to a general budget (level 2.1). Although the facility is ultimately funded by this budget, the indirectness of this scheme loses the identity of the source of these funds, with no special restrictions applying to their use beyond those that affect funds from any source. This level is therefore defined in the typology to provide a level within dimension 3 that is compatible with level 2.1.

### LEVEL 3.1 RIGHT OF WAY AND CONSTRUCTION COSTS ONLY

Expenses incurred in right of way acquisition and construction of a toll facility are usually funded through the sale of bonds, which in turn are repaid by toll revenue. The dedication of toll revenues to this purpose is encountered in one situation where maintenance is provided by another agency (Richmond Metropolitan Authority).

### LEVEL 3.2 MAINTENANCE COSTS ONLY

At some facilities, revenues are dedicated only to the maintenance and rehabilitation of the highway.

This characteristic is exemplified by authorities implementing tolls on existing facilities where ROW and construction have already been paid for such as by the City of Colorado Springs.

### LEVEL 3.3 ROW, CONSTRUCTION, AND MAINTENANCE COSTS

This level is provided to characterize the vast majority of facilities that toll for support of all operating expenses (ROW, construction, and maintenance). This level represents those agencies operating on existing facilities where repayment of original funding classifies them as providing financing for ROW and construction as well as those operating new facilities that fund their own maintenance.

## DIMENSION 4: PRIMARY OBJECTIVES OF TOLL FINANCING

Tolling can contribute to multiple objectives, though the relative importance of each may vary from one case to another. The following levels are typical objectives that could be addressed by tolling and as such are not mutually exclusive, unlike the previous dimensions. This is because this dimension is not intended for classification purposes as much as to provide a vehicle for examining the compatibility of these objectives with the various operating characteristics identified in this typology.

### LEVEL 4.1 ROAD FUNDING

Although various tolling objectives have promoted other types of facilities, such as bridges and tunnels, road funding is currently the primary objective exhibited by agencies collecting tolls for highway financing (see survey section).

### LEVEL 4.2 EXCESS REVENUE GENERATION

An objective of toll collection that has been considered for heavily used facilities is excess revenue production. High growth corridors and congested areas are both candidates for revenue tolling. A public acceptance issue might arise, however, as this objective goes beyond the user pay concept of tolling; in this case the users would be burdened with subsidizing other projects in addition to the cost of the tolled facility. However, in the absence of strong opposition, revenue tolling could provide a viable alternative to increasing taxes, particularly when the revenues are kept within jurisdictional areas.

### LEVEL 4.3 PERPETUAL FUNDING

Perpetual funds are savings accounts that are deposited from toll revenues during the bond life. Once the bonds are retired or the initial debt is payed off, the interest from the perpetual fund is spent for maintenance or reconstruction. Although this procedure would increase tolls, the assurance of good maintenance after tolls are lifted would be appealing to both users and highway departments that are finding it increasingly difficult to take over care of these facilities.

### LEVEL 4.4 CONGESTION RELIEF

Pricing objectives may also include congestion relief in urban areas. Tolls could be adjusted during the day to reflect the "true" cost imposed by drivers on the system, and provide incentives for drivers to change trip making habits. A system such as this has been tried in Singapore (7). There are other non-technical issues associated with the implementation of congestion tolls, such as the debate on income redistribution, whereby high income individuals receive a greater benefit from congestion pricing than do low income people. The travel choices available to the user when faced with congestion tolls include changing the time, destination, route, or frequency of the trip, as well as making the same trip and paying the toll (8). Any of these choices improves the situation of the facility; the latter by increasing revenues, and the others by increasing the level of service.

## LEVEL 4.5 TRUCK OR AUTHORIZED VEHICLE LANE TOLLING

In some states, trucks are already assigned to specific lanes or are prohibited from using certain facilities. Accommodating increasing traffic of larger and heavier trucks can be facilitated by constructing new turnpikes for truck use or by designating certain new or existing lanes as truck lanes and requiring only trucks to pay a substantial toll for the use of these facilities. Depending on the details of its implementation and perceived equity, this concept could receive opposition from the trucking industry, or actually be welcomed by many truckers who would prefer paying for premium, well maintained, and safe roads.

Authorized vehicle lanes (AVL's), including high occupancy vehicle lanes (HOV lanes), provide another example of restricted lane use. It has been proposed that the excess capacity of some of these lanes could be utilized by toll paying automobiles or trucks, thereby generating significant revenue and still allowing for a sufficiently high level of service. The basic concept consists of operating only the AVL as a toll facility on a "free" roadway or treating the AVL separately as another facility if the main lanes are tolled and then implementing a pricing scheme that would charge different rates to various user categories.

## FORMULATION OF TYPOLOGY CELLS

Dimension 4 will subsequently be used to examine the compatibility of the typology's feasible cells and various levels with the objectives defining levels 4.2 through 4.5. The total number of cells that can be formed is equal to the product of the respective numbers of levels within each of the first three dimensions, or 36. This number is further reduced by eliminating cells which are conceptually inconsistent.

## ELIMINATION OF INCONSISTENT CELLS

Of the 36 cells, many can be shown to be internally inconsistent. The following cell inconsistencies have been identified: (See Figure 3 for identification of all 36 cells and for cells eliminated by inconsistency.)

1) If all revenue is channelled into a general budget (2.1), no funds are directly used for support of facility ROW and construction (3.1), maintenance (3.2), or both (3.3).

2) The combination of self supporting facility (2.2) and no operations supported by tolls (3.0) is inconsistent.

3) New (1.1) self supporting (2.2) facilities must fund ROW, construction, and maintenance (3.3).

4) Existing facilities (1.3) do not provide funds for ROW and construction (3.1) or all operations(3.3).

5) Existing repay facilities (1.2) provide support for ROW and construction (3.1) or (3.3) in the form of repayment.

6) New facilities (1.1) will partially fund ROW and construction (3.1), maintenance (3.2), or all operations (3.3), unless all revenues go into the state's general fund.

7) Placing tolls on an existing facility with no payback (1.3), and where none of the toll revenues go directly to road operations (3.0) is politically infeasible. This is just revenue generation.

8) Finally, tolls placed on existing facilities with payback (1.2) is inconsistent with tolls being spent only to repay ROW and construction costs (3.1).Elimination of inconsistent cells together with the omission of dimension 4 (since road funding is the only current pricing objective) produces a final typology consisting of 9 cells. (See Figure 3.)

# TYPOLOGY FOR TOLL ROADS FINANCING

**ELIMINATION OF INCONSISTENCIES**
**AND**
**IDENTIFICATION OF CELLS**

(LETTERS REPRESENT FACILITY OPERATORS - SEE APPENDIX A)

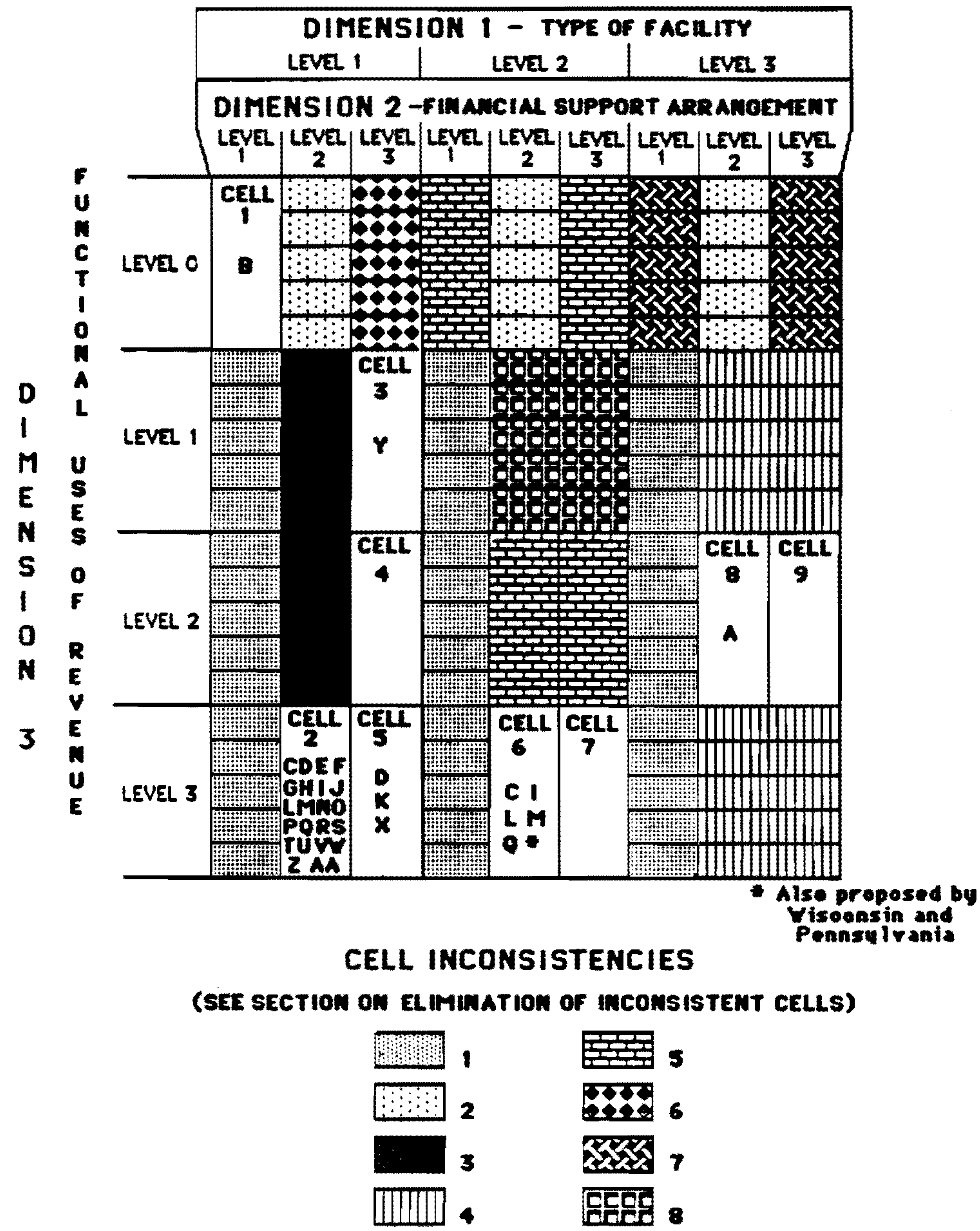



FIGURE 3

## SURVEY

To substantiate the typology's usefulness as a classification tool and to document current toll operations, a survey of toll operators was conducted. The survey aided in determining 1) the relative prevalence of the various cells among current toll operations, 2) cells not currently represented, and 3) related issues and trends. The survey procedure is described next, followed by a discussion of the results.

### PROCEDURE

A questionnaire was sent to all toll road authorities in the United States that were on the 1985 IBTTA membership. This survey was followed by phone calls to most operators including all those not members of IBTTA. The data were collected on an agency basis, and represented 27 major toll road operators. These authorities operate sixty-two toll roads with two more under construction. Although other toll agencies exist, they either operate only bridges, tunnels, short road segments connected to bridges or tunnels, or seasonal roads or were not identified in the search. Due to the different operating characteristics of bridges and tunnels, and the above stated scope of the present study, they were not included in the data base. Future research could produce an effective typology for study of the facilities excluded from this study.

### DISCUSSION:

The survey results led to the grouping of the 27 agencies into six of the nine cells of the typology. Cells are numbered in order of appearance in the dimensions and levels of the typology and descriptions of the cells' characteristics are as follows:

1 - Cell 1 is represented by one agency and is characterized by collecting tolls on a new facility (level 1.1) with all revenues going to the state's general fund (level 2.1). The facility is wholly supported by an allotment from this fund (level 3.0).

2 - Cell 2 is by far the best represented cell with 22 of the 27 agencies. The cell's characteristics are appealing to user-pay advocates since it involves the operation of new facilities (level 1.1), which are self supporting (level 2.2), and which pay for ROW and construction as well as maintenance (level 3.3).

3 - Cell 3 is represented by one toll road operator. This method of operation on a new facility (level 1.1) includes two forms of subsidy. First, maintenance is provided by another agency (level 3.1), and second, support is available in the event of inadequate gate receipts (level 2.3).

4 - Cell 4 is currently unrepresented by toll road agencies. It characterizes new facilities (level 1.1) operating with subsidies (level 2.3) where only maintenance is funded by revenues (level 3.2). It is unlikely that this cell will be very useful, since new facilities are expected to recover at least some of the ROW and construction costs.

5 - Cell 5 is represented by 3 toll agencies and is similar to cell 2 (level 1.1) in that all operating expenses may receive funds from toll revenues (level 3.3). However, tax or other subsidies make up possible operating deficits (level 2.3).

6 - Cell 6 is represented by 5 agencies. Pennsylvania and Wisconsin are also proposing such facilities. This cell is characterized by facilities that are completely self supporting (level 2.2), (level 3.3) and that have been converted from free facilities by repayment of original financing (level 1.2).

7 - Cell 7 is not represented at this date. It characterizes existing facilities tolled with payback of original funding (level 1.2), subsidized for operations (level 2.3), and using revenues to fund the repayment and maintenance (level 3.3). This cell could become more prevalent if subsidy requirements for operation are not extensive.

8 - Cell 8 is represented by one agency. This cell is characterized by the use of tolls only for

maintenance (level 3.2). The operation can be labeled self sufficient (level 2.2) because the road was constructed before tolls were introduced (level 1.3). This cell could become better represented in the future as less tax revenues are being made available for road funding.

9 - Cell 9 is not represented by any toll road authority. It characterizes tolls placed on existing facilities (level 1.3) where subsidy is required (level 2.3 and maintenance is at least partially funded by tolls (level 3.2). This cell could become represented in the future by authorities having problems with support of maintenance on heavily travelled roads.

## APPLICATION TO THE TEXAS CONTEXT (9)

The typology was used to examine existing and proposed toll facilities in Texas. The Texas Turnpike Authority (TTA), a state agency, was created to "build toll traffic facilities in areas where need and feasibility were present, but public tax funds for highway construction were not" (10). The Harris County Toll Road Authority (HCTRA) was created by the Harris County (Houston) Commissioners Court after a referendum was approved in 1983 by voters. The vote authorized creation of the HCTRA and the issue of up to $900 million in general obligation/revenue bonds for the purpose of constructing two county toll roads.

### THE TEXAS TURNPIKE AUTHORITY

The agency was created by the Texas legislature in 1953 to construct, maintain, and operate toll financed turnpikes and bridges within the state of Texas and to issue turnpike revenue bonds redeemed solely from revenues generated by these facilities. Excess revenues are applied toward the early retirement of bond debt. The credit of the state is not pledged to support the projects of the TTA, and the agency is the only toll authority in the U.S. currently using revenue bonds as its sole source of income (2). Hence, its Moody bond rating is Baa, which causes the agency to pay an interest rate 1.25 percent higher than that of AAA bonds. Its board of directors consists of 12 appointees which includes the three members of the State Department of Highways and Public Transportation (SDHPT) Commission. In addition, the SDHPT must approve all TTA projects (11).

Within the first dimension of the typology, type of facility, all roads tolled by the TTA are new (Dimension 1, Level 1) and are financed by revenue bonds. The authority operates, by law, only self supporting facilities (Dimension 2, Level 2). No outside funding is permitted; however, legislation has been proposed that would allow tax support within a limited geographical region (county). With this change, the TTA would then become classified under level 3 of dimension 2 (subsidized facilities). All operating expenses including right of way purchase and development, construction, and maintenance (Dimension 3, Level 3) are provided through gate receipts. Finally, the objectives of the TTA for their toll facilities are road funding (Dimension 4, Level 1) and congestion relief (Dimension 4, Level 3).

In 1957, the TTA opened the Dallas-Fort Worth Turnpike, a 30 mile traffic thoroughfare linking downtown Dallas to Fort Worth. Each end of the turnpike connected with Interstate 20, and the facility also connected with other major arteries in the area. Construction was completed in 23 months at a cost of $58,500,000.

In 1968, the TTA opened the Dallas North Tollway, a 9.8 mile section, extending from downtown to Interstate 635 North. Completion took 28 months and cost $33,650,000.

Although both the Turnpike and the Tollway were built and operated by the TTA, they were separate projects, with sharing of funds prohibited by state law. Both facilities were financed by the sale of revenue bonds and were planned to revert to the free highway system upon retirement of debt.

One amendment to the original bill creating the TTA allows a one time pooling of projects by the TTA within the same county. This permits a financially profitable project to subsidize a less feasible one, and equity problems are reduced by restricting the pooling to the smaller geographical area. Another amendment to the bill allowed up to one million dollars of excess revenues from the TTA's first project, the

DFW Turnpike, to be used to create a feasibility study fund. This fund is used to investigate alternative sites for the implementation of a new toll road, with the money being replaced by the new project's revenues.

In 1977, the bonds on the Turnpike were retired, and on December 31, the tolls were removed. The Dallas North Tollway remains a toll facility and is currently being extended to include an additional 17.1 miles that will serve to relieve traffic congestion in northern Dallas County. An existing roadway in the proposed path of the extension would have to be removed, so construction has begun on free access lanes parallel to the Tollway to be consistent with state law prescribing that free access facilities must remain free.

### THE HARRIS COUNTY TOLL ROAD AUTHORITY

The HCTRA does not currently operate any toll road facilities; however, it is constructing the two new roads (Dimension 1, Level 1) mandated in the aforementioned referendum: the Hardy toll road, and the West Belt toll road. These facilities are being constructed on right of way presently supporting free roads. Because state law prohibits the conversion of free roads to toll, the HCTRA is obligated to maintain free access along these routes. This will be accomplished by reconstruction of old Hardy Road parallel to the toll facility. On the West Belt section, the Texas State Department of Highways and Public Transportation is constructing free access roads. The major difference between the TTA and HCTRA can be identified in 2 of the typology. In the event of revenue shortfall, HCTRA's facilities may be subsidized by county taxes (Dimension 2, Level 3). Dimension 3, functional uses of revenue, characterizes all expenses at the facility which are supported by the agency (Dimension 3, Level 3). Finally, the objective of the toll financing can be characterized as road funding and congestion relief (Dimension 4, Levels 1 and 3).

## CONCLUSION

With regard to the Texas situation, there are four state laws that govern the role of toll financing of highways. Some of this legislation precludes the use of tolling in some of the methods defined by the levels of the typology, hence further reducing the number of presently feasible cells. The first two of these laws are contained in the bill creating the TTA. The TTA is not allowed to finance tolling by any method other than revenue funding or, in the same county, by cross subsidy from another project on a one time pooling basis. These laws prohibit the TTA from operating facilities characterized by levels 2.1, 2.3, 3.0, 3.1, 3.2, 4.2, or 4.4, and leave only cells 2 and 8 to be represented by the TTA (see figures 2 and 3). Another law prohibits the conversion of free state roads to toll, thereby excluding any combination with levels 1.2 or 1.3, and limiting the TTA to cell 2 only under current legislation. The final law examined permits the creation of local toll authorities within counties along the Texas gulf coast. This bill permitted the formation of the HCTRA. Because the HCTRA is not subject to the restrictions of the TTA bill, the authority can operate facilities within cells 1, 2, 3, 4, or 5. Although these are the only schemes for operation of toll facilities within the state currently possible, proposed legislation could allow more progressive methods and possibly more widespread use of toll financing in the future.

The results of a survey of agencies operating toll roads in the United States indicated that methods used by the agencies could be grouped into 6 of the 9 cells identified in the typology. These methods differed by type of facility on which tolls were introduced, administrative level of financial support, and the functional use of revenues. Cell 2 of the typology is represented by 22 of the nation's 27 toll road operators identified in this study. This cell characterizes facilities built specifically as toll financed facilities, that are completely self supporting, and that utilize gate revenues to support operations, right of way and construction obligations, and maintenance and rehabilitation.

Some of the typology's cells identify promising methods for toll financing of highways and will probably generate some interest in the future. If tolling is undertaken on a large level, cell 1 would present a method for consolidating funds (level 2.1), thereby facilitating the administration of operations. Cells 6 through 9 perhaps represent the methods for operations that exhibit the most promise. However, new legislation would be required as all of these cells represent conversion of existing facilities to tolling (level 1.2 for cells 6 and 7, level 1.3 for cells 8 and 9). Such legislative changes seem to be favored by current attitudes.

When the nine presently feasible cells are combined with the five primary objectives for tolling comprising dimension 4, a number of new possibilities emerge. However, some inconsistencies reduce the number of possible schemes. The following inconsistencies involving the dimension 4 combinations have been identified:

a) The objective of revenue generation (level 4.2) is inconsistent with operating a subsidized facility (cells 3, 4, 5, 7, and 9)

b) The objective of perpetual funding (level 4.4) is inconsistent with all revenues going to a general fund (cell 1), operation of a subsidized facility (cells 3,4,5,7, and 9), and exclusive use of funds for ROW and construction (cell 3).

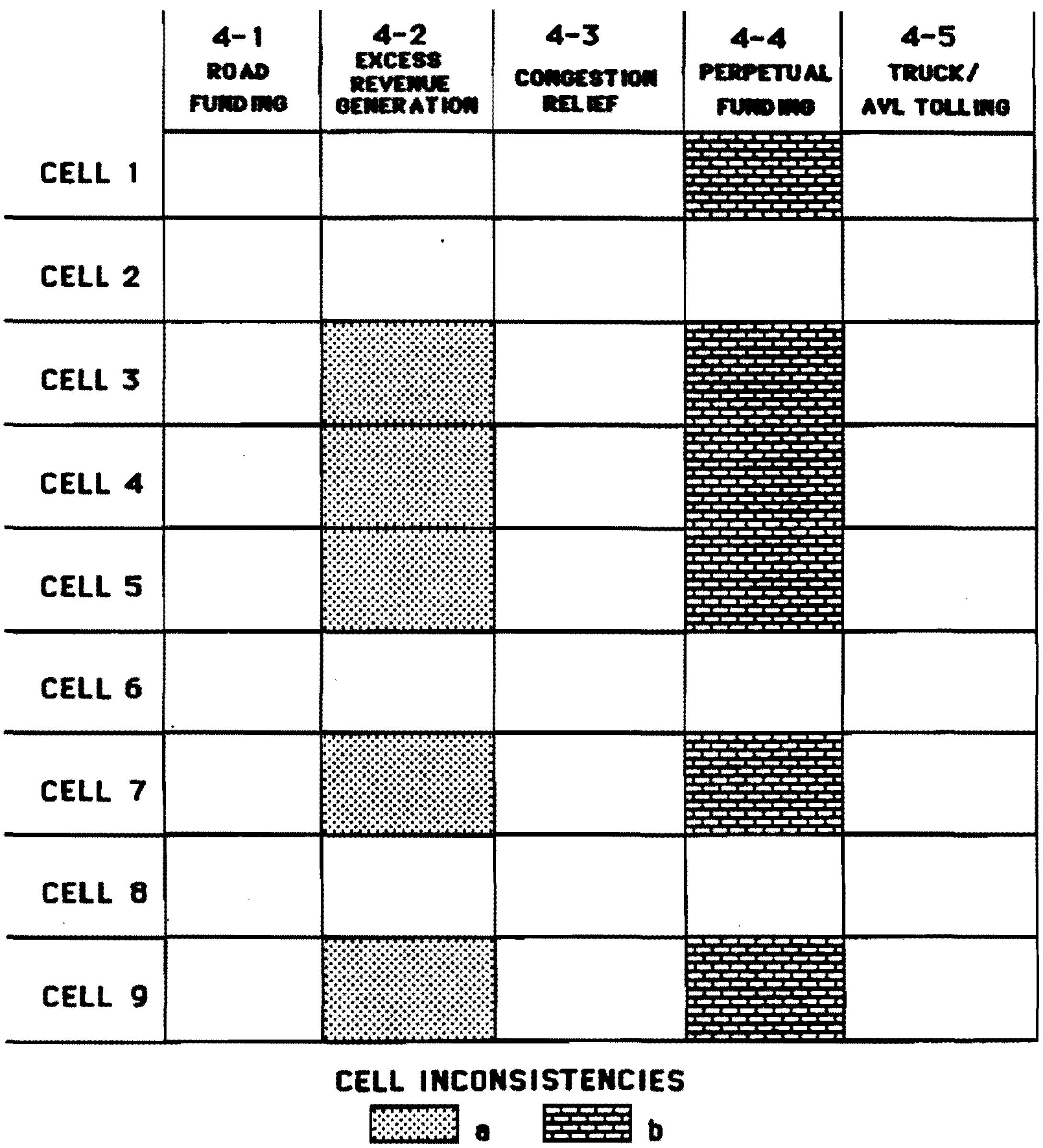
These inconsistencies are illustrated in figure 4.

The typology provides an organizing framework for the discussion of legislative issues related to tolling. Subsidy, perpetual funding, truck tolling, revenue generation, congestion tolling, and especially repayment of original financing are some of the currently or potentially controversial issues that are of importance to transportation planners and decision makers.

The typology should be of particular interest to those agencies investigating the possibility of toll financing for their projects, in that it serves as a mechanism for identifying the various toll road financing and operating schemes, thereby providing a starting point and an essential input to the evaluation and decision-making process.

# TYPOLOGY FOR TOLL ROADS FINANCING

COMBINATIONS OF CELLS WITH TOLLING OBJECTIVES




(SEE CONCLUSION OF CHAPTER)

FIGURE 4

## CHAPTER 3 - TOLL REVENUE AND ROUTE SHARE MODEL

### INTRODUCTION

The second step beyond use of the typology to determine type of facility and method for toll operation is economic screening of candidate locations. To facilitate this type of screening, this chapter presents a revenue and route share model. The model estimates revenues and traffic shares for a candidate facility as well as for any competing routes identified by the analyst within a traffic network.

In later chapters, this model is used to provide input for study of a toll facility's economic impact. In the chapter on revenue to expenditure (R/E) analysis, the model predicts expected revenues for a given toll financing scenario. For benefit cost analysis, the model provides supporting information and insight into the potential effect of various pricing strategies on equity of pricing and traffic diversion.

In the following sections, the model is presented. First, the basis of the model is discussed along with data requirements and formulation. Next, model parameters are presented. Finally, limited sensitivity analysis is performed to show the effect of the various model inputs on revenues, traffic flows, and travel times.

### BASIS

The model is based on a stochastic user equilibrium formulation, where the travel times on the alternate routes are a function of the flows on the respective facilities, and the flows are in turn dependent on the relative travel times and costs which enter into the specification of a route choice model. The total number of users going from one origin to one destination is assumed to be fixed and known to the analyst. The route share model is a random utility maximization model of the logit form, where utility is defined as the negative of the generalized cost incurred by a user on a certain facility. The dependence of travel times on flows is captured using performance functions of the well known BPR type. The model solves for equilibrium flows using a simple procedure known as the "successive averages" algorithm (12). The logit model was chosen due to its well accepted use to predict user choice behavior. The general equation for the choice probability given by the logit model is:

$$P(J) = \frac{e^{U(J)}}{\text{SUM } e^{U(J)}}$$

where P(J) = probability of choosing alternative J
U(J) = the utility of choosing alternative J
SUM is the sum taken over all choice alternatives

### DATA REQUIREMENTS

In this section, data requirements are specified for the currently operational computer implementation of the model. The model requires the following data as input from the analyst:

#### GENERAL DESCRIPTORS OF PROBLEM CONTEXT

M = number of user groups

N = number of facilities

TOLL(I,J) = toll to user group I on facility

USERS(I) = total number of users in group I

CAP(J) = capacity of facility J in vph

SPEED(J) = free flow speed on facility J

DIST(J) = length of facility J

**ROUTE CHOICE MODEL PARAMETERS:**

VCOST(I) = average costs of vehicle operation per mile (also from secondary sources)

TVALUE(I) = value of travel time for user group I (from secondary sources)

CATCH(I,J) = miscellaneous costs incurred by user group I on facility J (this alternative-specific constant can be specified to calibrate the model for a particular location)

**PERFORMANCE FUNCTION PARAMETERS:**

ALPHA(J) = site specific v/c parameter

BETA(J) = site specific v/c parameter

These inputs are read by the program from a user specified file or other input device.

## FORMULATION

In this section, the model program algorithm is described.

1) The variables needed are dimensioned and data are read from a user specified data file. Some of the data are echoed for verification purposes.

2) Next, each free flow travel time [FFTIME(J)] is calculated as the distance [DIST(J)] divided by the free flow speed [SPEED(J)] for each facility.

3) The actual facility travel times [TTIME(J)] are initiated as the free flow travel times [FFTIME(J)], and, initially, the facility volumes [VOL(J)] are set to zero.

4) Next, the travel costs [COST(I,J)] to each user group for each facility are evaluated as the sum of the user group's value for travel time [TVALUE(I)] multiplied by the travel time on the facility [TTIME(J)], the toll to the user group on the facility [TOLL(I,J)], the operating costs per mile of the user [VCOST] multiplied by the length of the facility [DIST(J)], and the calibration parameter [CATCH(I,J)], which represents costs associated with aesthetics, reliability, or other site specific factors.

5) The probability that a user from group I will choose facility J, [PROB(I,J)], is evaluated by application of the logit model, where the probability [PROB(I,J)] is equal to the exponential of the negative cost to the user [EXP(-COST(I,J)] divided by the sum of the exponentials across all user groups:

$$[\text{SUM } e^{(-\text{COST } (I,J))}].$$

6) After this first iteration, the volumes for each facility are updated. The volumes for each facility [VOL(J)] are calculated as the sum over all user groups of the probability of a user choosing the facility [PROB(I,J)] multiplied by the total number of users in that user group [USERS(I)].

7) Convergence to the equilibrium flows is obtained using the method of successive averages, which is an iterative procedure whereby the volumes are updated, at each iteration, as follows. The new volume is equal to the sum of 1) the old volume and 2) the inverse of the iteration number multiplied by the difference between the old volume and the updated volume

$$\text{NEW VOL(J)} = \text{VOL(J)} + \frac{1}{\text{COUNT}} \times (\text{VOLN(J)}-\text{VOL(J)})$$

8) After the volumes are updated, the travel times for each facility [TTIME(J)] are calculated using the route performance functions, which estimate travel time as a function of the facility's volume to capacity ratio.

$$[\text{TTIME(J)}] = \text{FFTIME(J)} \times \{1 + \text{ALPHA(J)} \times \frac{\text{VOL(J)}^{\text{BETA(J)}}}{\text{CAP(J)}}\}$$

9) After each iteration, convergence is checked. If the volumes change by less than one vehicle per hour, the program is terminated and the following outputs are printed: the number of users from each group using each facility, the cost to each user, the revenue produced by each facility, and the travel time associated with each facility. (See Appendix B for program listing.)

## MODEL PARAMETERS

Some of the user specified inputs to the model may be obtained from secondary data. The next section illustrates the sensitivity of volumes and revenues to travel time values [TVALUE(I)]. In this section, a data input set is used that approximates conditions on the Dallas North Tollway (DNT). These data, however, are not intended to reproduce actual traffic flows or revenues of the DNT, but rather are intended to provide a realistic setting for illustrating the sensitivity of data input levels in a case similar to an actual urban toll facility.

### SECONDARY DATA

This section presents secondary data obtained in their search. These data, for user time and operating cost values, are obtained from published national studies of travel demand, and are used in the example application given in the next section. (See tables 1 and 2.)

## EXAMPLE DATA INPUTS

The following section presents site specific data for example implementation of the route share model. As noted in the previous section on data requirements, the following inputs are needed:

### TABLE 1 - VALUE OF TIME, BY TRIP PURPOSE

| YEAR (REF) | TRIP TYPE | TIME VALUE ($/HR.) | 1985 TIME VALUE ($/HR.) |
|---|---|---|---|
| 1975 (13) | WORK (MTS) MEDIUM TIME SAVINGS | 2.42 | 4.83 |
| | PERSONAL BUSINESS (MTS) | 1.12 | 2.24 |
| | RECREATIONAL (MTS) | 0.87 | 1.74 |
| | WORK (HTS) HIGH TIME SAVINGS | 4.06 | 8.11 |
| | PERSONAL BUSINESS (HTS) | 4.31 | 8.61 |
| | RECREATIONAL (HTS) | 2.24 | 4.77 |
| 1976 (14) | COMMUTER TOLL VS. NON-TOLL | 2.82 | 5.33 |
| 1979 (15) | WORK TRIP | 2.37 | 3.51 |
| | WORK TRIP | 2.36 | 3.49 |
| | WORK TRIP | 2.60 | 3.85 |
| 1981 (16) | MOTOR CARRIER | 26.00* | 30.68 |

* Obtained from an average cost of $0.52 per mile for driver time, and 50 mph average trip speed.

### TABLE 2 - VEHICLE OPERATING COSTS

| YEAR & REF. | VEHICLE TYPE | OPERATING COSTS ($/MILE) | 1985 OPERATING COSTS ($/MILE) |
|---|---|---|---|
| 1981 (16) | LARGE TRUCK | 0.66 | 0.78 |
| 1984 (17) | PASSENGER (AVG) | 0.28 | 0.29 |

| | |
|---|---|
| Facility data: | number of facilities<br>length<br>free flow speed<br>flow parameters alpha and beta<br>capacity |
| User group data: | number of user groups<br>time values (secondary)<br>operating costs (secondary)<br>number of users in each group |
| Other data: | toll pricing schedule<br>values for calibration parameter |

Table 3 presents inputs used for the example application. These parameters were developed to approximate conditions at the Dallas North Tollway for 1981. Several simplifying assumptions were made.

The number of alternate routes was chosen to be five, four are four lane arterials, and the other is an expressway. Another assumption placed a screenline at both ends of the toll way to simplify user choices. Only the trips that were made through the corridor were considered. This is a valid assumption as the routes represent a basically commuter corridor. Other assumptions included assigning 10 mile trip lengths on each route and estimating the travel time parameters for the four-lane arterials and the expressway (18). Also, only the out-of-pocket portion of vehicle operating costs (gas and oil) was included in trip cost.

## SENSITIVITY ANALYSIS

Evaluation of a number of candidate locations for toll financing prohibits extensive primary data collection. For this reason, use of secondary data is desired when practicable. Sensitivity analysis was performed on a peak, heavy direction traffic scenario, representing the Dallas North Tollway corridor. Results showed that traffic and revenues were not significantly sensitive to inputs for user values for travel time. (See Appendix C for data input and Figures 5 through 14 for graphical results.) However, the case data approximating conditions at the DNT are not suited for adequate sensitivity analysis of the route share model. Three characteristics of the data set disguise actual data sensitivities. First, the representation of user group 3 (less than 5 percent) restricts its impact on output, thereby producing a false impression of low sensitivity regardless of input. Second, all competing routes in the corridor have equal lengths. This characteristic prohibits identification of the true effects of distance-based costs parameters in the sensitivity analysis. The third limitation of the peak-hour data set is high traffic demand, which forces near capacity, and correspondingly insensitive conditions. To facilitate a more appropriate sensitivity analysis, some of the general descriptors of the data set were modified. For the aforementioned reasons, and to provide an example scenario for the analysis, the following changes were made:

1) For improvement of user group representation, user groups 1 and 2 were assigned 40% (each) and user group 3 was assigned the remaining 20% of the total demand volume.

2) The lengths of the facilities (in the data set) were changed to: Facility 1 — 7 miles (DNT)

Facility 2 — 12 miles
Facility 3 — 15 miles
Facility 4 — 8 miles
Facility 5 — 10 miles
Facility 6 — 12 miles

Note that the new length for the toll facility is shorter than the alternate facilities. Therefore, some users that choose the toll facility will trade off time savings for dollars (toll charged).

3) The total demand volume was changed to 15,000 vehicles per hour to prevent capacity conditions.

## TABLE 3 - EXAMPLE SITE DATA (19)

| | | | |
|---|---|---|---|
| FAC. 1: | DALLAS NORTH TOLLWAY | FACILITY 4: | HILLCREST ROAD |
| LENGTH: | 10 MILES | LENGTH: 1 | 0 MILES |
| SPEED: | 55 MPH | SPEED: | 40 MPH |
| ALPHA: | 1.1 | ALPHA: | 1.0 |
| BETA: | 6.9 | BETA: | 6.6 |
| CAPACITY: | 6000 VPH | CAPACITY: | 2400 VPH |
| FACILITY 2: | INWOOD ROAD | FACILITY 5: | MIDWAY ROAD |
| LENGTH: | 10 MILES | LENGTH: | 10 MILES |
| SPEED: | 40 MPH | SPEED: | 40 MPH |
| ALPHA: | 1.0 | ALPHA: | 1.0 |
| BETA: | 6.6 | BETA: | 6.6 |
| CAPACITY: | 2400 VPH | CAPACITY: | 2400 VPH |
| FACILITY 3: | PRESTON ROAD | FACILITY 6: | CENTRAL EXPRESSWAY |
| LENGTH: | 10 MILES | LENGTH: | 10 MILES |
| SPEED: | 40 MPH | SPEED: | 40 MPH |
| ALPHA: | 1.0 | ALPHA: | 1.1 |
| BETA: | 6.6 | BETA: | 6.9 |
| CAPACITY: | 2400 VPH | CAPACITY: | 8000 VPH |

| | |
|---|---|
| USER GROUP 1: | WORK TRIPS |
| TIME VALUE: | $5.00 PER HOUR |
| OPERATING COSTS: | $.06 PER MILE |
| NUMBER IN GROUP: | 14557 (PEAK HOUR HEAVY DIRECTION) |
| TOLL: | $.35 |
| CATCH PARAMETER: | 0.00 |
| USER GROUP 2: | NON WORK TRIPS |
| TIME VALUE: | $3.50 PER HOUR |
| OPERATING COSTS: | $.06 PER MILE |
| NUMBER IN GROUP: | 5328 (PEAK HOUR HEAVY DIRECTION) |
| TOLL: | $.35 |
| CATCH PARAMETER: | 0.00 |
| USER GROUP 3: | MOTOR CARRIERS |
| TIME VALUE: | $25.00 PER HOUR |
| OPERATING COSTS: | $.15 PER MILE |
| NUMBER IN GROUP: | 516 (PEAK HOUR HEAVY DIRECTION) |
| TOLL: | $.60 |
| CATCH PARAMETER: | 0.00 |

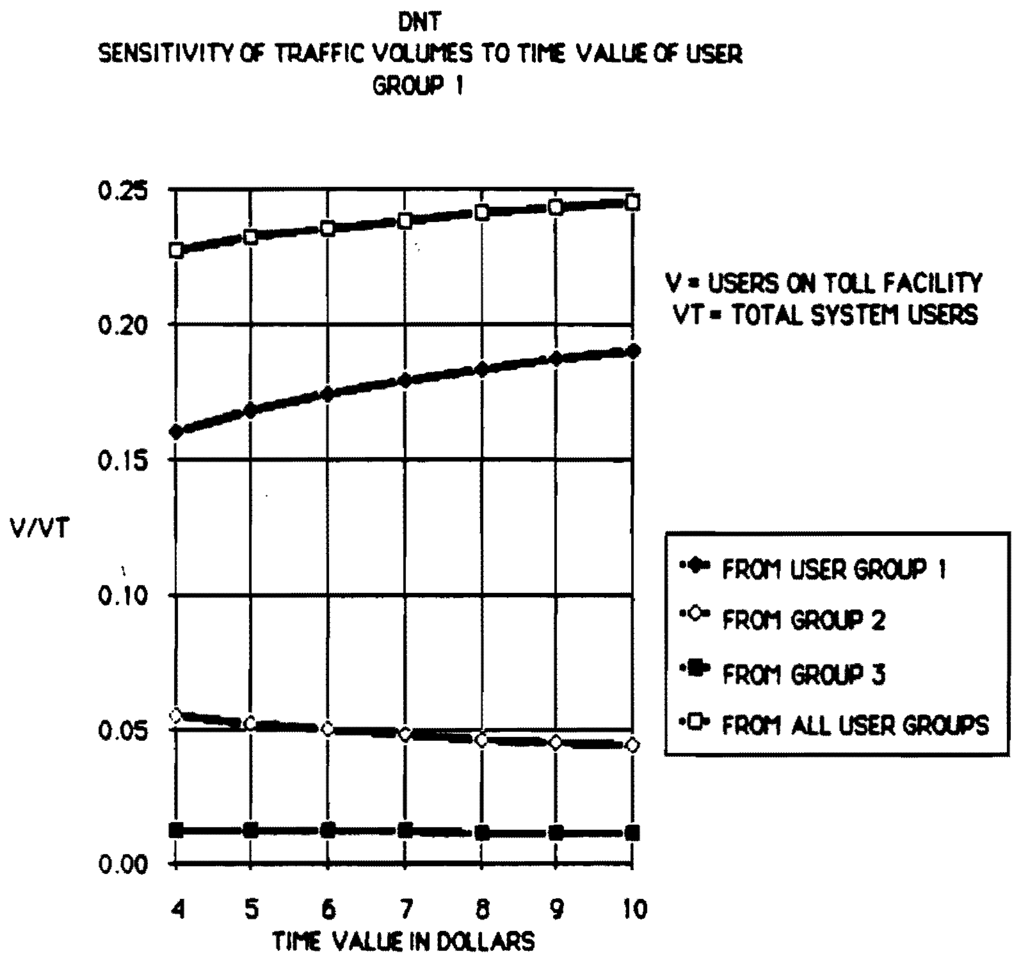

DNT
SENSITIVITY OF TRAFFIC VOLUMES TO TIME VALUE OF USER GROUP 1
0.25
0.20
0.15
0.10
0.05
0.00
V/VT
4
5
6
7
8
9
10
TIME VALUE IN DOLLARS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM USER GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 5

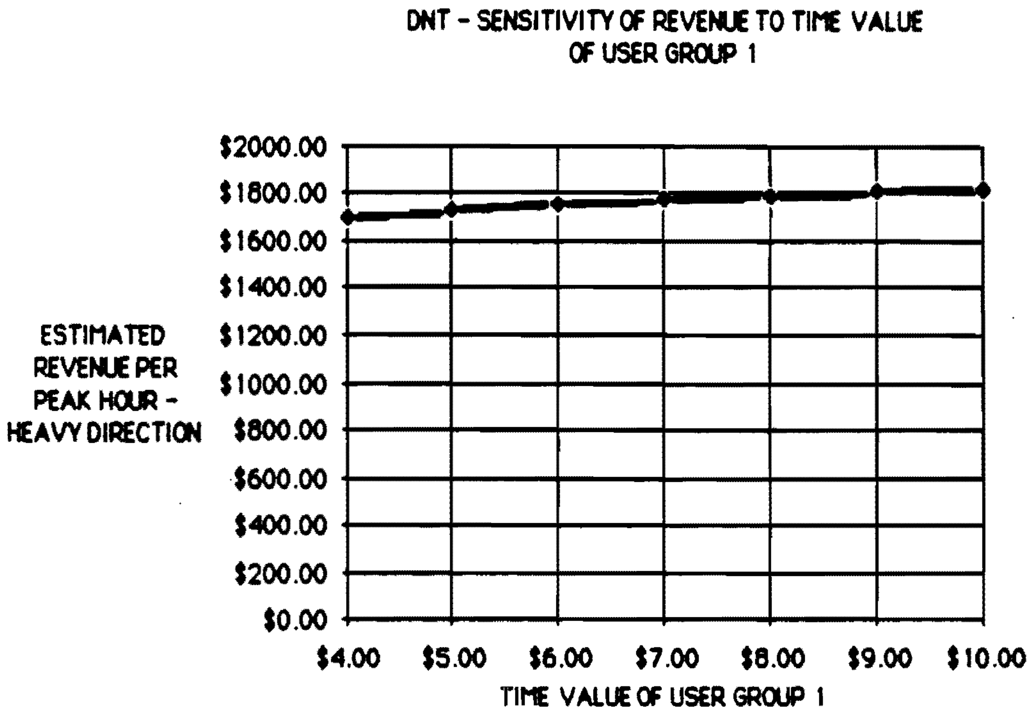

DNT - SENSITIVITY OF REVENUE TO TIME VALUE OF USER GROUP 1
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$2000.00
$1800.00
$1600.00
$1400.00
$1200.00
$1000.00
$800.00
$600.00
$400.00
$200.00
$0.00
$4.00
$5.00
$6.00
$7.00
$8.00
$9.00
$10.00
TIME VALUE OF USER GROUP 1

FIGURE 6

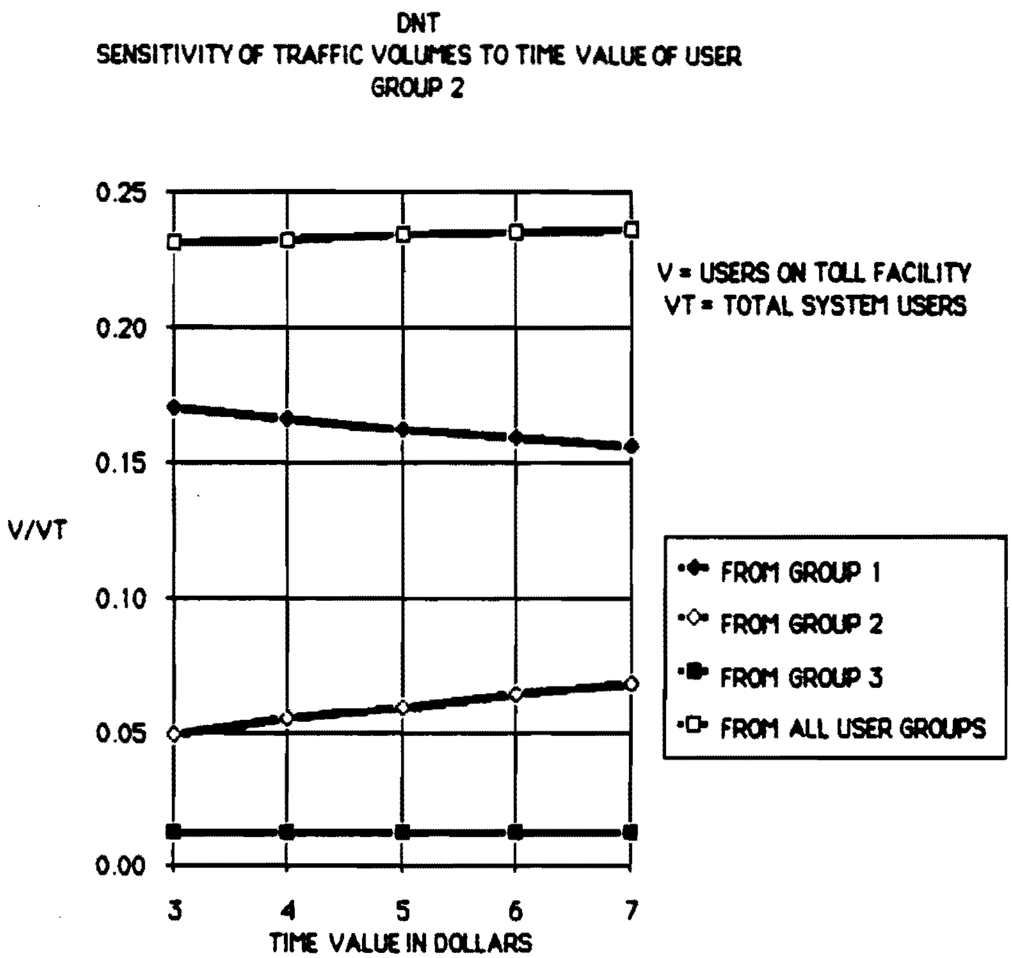

DNT
SENSITIVITY OF TRAFFIC VOLUMES TO TIME VALUE OF USER
GROUP 2
V/VT
0.25
0.20
0.15
0.10
0.05
0.00
3
4
5
6
7
TIME VALUE IN DOLLARS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 7

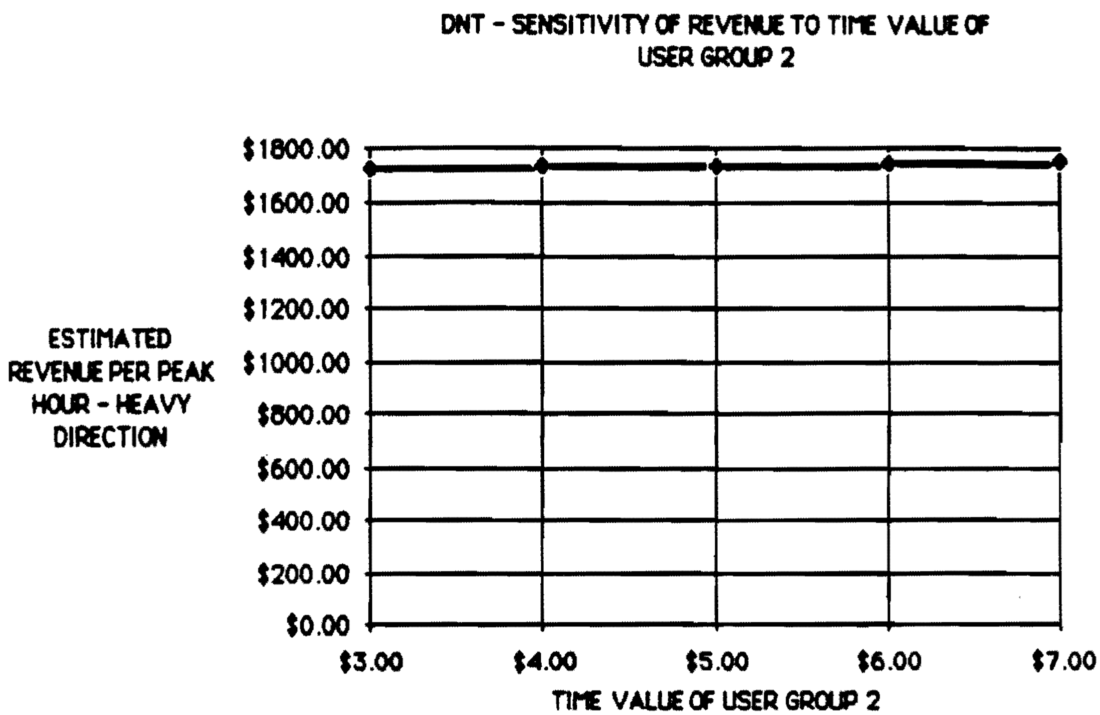

DNT - SENSITIVITY OF REVENUE TO TIME VALUE OF USER GROUP 2
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$1800.00
$1600.00
$1400.00
$1200.00
$1000.00
$800.00
$600.00
$400.00
$200.00
$0.00
$3.00
$4.00
$5.00
$6.00
$7.00
TIME VALUE OF USER GROUP 2

FIGURE 8

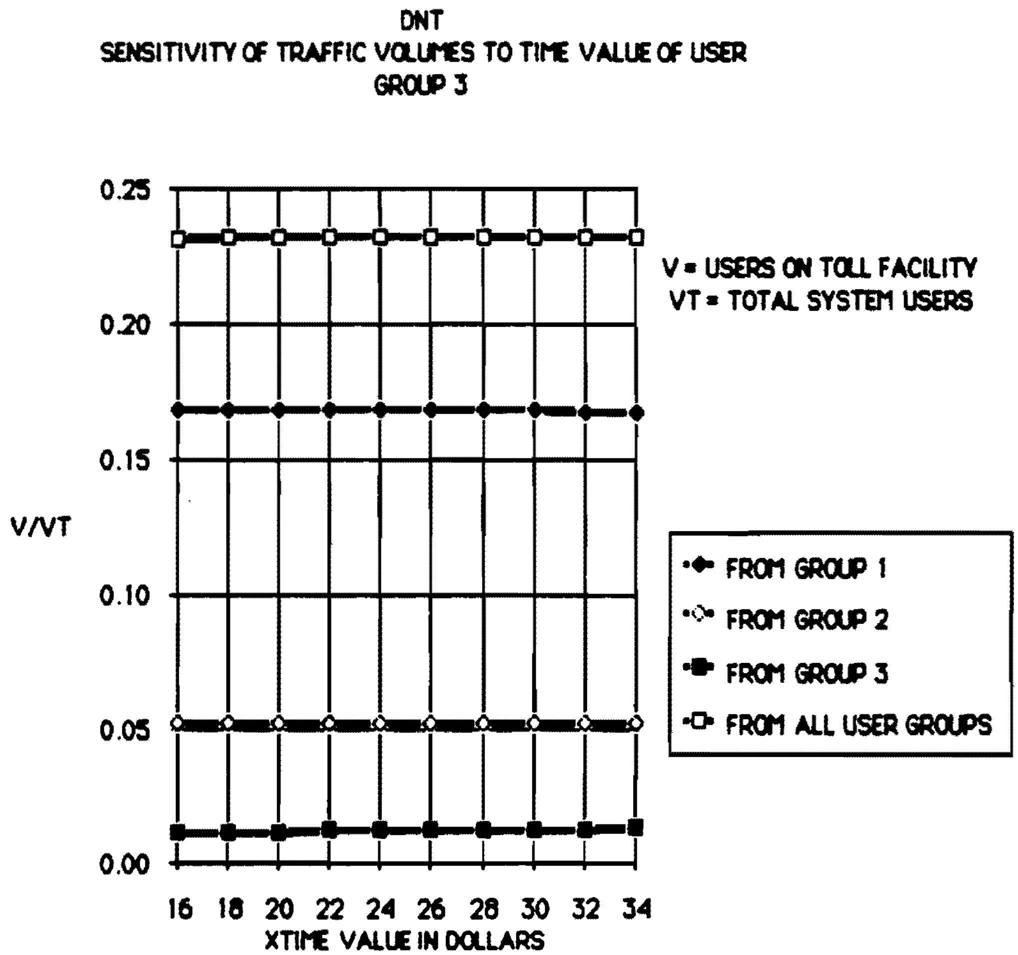

DNT
SENSITIVITY OF TRAFFIC VOLUMES TO TIME VALUE OF USER
GROUP 3
0.25
0.20
0.15
0.10
0.05
0.00
V/VT
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS
16 18 20 22 24 26 28 30 32 34
XTIME VALUE IN DOLLARS

FIGURE 9

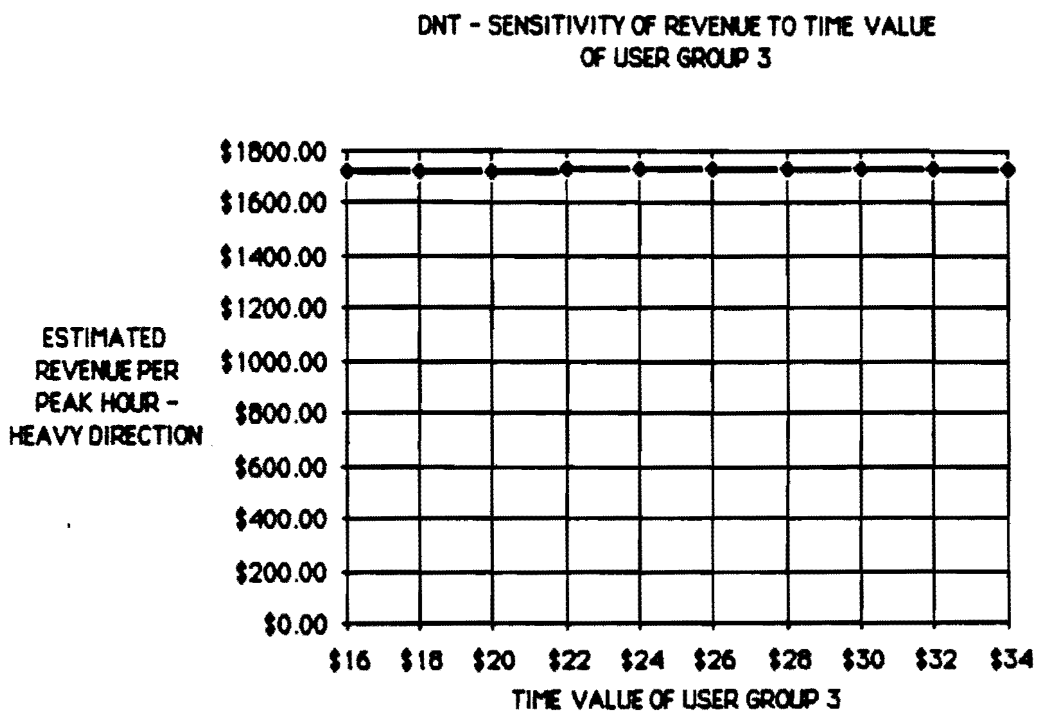

DNT - SENSITIVITY OF REVENUE TO TIME VALUE
OF USER GROUP 3
ESTIMATED
REVENUE PER
PEAK HOUR -
HEAVY DIRECTION
$1800.00
$1600.00
$1400.00
$1200.00
$1000.00
$800.00
$600.00
$400.00
$200.00
$0.00
$16
$18
$20
$22
$24
$26
$28
$30
$32
$34
TIME VALUE OF USER GROUP 3

FIGURE 10

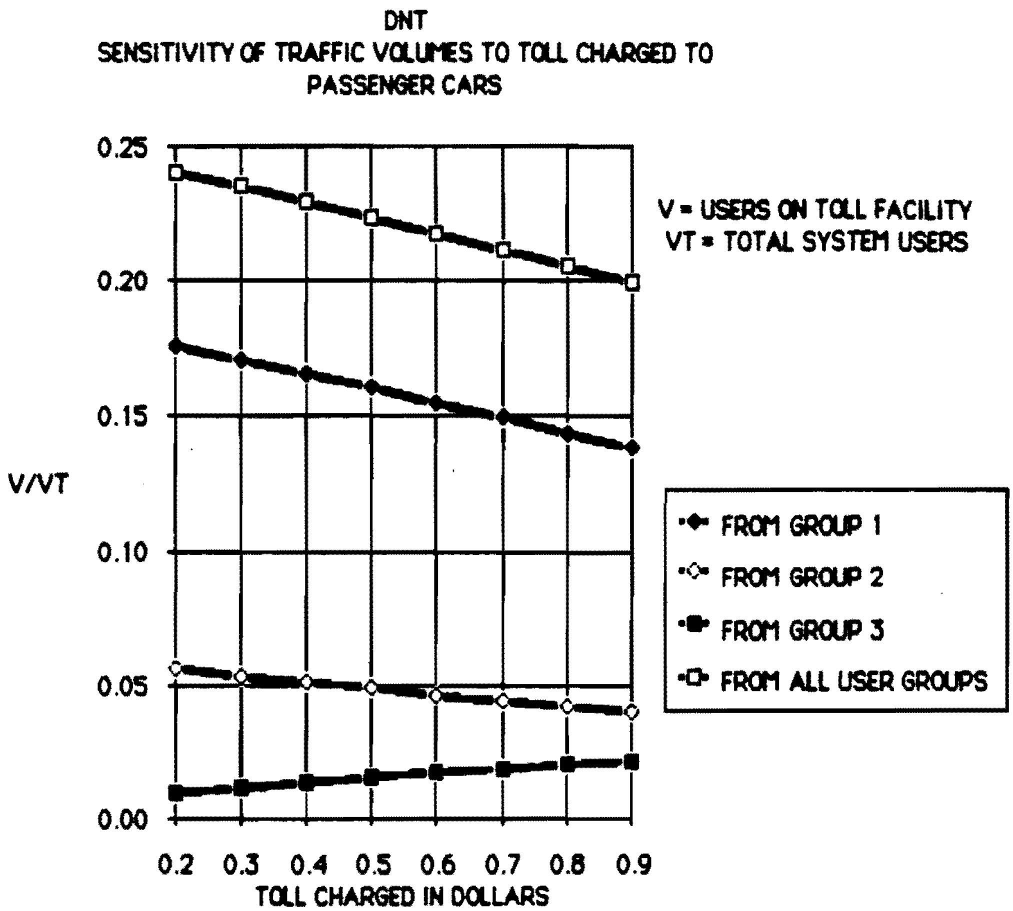

DNT
SENSITIVITY OF TRAFFIC VOLUMES TO TOLL CHARGED TO PASSENGER CARS
0.25
0.20
0.15
0.10
0.05
0.00
V/VT
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
TOLL CHARGED IN DOLLARS

FIGURE 11

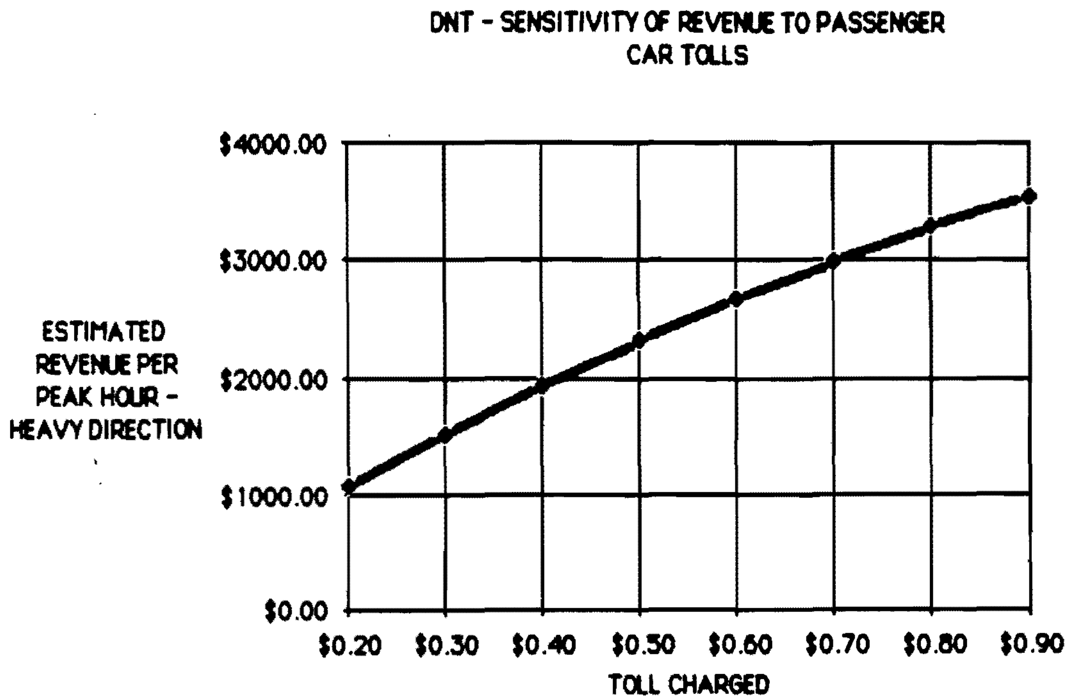

DNT - SENSITIVITY OF REVENUE TO PASSENGER CAR TOLLS
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$4000.00
$3000.00
$2000.00
$1000.00
$0.00
$0.20
$0.30
$0.40
$0.50
$0.60
$0.70
$0.80
$0.90
TOLL CHARGED

FIGURE 12

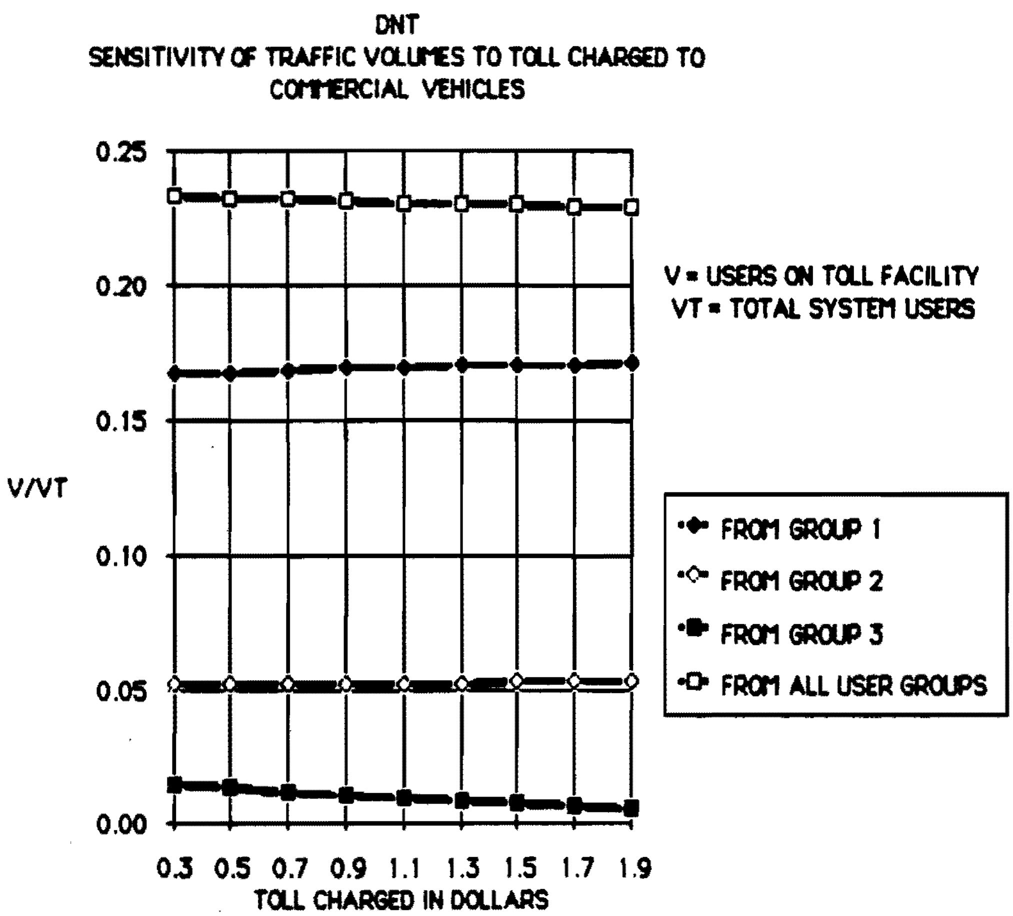

DNT
SENSITIVITY OF TRAFFIC VOLUMES TO TOLL CHARGED TO COMMERCIAL VEHICLES
0.25
0.20
0.15
0.10
0.05
0.00
V/VT
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS
0.3 0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9
TOLL CHARGED IN DOLLARS

FIGURE 13

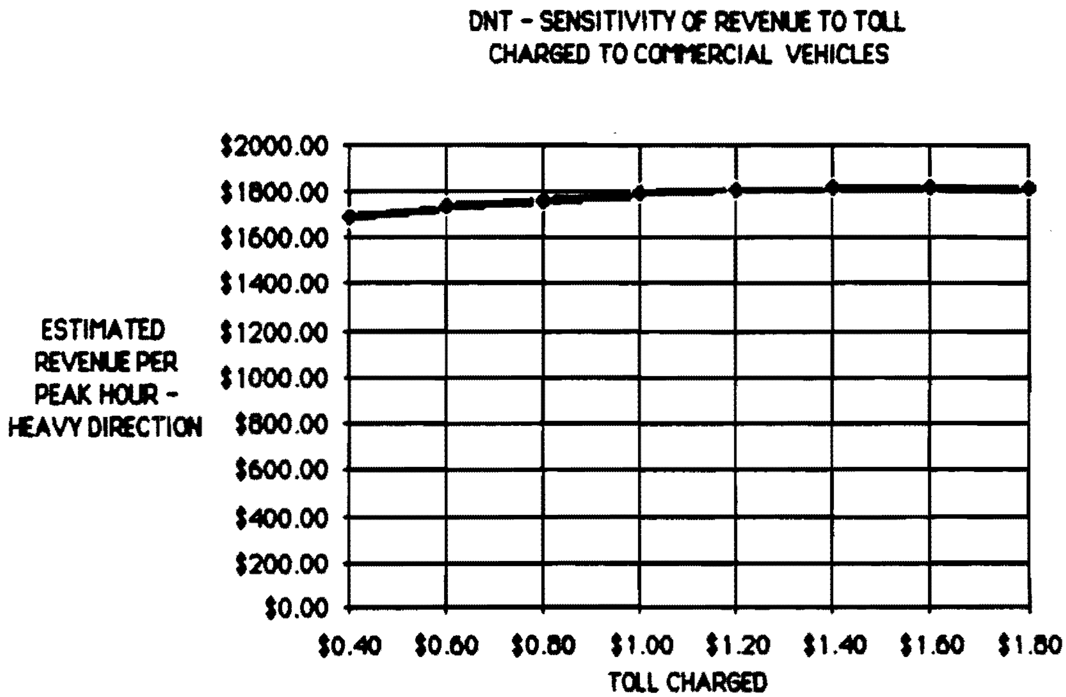

DNT - SENSITIVITY OF REVENUE TO TOLL CHARGED TO COMMERCIAL VEHICLES
$2000.00
$1800.00
$1600.00
$1400.00
$1200.00
$1000.00
$800.00
$600.00
$400.00
$200.00
$0.00
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$0.40
$0.60
$0.80
$1.00
$1.20
$1.40
$1.60
$1.80
TOLL CHARGED

FIGURE 14

The results of the sensitivity analysis for the example case are graphically summarized in Figures 15 through 28. There are two key features of the results.

As the time value of user group 3 (commercial vehicles) increases, the revenue predicted for the toll facility increases. This increase, which did not occur when passenger vehicle time value increased, is probably due to both the larger tolls assessed to motor carriers and to their higher values for travel time. Toll facilities have greater appeal to those groups with higher values of travel time (see Chapter 5). However, the increased revenue due to the larger volume of trucks may be offset by increased roadway maintenance costs.

The other key result of the sensitivity analysis is that, while the volume of users decreases on the toll facility with a corresponding increase in tolls, the effect on revenues is offset by the extra amount charged per user. There is an amount above which an increase in tolls would have a negative effect on revenues, but tolls that high would be inequitable and are not considered in the analysis.

## CONCLUSIONS

Application of the model to the tollway data provided some useful results. Revenues were estimated for the 1981 calendar year. Data similar to the peak hour heavy direction were input for other time periods and directions including peak, day, and night periods for both heavy and light (70 and 30 percent) directional traffic flows. Actual revenues for 1981 were just over 7 million dollars. Despite the major assumptions involved, the model was able to estimate the revenues to be 6.6 million dollars, slightly conservative, but within acceptable limits. Additional research is needed to show the effect of such assumptions for other facilities and years of operation. However, results are sufficiently robust for use in subsequent chapter's economic evaluations.

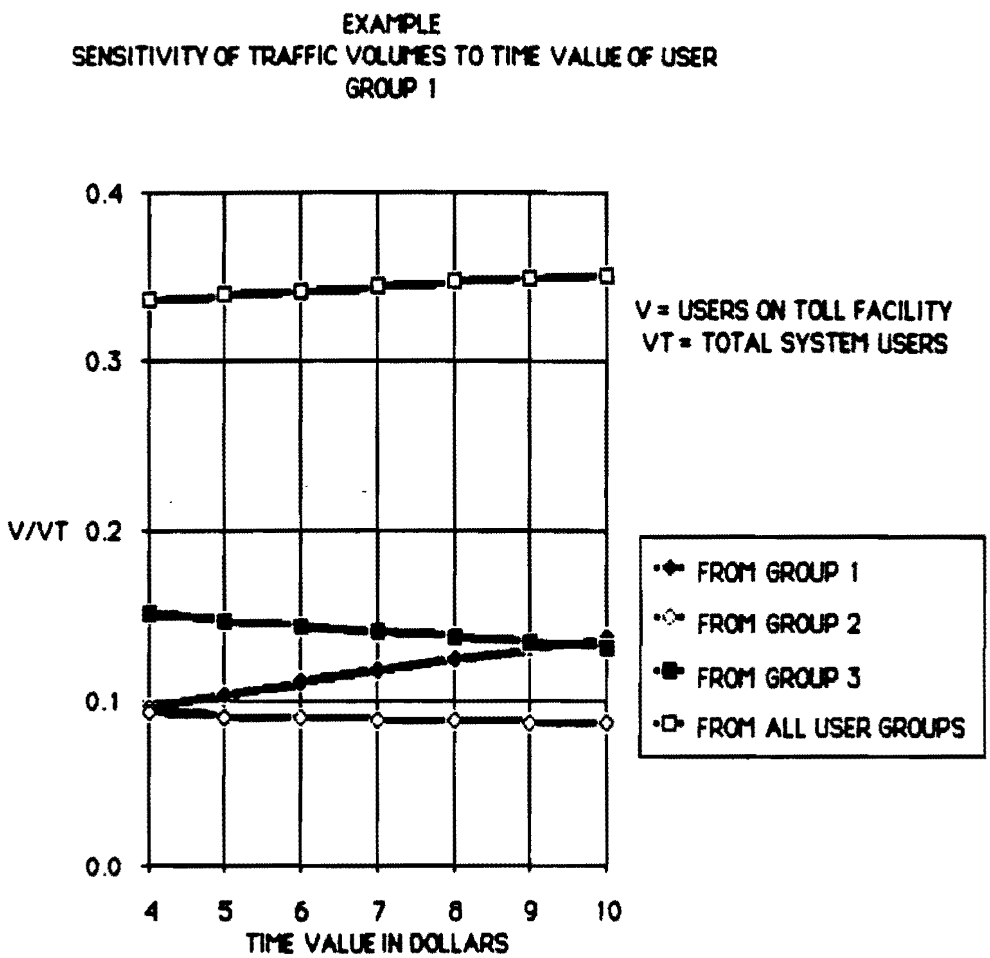

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO TIME VALUE OF USER GROUP 1
0.4
0.3
V/VT 0.2
0.1
0.0
4
5
6
7
8
9
10
TIME VALUE IN DOLLARS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 15

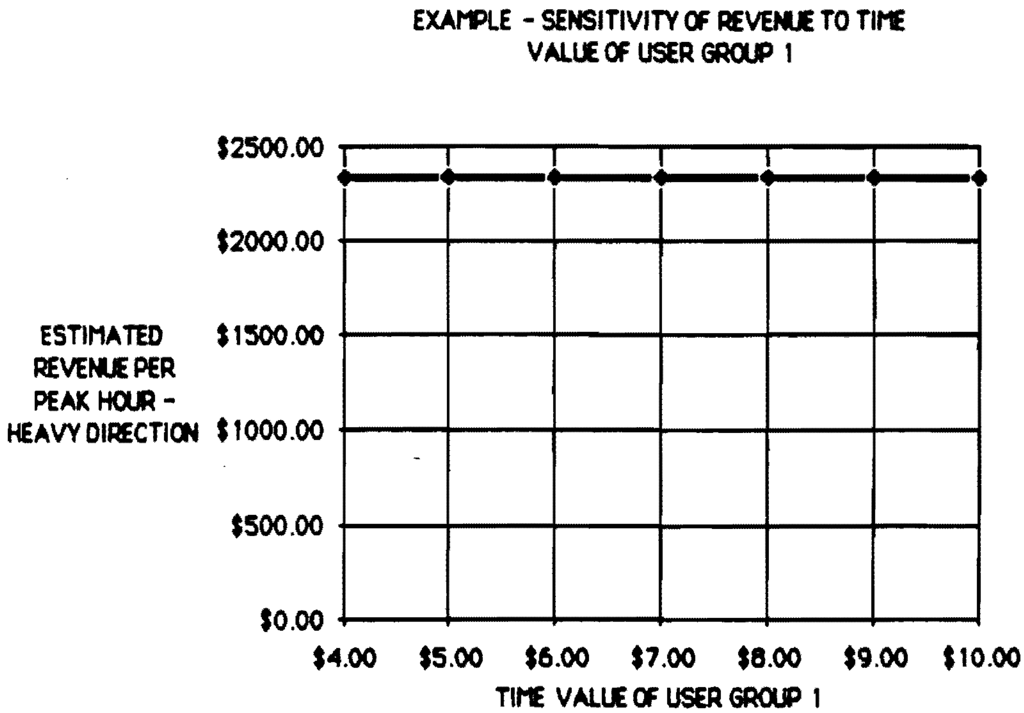

EXAMPLE - SENSITIVITY OF REVENUE TO TIME VALUE OF USER GROUP 1
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$2500.00
$2000.00
$1500.00
$1000.00
$500.00
$0.00
$4.00
$5.00
$6.00
$7.00
$8.00
$9.00
$10.00
TIME VALUE OF USER GROUP 1

FIGURE 16

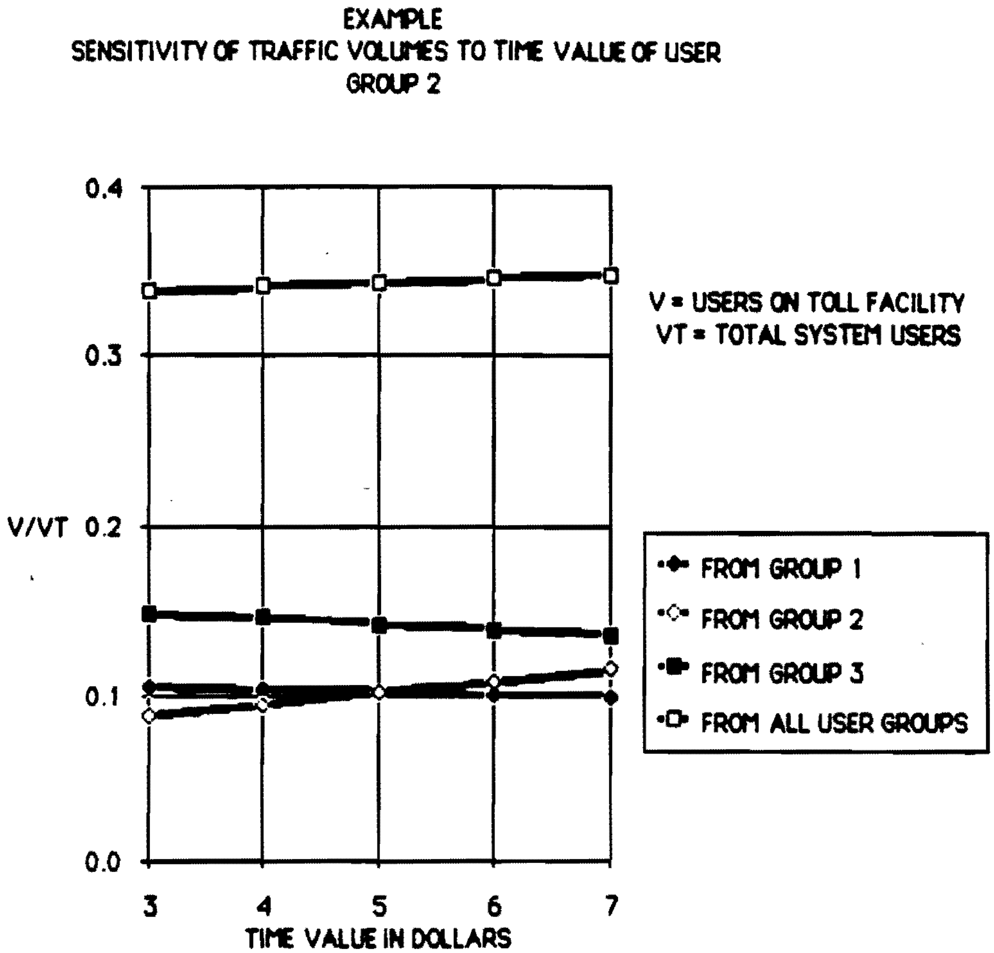

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO TIME VALUE OF USER
GROUP 2
0.4
0.3
V/VT 0.2
0.1
0.0
3
4
5
6
7
TIME VALUE IN DOLLARS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 17

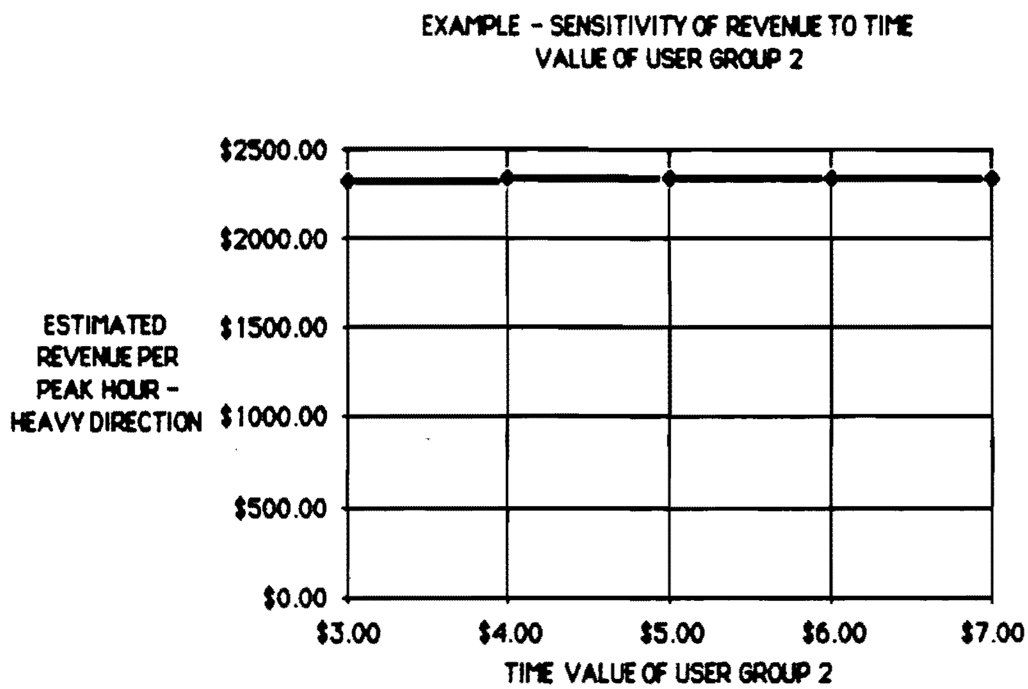

EXAMPLE - SENSITIVITY OF REVENUE TO TIME VALUE OF USER GROUP 2
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$2500.00
$2000.00
$1500.00
$1000.00
$500.00
$0.00
$3.00
$4.00
$5.00
$6.00
$7.00
TIME VALUE OF USER GROUP 2

FIGURE 18

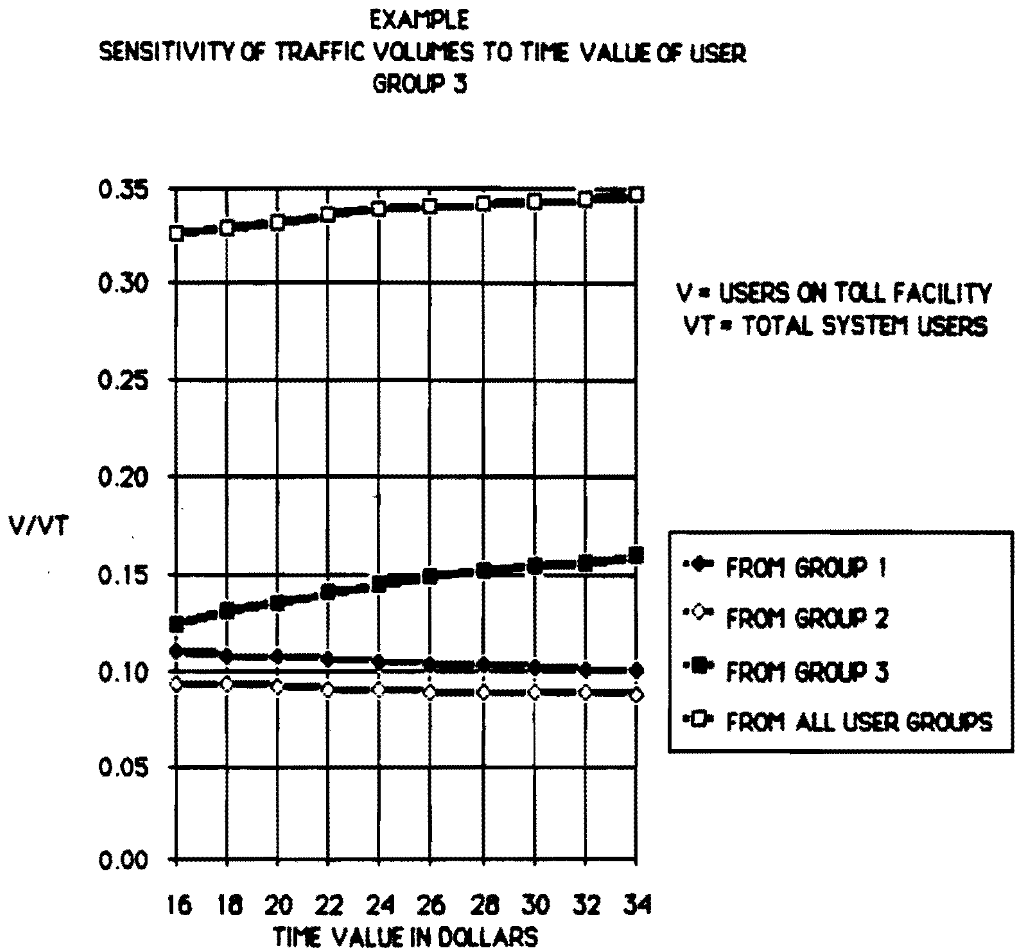

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO TIME VALUE OF USER
GROUP 3
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
V/VT
16 18 20 22 24 26 28 30 32 34
TIME VALUE IN DOLLARS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 19

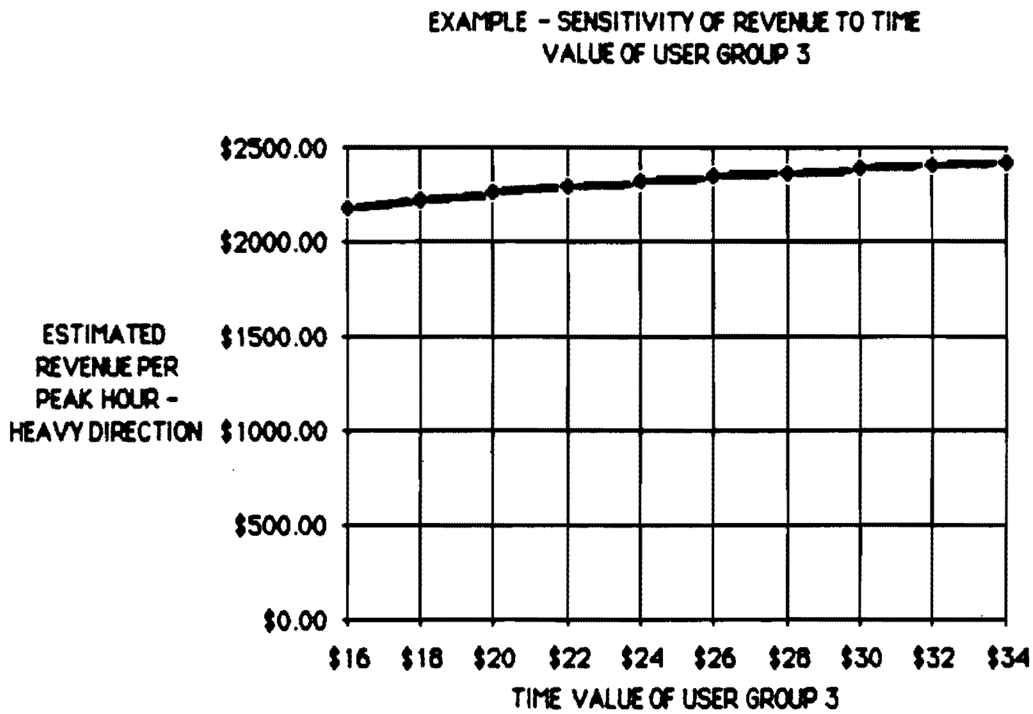

EXAMPLE - SENSITIVITY OF REVENUE TO TIME VALUE OF USER GROUP 3
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$2500.00
$2000.00
$1500.00
$1000.00
$500.00
$0.00
$16
$18
$20
$22
$24
$26
$28
$30
$32
$34
TIME VALUE OF USER GROUP 3

FIGURE 20

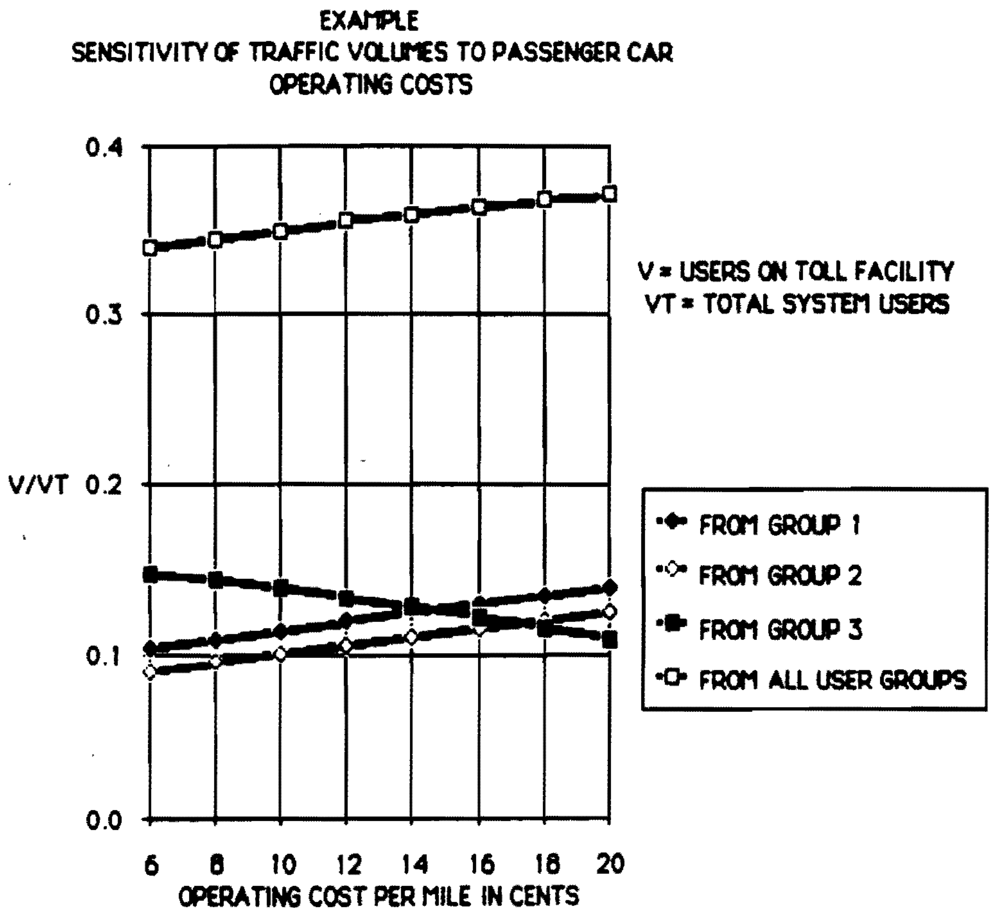

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO PASSENGER CAR OPERATING COSTS
0.4
0.3
V/VT 0.2
0.1
0.0
6 8 10 12 14 16 18 20
OPERATING COST PER MILE IN CENTS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 21

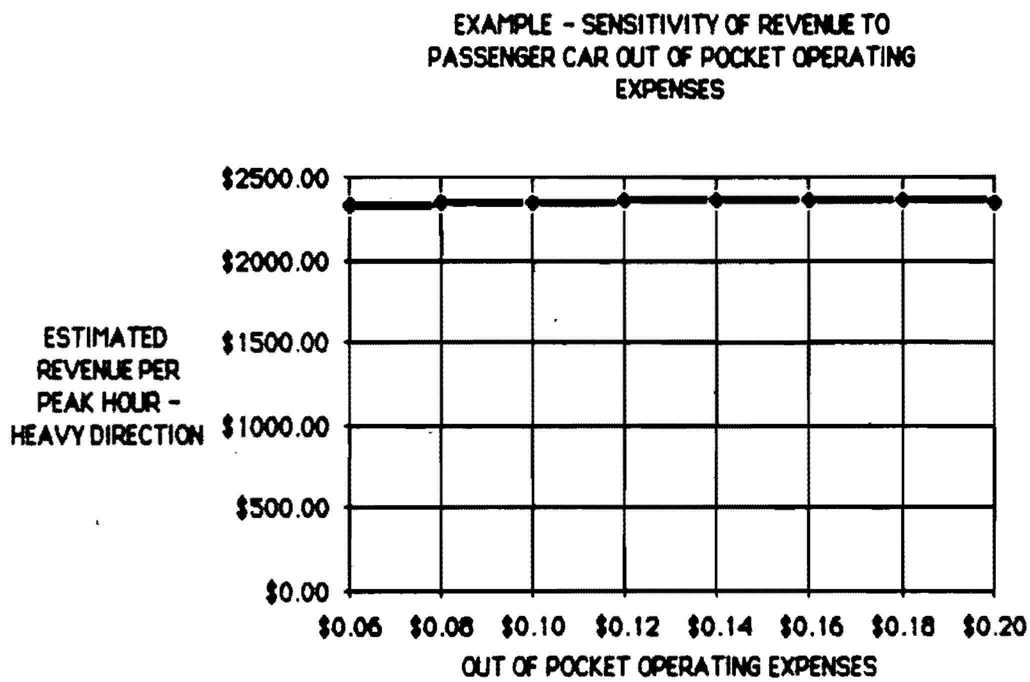

EXAMPLE - SENSITIVITY OF REVENUE TO PASSENGER CAR OUT OF POCKET OPERATING EXPENSES
ESTIMATED REVENUE PER PEAK HOUR - HEAVY DIRECTION
$2500.00
$2000.00
$1500.00
$1000.00
$500.00
$0.00
$0.06
$0.08
$0.10
$0.12
$0.14
$0.16
$0.18
$0.20
OUT OF POCKET OPERATING EXPENSES

FIGURE 22

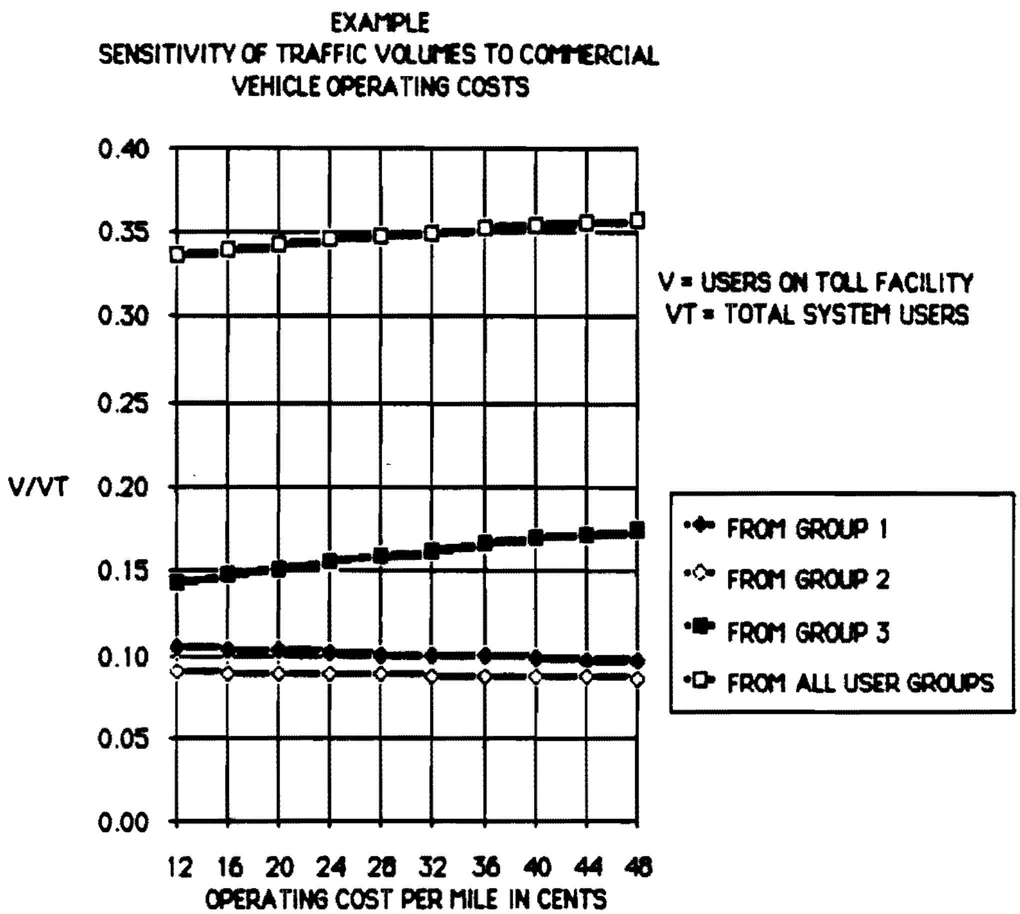

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO COMMERCIAL VEHICLE OPERATING COSTS
0.40
0.35
0.30
0.25
V/VT 0.20
0.15
0.10
0.05
0.00
12 16 20 24 28 32 36 40 44 48
OPERATING COST PER MILE IN CENTS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 23

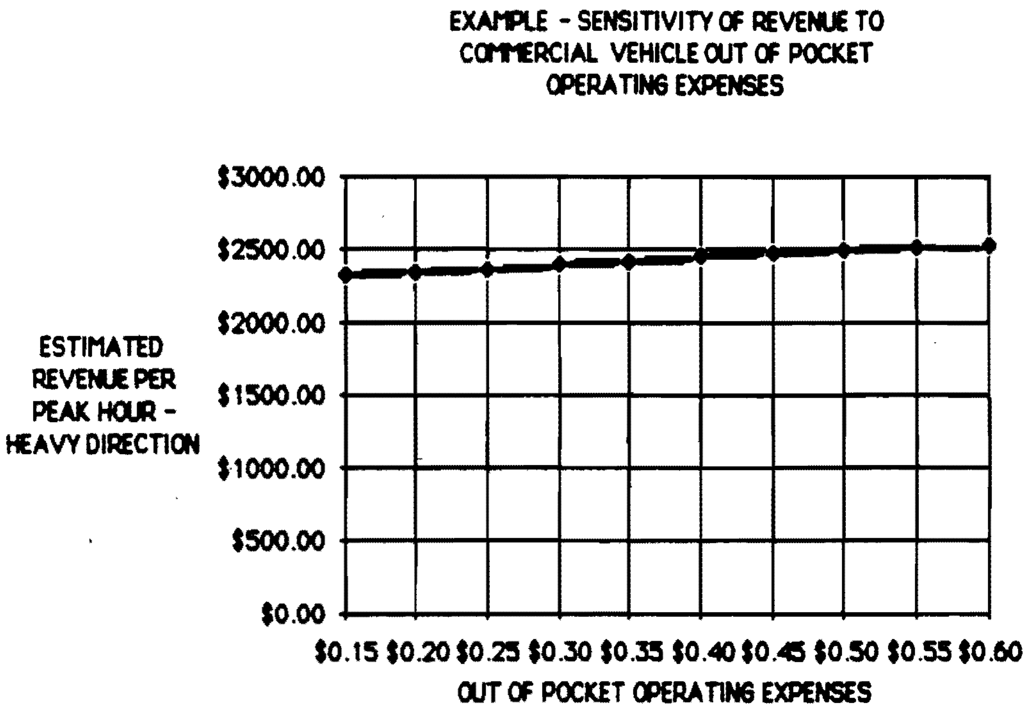

EXAMPLE - SENSITIVITY OF REVENUE TO
COMMERCIAL VEHICLE OUT OF POCKET
OPERATING EXPENSES
ESTIMATED
REVENUE PER
PEAK HOUR -
HEAVY DIRECTION
$3000.00
$2500.00
$2000.00
$1500.00
$1000.00
$500.00
$0.00
$0.15 $0.20 $0.25 $0.30 $0.35 $0.40 $0.45 $0.50 $0.55 $0.60
OUT OF POCKET OPERATING EXPENSES

FIGURE 24

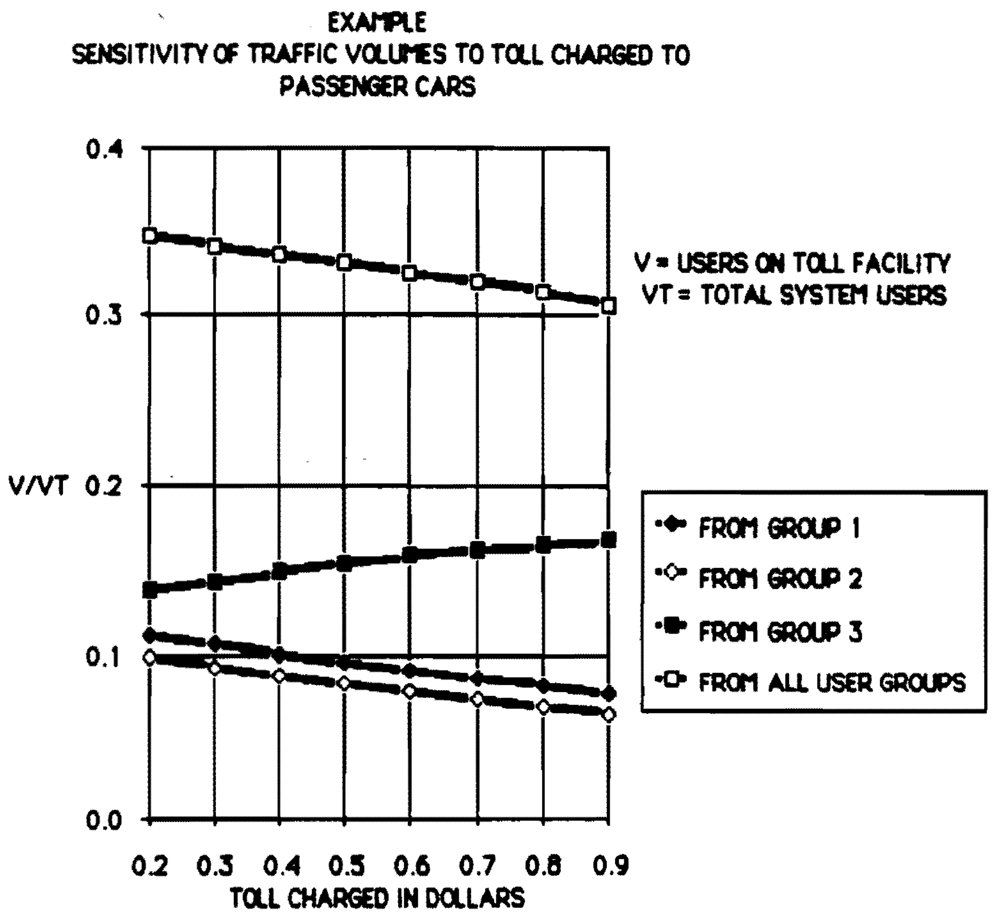

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO TOLL CHARGED TO PASSENGER CARS
0.4
0.3
V/VT 0.2
0.1
0.0
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
TOLL CHARGED IN DOLLARS
V = USERS ON TOLL FACILITY
VT = TOTAL SYSTEM USERS
FROM GROUP 1
FROM GROUP 2
FROM GROUP 3
FROM ALL USER GROUPS

FIGURE 25

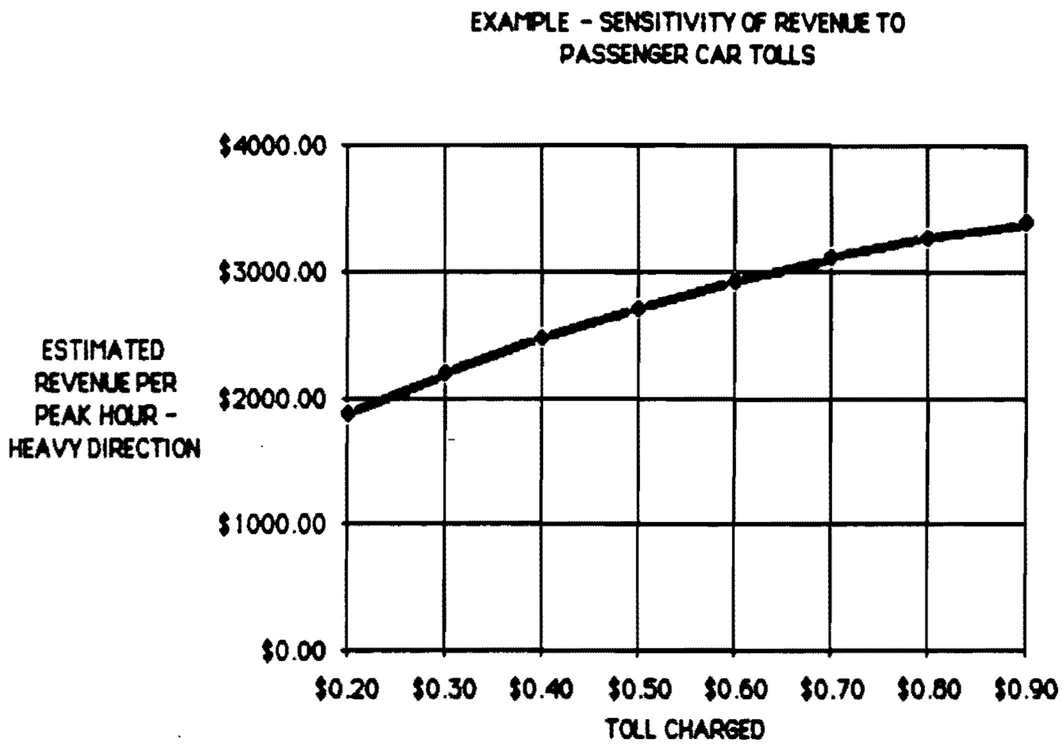

EXAMPLE - SENSITIVITY OF REVENUE TO
PASSENGER CAR TOLLS
ESTIMATED
REVENUE PER
PEAK HOUR -
HEAVY DIRECTION
$4000.00
$3000.00
$2000.00
$1000.00
$0.00
$0.20
$0.30
$0.40
$0.50
$0.60
$0.70
$0.80
$0.90
TOLL CHARGED

FIGURE 26

EXAMPLE
SENSITIVITY OF TRAFFIC VOLUMES TO TOLL CHARGED TO COMMERCIAL VEHICLES

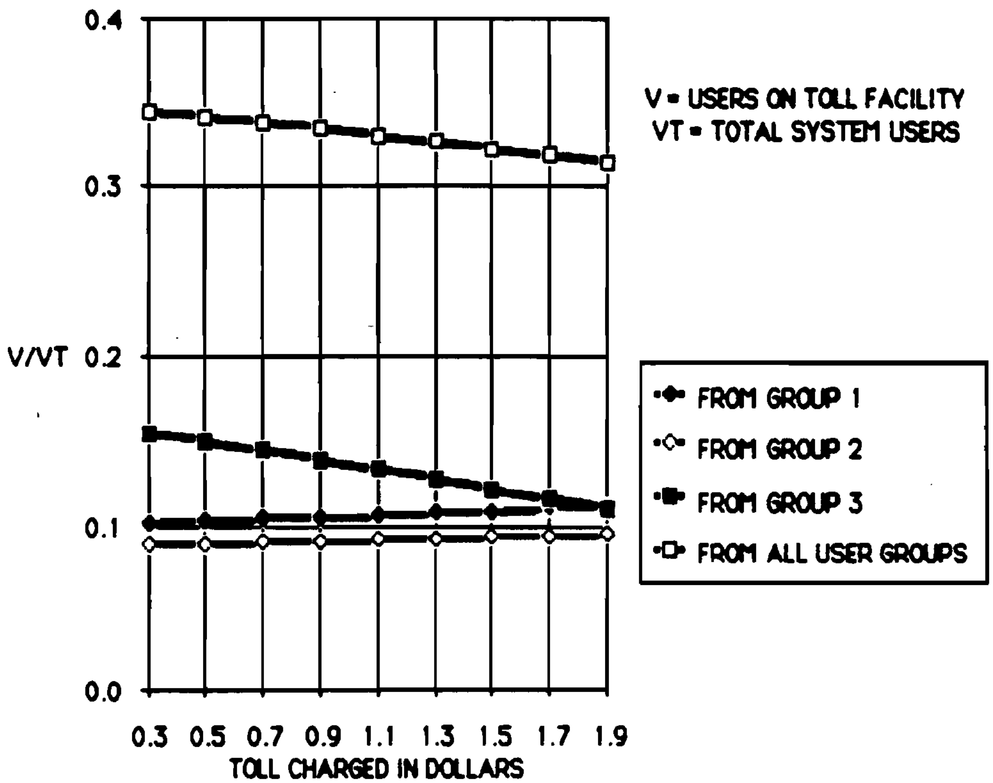



FIGURE 27

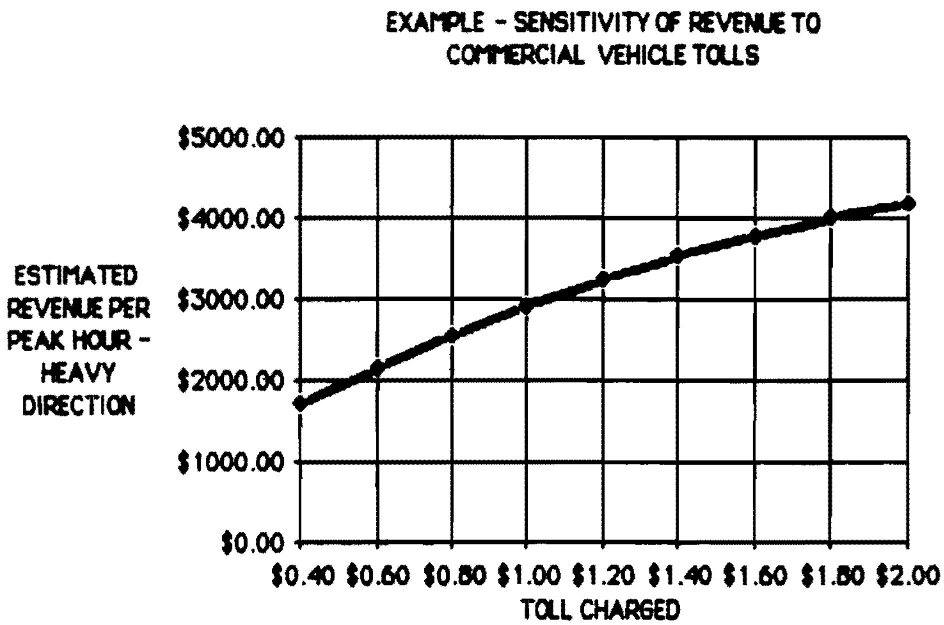

EXAMPLE - SENSITIVITY OF REVENUE TO
COMMERCIAL VEHICLE TOLLS
ESTIMATED
REVENUE PER
PEAK HOUR -
HEAVY
DIRECTION
$5000.00
$4000.00
$3000.00
$2000.00
$1000.00
$0.00
$0.40 $0.60 $0.80 $1.00 $1.20 $1.40 $1.60 $1.80 $2.00
TOLL CHARGED

FIGURE 28

# CHAPTER 4 - REVENUE/EXPENDITURE ANALYSIS

## INTRODUCTION

After the analyst is presented with the various toll mechanisms that may be implemented (Chapter 2) and a model to estimate traffic and revenues (Chapter 3), screening of a set of candidate locations to produce a subset of economically viable alternatives is possible. The revenues estimated by the route share model can be used to compute an expected revenue to expenditure (R/E) ratio. Those sites assigned infeasible R/E ratios would then be eliminated from further consideration.

This chapter's objective, then, is to develop this R/E method in three sections. First, components of revenues and expenditures are identified. The second section presents required R/E ratios for the various possible operating schemes (cells, as presented in Chapter 2). The third section presents quantification of revenue and expenditure components. Revenues and expenditures from a sample of five toll agencies are examined. Presented in this section are data concerning gate, concessions, and miscellaneous revenues; operational, administrative, debt service, and maintenance expenditures; and facility characteristics for one urban and four rural toll roads.

As noted in Chapter 1, it is the task of comprehensive feasibility studies to project detailed revenue and expenditure estimates. For the R/E method of this study, these estimates are not intended be on the level of the feasibility study. Instead, inputs to the method are intended to permit the analyst to obtain values for the ratio that will allow each of the candidate corridors to be compared, thereby facilitating the choice of viable candidates for toll financing.

## COMPONENTS OF REVENUES AND EXPENDITURES

The following section identifies the revenues and costs that can be expected at a toll facility. Gate revenues for a toll facility depend on several factors. Primarily, there must be a demand for use of the facility. Factors influencing demand include 1) travel time for the facility and for the existing network, 2) road quality and esthetics, 3) reliability of service, and 4) direct costs to users. These factors are inputs to or outputs from the developed route share model that predicts revenues for the gate receipts.

Another component of revenues that may be expected for a toll facility is income from concessions. The survey of financial data from toll facilities indicates levels of income that may be expected from concessions.

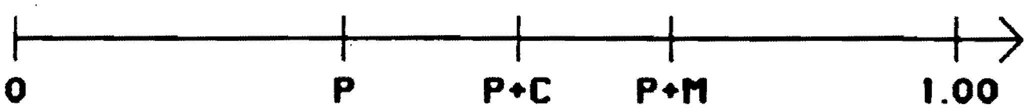
The final component of revenues is income from investments. At many facilities, these investments are financed by proceeds from bond sales that are not immediately used for expenses.

Expenditures at a toll facility include 1) construction capital; 2) right of way investment (expenditures 1 and 2 vary by location, by whether the facility is new or existing, and by whether the facility is expected to repay original financing costs if existing); 3) maintenance costs; 4) operations (toll collection and enforcement); 5) cost of administration; and 6) interest expense.

## R/E REQUIREMENTS FOR CELLS OF OPERATION

For feasible operation of toll facilities characterized by the cells of the typology, various R/E ratios are required. All toll facilities are expected to at least cover expenses related to the collection of the tolls. These expenditures are defined as component P. The amount needed for maintenance is labeled M and similarly, C will represent the expenditures necessary to support right of way purchase and construction. Amount C is usually paid in the form of debt service. (See Figure 29.)

## R/E ANALYSIS




P = %E REQUIRED TO COVER COSTS ASSOCIATED WITH TOLL COLLECTION

C = %E REQUIRED TO COVER CAPITAL AND INTEREST EXPENSES

M = %E REQUIRED TO COVER MAINTENANCE COSTS

FIGURE 29

For this study, two corrections have been applied to normalize some expenditure data from a sample of toll facilities. First, all expenditures will be listed on a per mile basis to account for differences in facility size. In addition, expenditures from previous years will be multiplied by the ratio of the consumer price index of that year to the index of 1985. This will enable all analyses to be performed using 1985 dollars. Table 4 lists ratios of the value of the dollar for previous years to that of 1985 (using 1950 to 1985 consumer price indices (CPI)).

The next section presents the R/E requirements for the 9 feasible cells of operation introduced in chapter 2. (See Figure 30.)

1 - Cell 1 is characterized by the collection of tolls on a new facility with all revenues going to the state's general fund. The facility is wholly supported by an allotment from this fund.

**TABLE 4 - CPI RATIOS**

| YEAR | RATIO | YEAR | RATIO | YEAR | RATIO |
|---|---|---|---|---|---|
| 1985 | 1.00 | 1973 | 2.43 | 1961 | 3.60 |
| 1984 | 1.04 | 1972 | 2.58 | 1960 | 3.63 |
| 1983 | 1.08 | 1971 | 2.66 | 1959 | 3.69 |
| 1982 | 1.12 | 1970 | 2.77 | 1958 | 3.72 |
| 1981 | 1.18 | 1969 | 2.94 | 1957 | 3.83 |
| 1980 | 1.31 | 1968 | 3.10 | 1956 | 3.96 |
| 1979 | 1.49 | 1967 | 3.23 | 1955 | 4.02 |
| 1978 | 1.65 | 1966 | 3.32 | 1954 | 4.01 |
| 1977 | 1.78 | 1965 | 3.41 | 1953 | 4.03 |
| 1976 | 1.89 | 1964 | 3.47 | 1952 | 4.06 |
| 1975 | 2.00 | 1963 | 3.52 | 1951 | 4.15 |
| 1974 | 2.19 | 1962 | 3.56 | 1950 | 4.47 |

A wide range of possible R/E ratios exist for cell 1 because all operations are financed by the fund. Implications include:

a) R/E < 1 - This may present a strain to the state or operating agency's budget, but may provide a way to subsidize roads with toll receipts that would otherwise have to be financed 100 percent by taxes.

b) R/E = 1 - This may be the desirable scenario, as there is no subsidy issue to deal with, and if necessary, this facility could be converted to a completely self-supporting facility.

c) R/E > 1 - Problems with public perceptions may arise as users see that they are paying more than their fair share. However, overcharging would be less apparent than if the facility were independently financed and operated. This may be the best cell for operation of a revenue producing facility.

2 - Cell 2's characteristics are appealing to user-pay advocates since it involves the operation of new facilities, which are self supporting and which pay for ROW and construction as well as maintenance.

Cell 2 requires an R/E ratio of at least 1 for self sufficiency to be maintained. Implications include:

a) R/E = 1 - This is the minimum case for self sufficiency. Most current toll agencies operate with this strategy.

b) R/E > 1 - In this case, the perception problem associated with excess revenue generation is usually solved by early retirement of bond indebtedness.

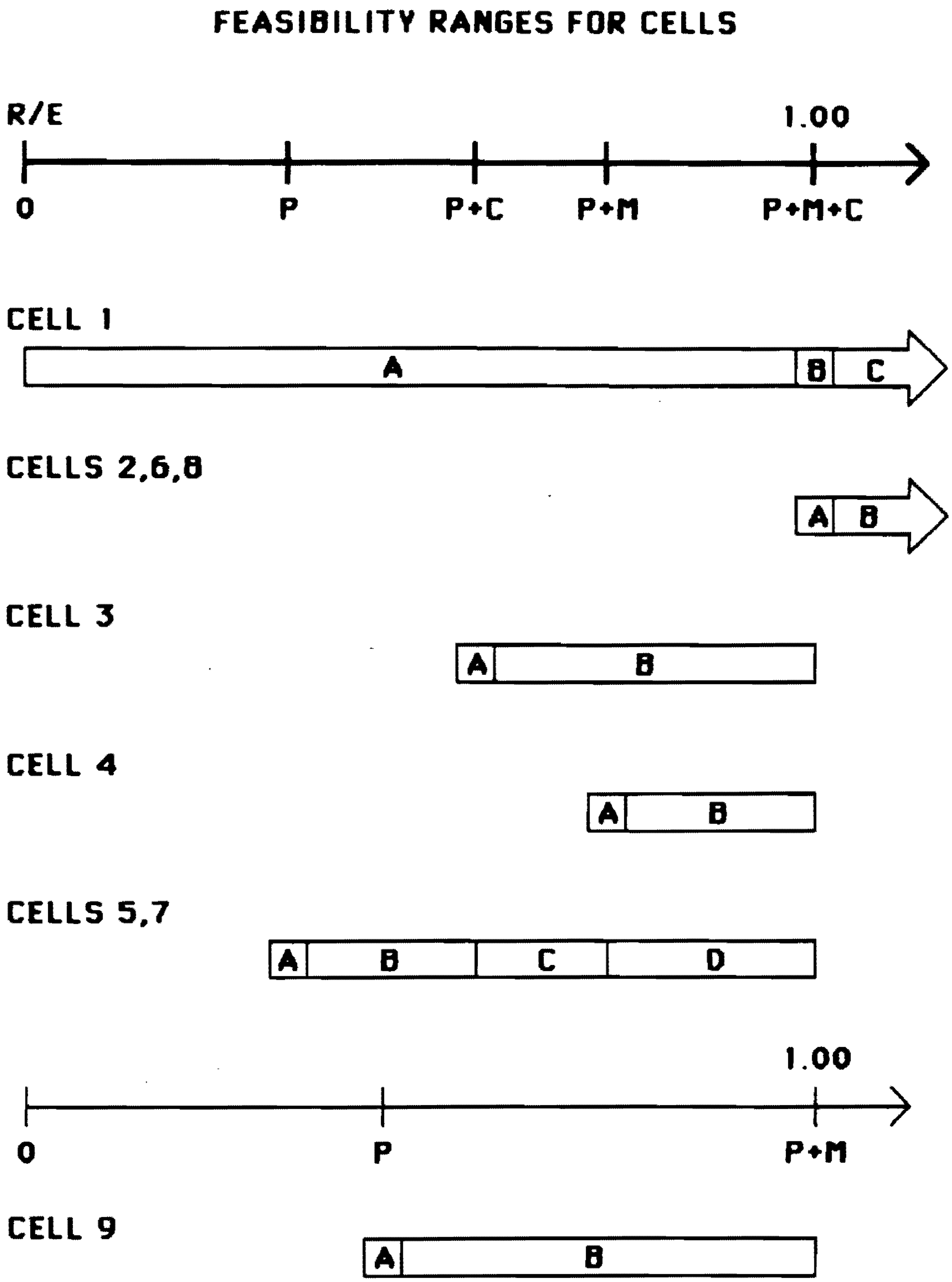

FEASIBILITY RANGES FOR CELLS
R/E
1.00
0
P
P+C
P+M
P+M+C
CELL 1
A
B
C
CELLS 2,6,8
A
B
CELL 3
A
B
CELL 4
A
B
CELLS 5,7
A
B
C
D
1.00
0
P
P+M
CELL 9
A
B

FIGURE 30

3 - Cell 3 represents a method of operation on a new facility that includes two forms of subsidy. First, maintenance is provided by another agency, and, second, support is available in the event of inadequate gate receipts.

For cell 3, where maintenance costs may be subsidized, the R/E requirement is less than 1. The new requirement is (P+C)/E where E is the expenditure required had the facility been self supporting. Implications are:

a) R/E = (P+C)/E - This is the minimum case where only toll operations and debt service are funded by receipts. All maintenance must be provided by another agency or fund.

b) 1.00 > R/E > (P+C)/E - In this case, some of the maintenance may be financed by gate receipts (possibly by providing part or all of the routine maintenance or major repairs or reconstruction). Alternatively, instead of funding part of the maintenance, some of the revenues might be spent on early bond retirement or perpetual funds.

4 - Cell 4 characterizes new facilities operating with subsidies where only maintenance is funded by revenues. If operated, the R/E minimum requirement would be (P+M)/E. Implications include:

a) R/E = (P+M)/E - This is the minimum case where all original construction and ROW costs are provided through another agency or fund.

b) 1.00 > R/E > (P+M)/E - In this case, some of the original debt may be financed by gate receipts (possibly by paying for part or all of the principal or interest payments). Some of this revenue could also be spent on perpetual funds.

5 - Cell 5 is similar to cell 2 in that all operating expenses may receive funds from toll revenues. However, tax or other subsidies make up possible operating deficits.

For cell 5, a wide range of R/E values are possible. Due to maintenance or construction/ROW being subsidized, to cover toll operations expenses, the minimum R/E ratio is P/E. Implications are the following:

a) R/E = P/E - Only those expenses that are necessary for toll administration, collection, and operations are covered. Maintenance and debt service require 100 percent subsidy.

b) P/E < R/E < (P+C)/E - In this case, debt service requires some level of subsidy. Revenues may or may not be adequate to cover all of the maintenance costs. If M is less than C, all maintenance may be serviced, or, if not, revenues in excess of P may be applied to reduce the subsidy of maintenance or debt service.

c) P/E < R/E < (P+M)/E - In this case, maintenance requires some level of subsidy. Revenues may or may not be adequate to cover all of the debt service. If C is less than M, all debt may be serviced, or, if not, revenues in excess of P may be applied to reduce the subsidy of maintenance or debt service.

d) 1.00 > P+[M or C])/E - For this case, one expenditure, either maintenance or debt service, still requires some subsidy.

Cells 6 thru 9 are economically similar to the previous cells with distinctions due only to original financing.

6 - Cell 6 is is characterized by facilities that are completely self-supporting and that have been converted from free facilities by repayment of original financing. For the cases concerning repayment of original financing, the repayment is considered as indebtedness.

For R/E requirements for cell 6, see above under cell 2.

7 - Cell 7 characterizes existing facilities tolled with payback of original funding, subsidized for

operations, and using revenues to fund the repayment and maintenance. For R/E requirements for cell 7, see above under cell 5.

8 - Cell 8 is characterized by the use of tolls only for maintenance. The operation can be labeled self sufficient because the road was constructed before tolls were introduced.

Since no repayment is necessary for original financing, expenditures consist only of toll operations and maintenance costs. Otherwise, this cell has the same R/E requirements as cells 2 and 6 (see above).

9 - Cell 9 characterizes tolls placed on existing facilities where subsidy is required and maintenance is at least partially funded by tolls. Again, since no repayment is necessary for original financing, expenditures consist only of toll operations and maintenance costs. Implications include:

a) R/E = P/E - Only the toll operations may be funded by gate receipts. Maintenance is completely subsidized.

b) 1.00 > R/E > P/E - In this case, part of the maintenance for the facility may be financed from revenue.

Given the preceding discussion, an R/E requirement chart may be developed. Using this chart, along with input of site specific data for values of P, C, and M, an agency will be able to see the options available to them for toll implementation at a particular site.

## EXAMPLE FACILITY REVENUES AND EXPENDITURES

In Appendix D, example figures for five toll agencies are presented to show practical ranges for revenues and expenditures. These tables include revenues and expenditures for four intercity toll facilities (Maine turnpike, Ohio turnpike, New Jersey Turn pike, and Illinois Turnpike), and one urban toll road (Dallas North Tollway). Included in the tables are the R/E ratios required at each of the facilities (Note that all facilities except Maine are classified by the typology to belong in cell group 2 (self supporting, new facilities), while Maine is classified in cell group 6 (self supporting, existing facility).)

It is expected that, accounting for local conditions, the analyst will develop ranges for R/E values that will enable economic evaluation of candidate locations.

# CHAPTER 5 - BENEFIT COST ANALYSIS

## INTRODUCTION

Through the procedure described in the previous chapter on revenue and expenditure analysis, a set of economically feasible candidate corridors for toll financing can be established. In addition the R/E analysis allows determination of the tolling concept or strategy that is feasible for a particular location. The next level of analysis, to determine which of these remaining locations are the most viable candidates for tolling, involves the consideration of a more comprehensive array of costs and benefits for each of the corridors in question. This analysis differs from the more limited R/E analysis in that it includes not only financial aspects of the operation, but more general, possibly qualitative considerations. These will be dependent not only on site specific characteristics, but on the objective of the toll financing, the type of facility (whether new or existing), the involvement and attitudes of the business and political community, and the conditions of the existing transportation network. There are many components to consider for both the benefits and the costs. This chapter provides the analyst with an examination of these components. In addition, the benefits and costs associated with various pricing strategies are analyzed by application of the route choice model to estimate the impact on user equity and traffic diversion.

## DISCUSSION OF BENEFITS AND COSTS

Many of the benefits and costs associated with any transportation scheme are not readily quantifiable. For example, local attitudes toward tolling may strongly impact the viability of toll financing. In this section the components of benefits and costs associated with toll financing are presented to provide the analyst with a systematic procedure for the examination of such issues.

### BENEFITS

A primary requirement of a proposed site for toll financing is economic feasibility. The previous chapter on revenue and expenditure analysis assists the analyst in the task of preliminary economic evaluation. A 1985 report entitled "Toll Financing of U.S. Highways" by the Congressional Budget Office also provides guidelines for the economic feasibility of proposed toll facilities (20). The report lists daily traffic requirements for rural and urban facilities operated with and without subsidy, and with and without existing infrastructure. It is recommended that, along with the procedure described in the previous chapter, the analyst utilize the CBO guidelines.

1) Revenues are the first benefit of toll financing. They serve also to present another benefit; however, that is, since toll roads do not collect revenue until after they are in operation, there is a great incentive for expeditious construction of the facility. This benefit often means that the road will be available for public use 2 to 5 years earlier than would a tax supported highway (20). Given serious congestion levels in many corridors, early completion is advantageous.

2) Another benefit of toll financing is that toll roads are built and operated at higher standards in order to meet the requirements of the municipal bond market. These higher standards may contribute to the excellent safety record of the industry.

3) Higher standards also mean less damage to vehicles. An approximately 5 percent operating cost saving over interstate travel to users results from less wear and tear while using a toll facility (19). Better esthetic quality of toll roads and higher reliability of service are other benefits due to high standards. These benefits to users may be represented as inputs to the route choice model as the "catch" parameter.

4) Another benefit of toll financing is the freeing of tax dollars to support other roads in need of construction or maintenance. The magnitude of this benefit will vary according to current budgetary requirements.

5) Except in rare cases, the addition of infrastructure to a road network will at least partially relieve congested conditions. This benefit may be quantified in user time savings by a before and after analysis.

6) Under current legislation, toll roads are built with out the assistance of federal funds. Because of this, wages paid for construction and operation are not subject to Davis-Bacon Act minimum levels. Additional savings may be experienced as the toll facility may be constructed and operated without federal environmental restrictions (20).

7) One of the more traditional benefits of toll financing is cost savings to users due to less delay. This reduction in delay can be attributed to congestion relief or the provision of a faster or shorter facility.

8) Enhanced accessibility to various sections (either rural or urban) served by a facility is another benefit of toll financing.

9) A final benefit of toll financing is the reduction of capital requirements due to the necessity of typically fewer costly interchanges on toll highways (19).

## COSTS

This section illustrates the components of costs at toll facilities. Due to the site specific nature of these components, an analyst must assign prices to each according to local economies and attitudes.

1) Toll financing represents a more costly method of revenue collection than do traditional fuel taxing and vehicle registration fees. However, with the implementation of new collection technologies,such as automatic vehicle identification, toll collection may become more competitive.

2) Toll highways require more extensive capital expenditures than do free facilities. These expenditures include payments for acquisition of greater amounts of right of way and construction of toll collection facilities.

3) Toll highways also incur extra administrative costs as well as legal, auditing, and consulting fees.

The above costs, however, are components of the expenditures of toll facilities. Other, less easily quantifiable costs include the following:

4) Some delay is experienced by motorists required to stop and pay a toll. Although this lost time may be recovered through increased average speed on the facility, this delay could be considerable during peak periods, especially if the collection facility is underdesigned. However, this delay is relative to operating the same facility without a toll and may not represent an actual delay when compared with travel times for the corridor had the new facility never been constructed. Other factors influencing this delay are type of toll collection system and number of toll lanes per lane of thru traffic. Again, improved collection methods, such as automatic vehicle identification, could greatly reduce the magnitude of this delay.

5) Since toll facilities have limited points of access, some motorists will incur delay in travelling to or from these access points.

6) Loss of business and income from tourism could result from the implementation of a restricted access facility. As toll roads have fewer interchanges than other free access highways, motorists may find it difficult or costly to patronize local merchants. Access can be improved by the implementation of an open toll collection system where barriers are placed at selected locations along the toll road. This method of toll collection is an alternate to closed systems where tolls are collected at every ramp. The impact of this loss of business is greater for converted facilities than for new. In fact, concession franchises at interchanges

on new toll facilities have been proven to be advantageous both to local economies and to revenues of the toll road itself.

7) and 8) Two other cost considerations are the potential inequities of pricing schemes and the diversion of traffic to other facilities. The following section shows the application of the route share model to estimate these impacts.

## IMPACT OF PRICING SCHEMES ON EQUITY AND TRAFFIC DIVERSION

An important goal for operation of a toll facility is the optimization of a toll pricing schedule. Revenue maximization, however, should not be the only consideration, particularly if the schedule that produces the highest income level significantly violates equity among users or creates unwanted traffic diversion. One such case is an example where levels of traffic at all competing facilities approach capacity. In this case, if tolls are increased, the cost of transportation to users must increase as there is no practical alternative to some other than paying the toll.

If a free road is converted to toll financing and prices are set too high, the competing routes could suffer major degradations in level of service. Other disadvantages include lower income users being forced to divert to free facilities.

It is advantageous also, that tolls be equitable to the cost of services provided to each group. These costs include both allocated and attributed costs (21). Allocated costs are the portion of costs assigned to users regardless of type of vehicle. These costs include payments for administration, right of way, and a portion of construction, maintenance, and toll collection expenses. Attributed costs are those costs which can be attributed to the damages caused by the vehicle class. These costs include the remaining part of construction and maintenance, as well as a portion of the toll collection expenses.

The route share model can be used to show the effect of toll pricing schedules on user equity and traffic diversion. Direct outputs from this model that are useful in this analysis are number of users from each group on each facility, total traffic volume on each facility, and revenues generated by user group and facility.

To design an equitable, cost based pricing scheme, the analyst may employ a method such as described in Hendrickson and McNeil's paper (21). However, this method requires as input the number of users on a facility from each user group. Since the data is not known for proposed facilities, the model estimations can be used. In the next section, application of the model to an equitable pricing method will facilitate design of equitable pricing for a sample case.

### COST BASED EQUITY PRICING EXAMPLE

Each expense for toll operation can be either allocated or attributed to users. For the purposes of this analysis, these expenses are divided into maintenance, administration, toll collection, and original construction costs. Hendrickson (21) showed how empirical methods can be used to equitably allocate and attribute costs to user groups. However, costs responsibilities are site specific in nature. For the Ohio turnpike, Hendrickson reported attributable expenses to be 1) 0.0019 times the number of equivalent standard axle loads for routine maintenance, 2) 4/9 of the major maintenance costs, 3) 80 percent of the original construction costs, and 4) all of the toll collection expenses. Realizing that these proportions are applicable only to Ohio, and to demonstrate the usefulness of the route share model in evaluation of the equity of a pricing scheme, some estimations and assumptions are made to approximate conditions at the Dallas North Tollway.

The process of estimating an equitable toll pricing schedule first requires the analyst to estimate expenditures for a proposed toll facility. For the Dallas North Tollway, expenses have been estimated to be the following:

**Construction Costs:**

Original financing costs for the tollway were $33,650,000. At the bond rate of 4 percent, yearly payment requirements would be approximately $1,700,000. However, early retirement of the bonds, before the 40 year maturity date was desired. Early retirement depends on the traffic potential at the facility and how large a toll users will bear. This additional amount could be set to any amount, but, for now, it will be estimated as the actual amount over debt requirement that was received during 1981, or approximately $2,700,000.

Of the $1,700,000, some amount can be directly attributed to traffic. Assuming half, this amount would be $850,000.

The remaining portion of the construction costs, $850,000 + $2,700,000 = $3,550,000, must be allocated to users.

**Maintenance Costs:**

An analyst may develop empirical approximations similar to Hendrickson's to estimate the attributable portion of maintenance expenses. This, however, is beyond the scope of this research. For the purposes of this analysis, half the maintenance expenditures are considered to be attributable, or about $200,000. The other $200,000 is allocated.

**Toll Collection Costs:**

At least half of the toll collection expenses cannot be attributed as toll booths and a minimum staff would be required regardless of number of users served. Some other portion (for this study, half is assumed) can be attributed. Each amount can be estimated to be $500,000 for the Dallas North Tollway.

**Administrative Costs:**

All of the administrative costs, or about $600,000, must be allocated to user groups.

After expenditures have been estimated, the first step in design of equitable tolls is use of the route share to estimate traffic volumes for each user group. For the first iteration, a toll pricing schedule is initiated.

The second step in designing an equitable schedule is to assign allocated and attributed expenses to the user groups.

**Allocated Expenses:**

The sum of all allocated expenses is $3,550,000 + $200,000 + $500,000 + $600,000 = $4,850,000. These expenses may be allocated by vehicle miles travelled (VMT). (21)

**Attributed Expenses:**

A portion of these costs may be attributed by volume; these are the toll collection expenses. An empirical relationship between volume served and expense incurred may be developed. Such a relationship that approximates DNT data is $.022 x (VOL). (*See Note)

The remaining expense must be attributed in a manner equitable to damages incurred by the infrastructure. Many methods exist, such as attribution by passenger car equivalents, or by equivalent standard axle loads. For simplicity and illustration, this analysis equates the damages of 1 truck-mile to 100 passenger car-miles (PCEM). Cost allocation studies show that this estimate is reasonable if not conservative. An empirical estimate that can be used to attribute costs of maintenance and original construction costs on the DNT is $.00105 x (PCEM). (* See Note)

NOTE: In practice, the analyst must estimate all of the above expenses. This is possible, but is beyond the scope of and is not requisite to this example. These relationships were derived from the use of 1981 DNT annual report data as input to the equitable design method described in Hendrickson's paper (20).

The third and final step of equitable toll design is to divide the total expenses assigned to a particular user group by the number of vehicle miles travelled by the group. Toll fees would be the product of this quotient and the trip length.

The above three step process of toll design comprises one iteration of the design process. The model is used to estimate traffic share for each set of newly developed tolls until convergence is established. The following section shows the example calculations for the approximated DNT scenario.

**Iteration 1:**

**Step 1**

For the first iteration, the tolls are established as 3.5 cents per mile for passenger vehicles and 6 cents per mile for trucks (or, for the entire 10-mile trip, 35 cents for cars and 60 cents for trucks). The same site data used previously in the route share model chapter were used to approximate conditions at the toll facility. Application of the route share model estimated the following annual results:

| | | | |
|---|---|---|---|
| Volume of cars | = | 17,265,040 | (95%) |
| trucks | = | 905,736 | (5%) |
| VMT of cars | = | 172,650,040 | (95%) |
| trucks | = | 9,057,360 | (5%) |
| PCEMs for cars | = | 172,650,040 | (16%) |
| trucks | = | 905,736,000 | (84%) |

**Step 2:**

**Allocated Expenses:**

Cars = \$4,850,000 x .95 = \$4,607,500

Trucks = \$4,850,000 x .05 = \$242,500

**Attributed Expenses:**

Cars = (\$.022 x 17,265,040) + (\$.00105 x 172,650,400) = \$561,114

Trucks = (\$.022 x 905,736) + (\$.00105 x 905,736,000) = \$970,949

**Total Expenses:**

Cars = \$5,168,614

Trucks = \$1,213,449

**Step 3:**

**Updated Toll Schedule:**

| | | | | |
|---|---|---|---|---|
| Cars | = | \$5,168,614 / 17,265,040 | = | \$.299 ... \$.30 |
| Trucks | = | \$1,213,449 / 905,736 | = | \$1.34 ...\$1.35 |

**Iteration 2:**

**Step 1:**

For the second iteration, the tolls were replaced by 3.0 cents per mile for passenger vehicles and 13.5 cents per mile for trucks (or, for the entire 10 mile trip, 30 cents for cars and \$1.35 for trucks). Application of the route share model estimated the following annual results:

| | | | |
|---|---|---|---|
| Volume of cars | = | 17,939,584 | (92.27%) |
| trucks | = | 504,400 | (2.73%) |
| VMT of cars | = | 79,395,840 | (92.27%) |
| trucks | = | 5,044,000 | ( 2.73%) |
| PCEMs for cars | = | 179,395,840 | (26.24%) |
| trucks | = | 504,400,000 | (73.76%) |

**Step 2:**

**Allocated Expenses:**

| | | | | |
|---|---|---|---|---|
| Cars | = | \$4,850,000 x .9227 | = | \$4,717,595 |
| Trucks | = | \$4,850,000 x .0273 | = | \$132,405 |

**Attributed Expenses:**

| | | | | | | |
|---|---|---|---|---|---|---|
| Cars | = | (\$.022 x 17,939,584) | + | (\$.00105 x 179,395,840) | = | \$583,036 |
| Trucks | = | (\$.022 x 504,400) | + | (\$.00105 x 504,400,000) | = | \$540,717 |

**Total Expenses:**

| | | |
|---|---|---|
| Cars | = | \$5,300,631 |
| Trucks | = | \$673,122 |

**Step 3:**

**Updated Toll Schedule:**

| | | | | |
|---|---|---|---|---|
| Cars | = | \$5,300,631 / 17,939,584 | = | \$.296 ... \$.30 |
| Trucks | = | \$673,122 / 504,400 | = | \$1.33 ... \$1.35 |

**Recommendation:**

The toll schedule estimated by this method is 30 cents for cars and $1.35 for trucks. The results of this analysis are not advocated for implementation at the Dallas North Tollway due to the previous assumptions and estimations; rather, this analysis is intended to show the use of the route share model in the design and analysis of toll pricing schemes.

## EFFECTS OF PRICING ON TRAFFIC DIVERSION

Output from the route share model also provides data for the examination of the effect of various pricing schemes on diversion of traffic. Traffic diversion is a consideration only with the conversion of an existing facility to toll, as construction of a new facility rarely has a negative impact on network congestion.

When tolls are introduced on a previously free facility, motorists are presented with several choices. First, the user may choose to continue driving on the facility and pay the toll. Second, the user may choose to make the trip at some other time (if congestion pricing is employed). A third choice could be to make the trip by some other mode such as carpool or bus. Fourth, the motorist could decide not to make the trip at all. But if the motorist chooses not to pay the toll, he is likely to make a fifth choice, that is to make the trip using a competing facility. This trip has been diverted to an alternate toll-free route. Only the first and fifth user choices are considered by the model. The magnitude of traffic diversion is a direct output of the model (volume on each facility). The analyst may therefore estimate the impact of a pricing schedule on traffic diversion by comparing present volumes on facilities with those predicted by the model. The next section shows an example application.

## IMPACT OF TRAFFIC DIVERSION

For example, for application of the route share model to estimate the impact of pricing strategies on traffic diversion, the following corridor scenario has been established:

— 3 facilities, all four-lane arterial streets before conversion of Facility 1 to toll

— 4 user groups representing low to high income users

Facility 1:

— 10 Miles in length
— Alpha parameter = 1.0
— Beta parameter = 6.6
— Capacity = 2400 Vehicles Per Hour
— Speed Limit = 40 MPH

Facility 2:

— 10 Miles in length
— Alpha parameter = 1.0
— Beta parameter = 6.6
— Capacity = 2400 Vehicles Per Hour
— Speed Limit = 40 MPH

Facility 3:

— 10 Miles in length
— Alpha parameter = 1.0
— Beta parameter = 6.6
— Capacity = 2400 Vehicles Per Hour
— Speed Limit = 40 MPH

User Group 1:

— $2.00 per hour value of travel time
— $.06 per mile operating costs
— 2500 users per hour

User Group 2:

— $5.00 per hour value of travel time
— $.06 per mile operating costs
— 2000 users per hour

User Group 3:

— $10.00 per hour value of travel time
— $.06 per mile operating costs
— 1000 users per hour

User Group 4:

— $20.00 per hour value of travel time
— $.06 per mile operating costs
— 500 users per hour

Total number of users = 6000 VPH
Capacity of network before conversion = 7200 VPH

Application of the route share model to this scenario estimated the following results:

1) Travel time for all facilities = .33 hours

2) Traffic on all facilities = 2000 VPH.

3) For the $2.00 per hour user group, the average trip cost is $1.25.
For the $5.00 per hour user group, the average trip cost is $2.23.
For the $10.00 per hour user group, the average trip cost is $3.85.
For the $20.00 per hour user group, the average trip cost is $7.10.

After Facility 1 is converted to toll and upgraded to freeway standards, the new facility operating characteristics are

— 10 Miles in length
— Alpha parameter = 1.1
— Beta parameter = 6.9
— Capacity = 4000 Vehicles Per Hour
— Speed Limit = 55 MPH

Updated network operating characteristics were estimated by the route share model for tolls of $.25, $.50, $.75, and $1.00.

## RESULTS

The chief results of the conversion to toll financing and the subsequent toll schedule are the following:

1) Travel time and traffic on the remaining free facilities were less for all tolls under $1.00. For tolls equal to or greater than $1.00, congestion increased. (See figures 31 and 32.)

2) All user groups experienced time savings under the new system. However, these savings were far greater for the higher time value users than for the low time value groups. In fact, for tolls approaching $1.00, the $2.00 per hour time value group experiences very little time savings. (See figure 33.)

3) For high time value users, average trip cost decreased dramatically, even for the higher tolls. However, for low value users, average trip costs actually increased after upgrade and conversion of Facility 1. (See figure 34.)

The benefits to higher time value groups and the costs to lower time value users can be quantified by the preceding method and used as inputs to the analyst's B/C analysis.

## CONCLUSION

The preceding sections identify benefit and cost components at toll facilities. An analyst, after using revenue and expenditure analysis to identify a set of economically feasible candidate locations, could evaluate this set according to the benefits and costs. This evaluation requires the site specific evaluation of each site according to the guidelines presented in this chapter. The analyst must consider such information as the level of competition for existing tax funds, the attitudes of the community toward tolling as an alternative financing mechanism, and the local business climate. For each of the candidate locations, a benefit cost ratio may be developed using only those components that can be quantified. Those candidates with the highest ratios could then be examined through detailed feasibility studies to determine whether toll financing should be implemented.

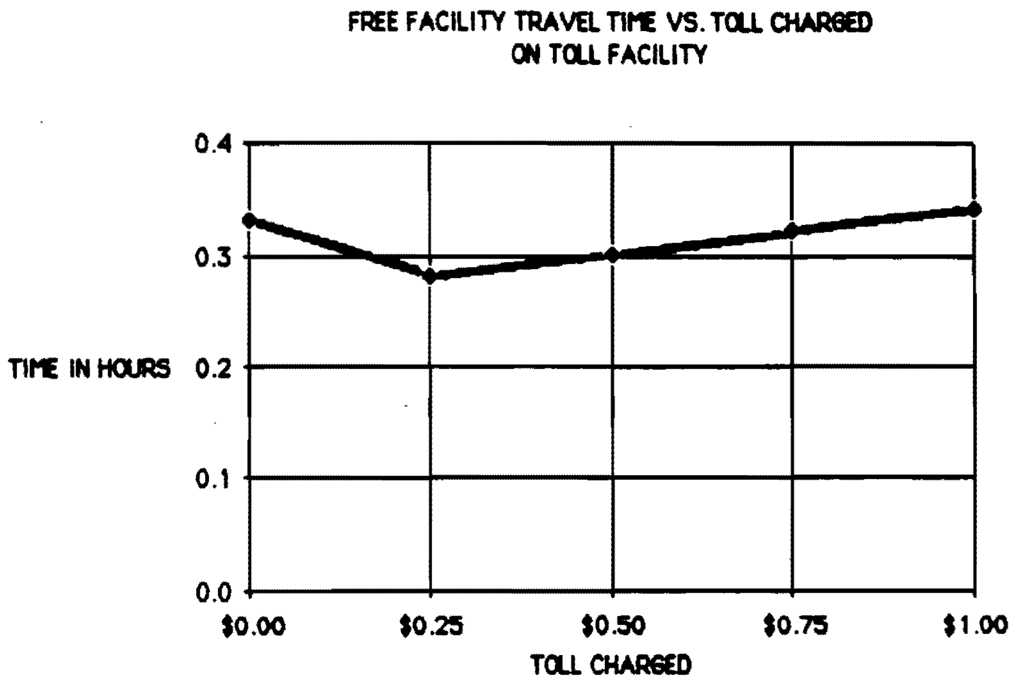

FREE FACILITY TRAVEL TIME VS. TOLL CHARGED
ON TOLL FACILITY
TIME IN HOURS
0.4
0.3
0.2
0.1
0.0
$0.00
$0.25
$0.50
$0.75
$1.00
TOLL CHARGED

FIGURE 31

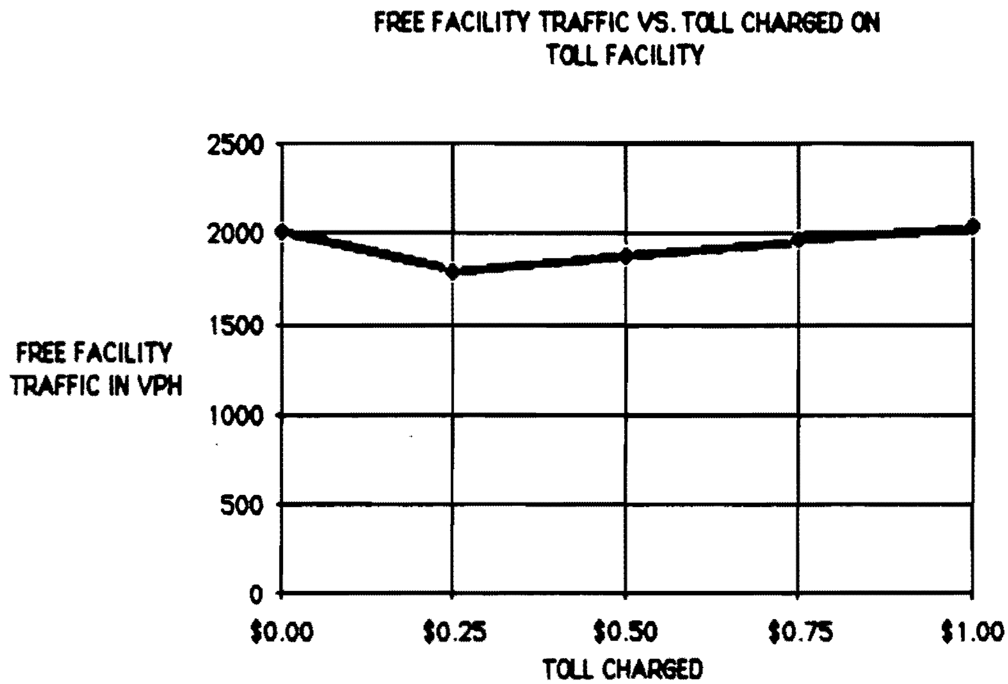

FREE FACILITY TRAFFIC VS. TOLL CHARGED ON
TOLL FACILITY
2500
2000
1500
1000
500
0
FREE FACILITY
TRAFFIC IN VPH
$0.00
$0.25
$0.50
$0.75
$1.00
TOLL CHARGED

FIGURE 32

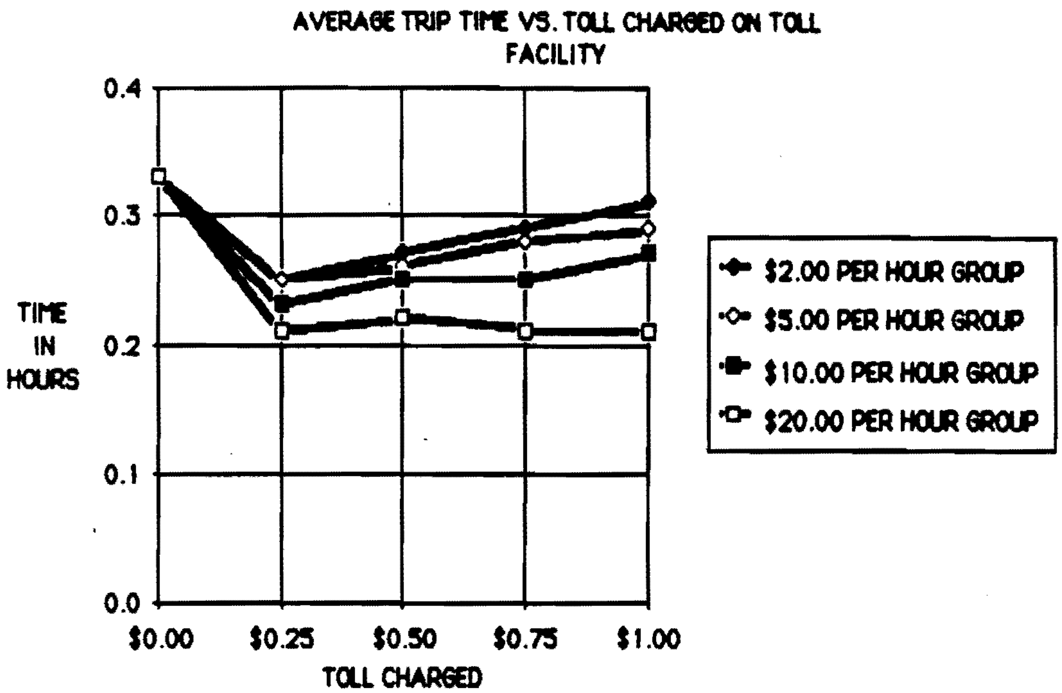
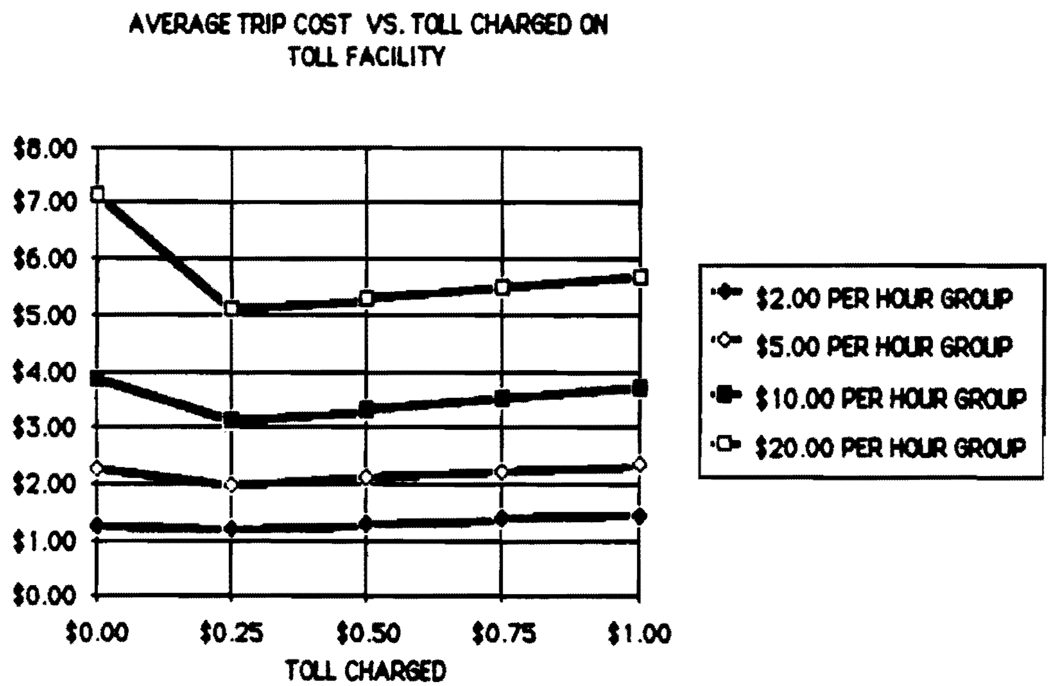

AVERAGE TRIP TIME VS. TOLL CHARGED ON TOLL FACILITY
0.4
0.3
0.2
0.1
0.0
TIME IN HOURS
$0.00
$0.25
$0.50
$0.75
$1.00
TOLL CHARGED
$2.00 PER HOUR GROUP
$5.00 PER HOUR GROUP
$10.00 PER HOUR GROUP
$20.00 PER HOUR GROUP

FIGURE 33



AVERAGE TRIP COST VS. TOLL CHARGED ON TOLL FACILITY
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
$0.00
$0.25
$0.50
$0.75
$1.00
TOLL CHARGED
$2.00 PER HOUR GROUP
$5.00 PER HOUR GROUP
$10.00 PER HOUR GROUP
$20.00 PER HOUR GROUP


FIGURE 34

# CHAPTER 6 - CONCLUSION

## SUMMARY OF REPORT

Traditionally, tolls have been used to finance highway construction on a case by case basis with system-wide application receiving little emphasis. Expensive, detailed feasibility studies have been conducted for each of these facilities. The objective of this report is the development of a systematic procedure whereby an analyst may identify and evaluate candidate locations for toll financing prior to execution of the extensive, consultant type, feasibility study. The report provides a methodology for screening and ranking of a number of candidate toll facilities, thereby reducing costs by eliminating studies for infeasible or undesirable candidate projects, and improving efficiency of site selection. More importantly, it provides a framework for addressing the complex issues associated with assessing the desirability of particular tolling strategies among the wide spectrum of possibilities.

A key component of this framework is the typology, which provides a classification and identification mechanism for various methods and characteristics for toll operation, thereby helping analysts and decision-makers organize the many issues and components of toll financing. The dimensions and levels of the typology result in nine cells, each corresponding different represent possible scheme of toll road operation. To illustrate the typology's usefulness as a classification mechanism, a survey of U.S. toll road operators was conducted. In addition, this typology is applied to the tolling scene in Texas, thereby identifying the key legal, institutional, and financial considerations surrounding the increased use of tolling as a financing mechanism in the State.

The third chapter of the report presents a model developed to estimate traffic volumes and revenues for a given corridor. Sensitivity analysis results showed that some model inputs could be derived from secondary data, while other data must be specified by the analyst. Application of the model to approximate conditions at the Dallas North Tollway for 1981 produced reasonable estimations. The model is used in subsequent chapters to estimate volumes and revenues for additional analysis.

The fourth chapter of the report, "Revenue/Expenditure Analysis", provides the analyst with a tool to screen potential economically infeasible candidate locations. Components of revenues and expenditures that may be expected at a toll facility are identified and described in the first section. The second section of this chapter presents minimum requirements of R/E ratios for each of the nine typology cells of operation. Those candidate facilities that fail to meet these criteria can be screened from further consideration. Finally, the third section of this chapter presents example revenue and expenditure data for five toll agencies.

The fifth chapter of the report, "Benefit-Cost Analysis", provides the analyst with a method for evaluating or ranking candidate facilities that meet the requirements presented in the previous chapter. Sections present qualitative discussions of benefits and costs associated with toll financing. In two other sections, the route share model is used to estimate effects of toll financing on cost based equity and traffic diversion. With the information presented in this chapter, an analyst may develop benefit-cost ratios for each of the candidate locations, there by facilitating comparison and selection of the most viable sites.

## APPLICATIONS

The methodology or parts thereof have several potential applications. Primarily, the methodology can be used as described above as an identification process. In this way, implementation of toll financing on a new, higher level may be facilitated on a state or other system-wide level by the identification of likely corridors to be developed as toll facilities.

Other uses include evaluation of one or more existing facilities. This use would allow, for example, the examination of existing toll facilities across the state to facilitate objective evaluation of existing policies and operational characteristics that could either be followed or modified for the implementation of any proposed toll facilities.

The route share model can be used to estimate the effects of building new or upgrading toll or free roads on users, such as the impact on equity and traffic diversion. One interesting application of this model would be the study of the effect of various fee-structures for commercial vehicles.

Finally, the methodology could be extended by its application to the evaluation of non-toll roads. Here, the same procedures used for identification and evaluation of toll facilities could be applied to free roads with the exception of such inherently toll attributes as administration and toll collection.

## STUDY RECOMMENDATIONS

Toll financing is gaining increased acceptance as a viable alternative to meet increasing needs for maintaining and upgrading the highway infrastructure. Greater reliance on toll financing as an alternative financing mechanism could provide many benefits to the Texas highway system, including:

1) alternative source of needed revenue
2) early completion of construction
3) high construction standards
4) improved safety for motorists
5) lower vehicle maintenance costs for users
6) better aesthetics
7) freeing of committed tax dollars to support other projects
8) congestion control and relief
9) user time savings
10) lower wages paid during construction
11) enhanced accessibility
12) less capital required for construction of intersections

These benefits may assist in offsetting the possible initial negative reaction that some users might have. Furthermore, advances in fee collection technology can greatly reduce some of the minor inconvenience encountered in that process. It is recommended that the Texas SDHPT consider the ramifications of a program of tolling at the state-wide level at selected proposed high volume, high maintenance corridors. With the expected increases in highway traffic by the year 2000, additional highway capacity will undoubtedly be required. Given current budget constraints, and trends in this regard, tolling may be a viable option for the expeditious construction of this needed infrastructure. Current Texas legislation allows only the Texas Turnpike Authority to construct toll facilities in non-coastal counties. Therefore, it is recommended that the SDHPT, in consort with TTA consider providing assistance to localities and highway districts interested in tolling options and devise criteria for identifying viable toll projects on a state-wide level with the aid of the methodology developed in this report. This list could include projects evaluated as new, self supporting, or new, subsidized facilities where all revenues are contributed to a general operations fund. This type of financial arrangement would be more conducive to system-wide development of toll facilities. Consideration should also be given to the conversion of existing, free, high maintenance roads with the required petitioning of Congress presently requisite to such conversion. To consider this option, changes in Texas legislation may be required to permit community financial support for the sale of general obligation bonds to back toll financed projects.

Consideration should be given to the establishment of user-fee structures for the proposed construction of toll facilities, especially with regard to the motor carrier industry. Consultation with the industry is important if the new facilities are expected to receive their support. Methods developed in this report (such as use of the route share model) could be used to analyze the proposed user fees, but further data collected from candidate locations and potential users (particularly motor carriers) is needed for proper, site-specific analysis.

Suggestions for further research aimed at enhancing the results of this study and supporting SDHPT's activities in this area are given in the following section.

## SUGGESTIONS FOR FURTHER RESEARCH

Several topics included in the report suggest that further research is warranted. The route share model has been applied to only the one case year at the Dallas North Tollway, with major assumptions. Future research should include application of this model to estimate volumes and revenues at both rural and urban toll roads for various years of operation. In addition, some of the assumptions made in this study, which are consistent with the current planning practice, could benefit from further verification through such research. Another subject for additional study would be inputs to the route share model; in particular, direct assessments of values for travel time and operating cost are needed. Results of such work would enhance the capability of the methodology developed herein and its field implementation for the identification and evaluation of existing and proposed toll financing of highways in Texas. Finally, it should be noted that toll financing should be viewed as one mechanism in a total strategy comprising various mechanisms, including taxation, public-private participation, and others to maintain the State's infra-structure needed to sustain its economy and the public's mobility. The proper integration of these various mechanisms into an overall strategy constitutes a challenge and opportunity worthy of further research.

## REFERENCES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# APPENDIX A

# PUBLIC TOLL ROAD OPERATORS

## APPENDIX A

## PUBLIC TOLL ROAD OPERATORS

A - City of Colorado Springs (Colorado)
  Pikes Peak Auto Highway

B - Connecticut Department of Transportation
  Connecticut Turnpike
  Merritt Parkway
  Wilbur Cross Parkway

C - Delaware Turnpike Administration
  John F. Kennedy Memorial Parkway

D - Florida Department of Transportation
  East-West (Miami) Tollway
  Alligator Alley (Everglades Parkway)
  36th Street (Miami) Expressway
  Airport Expressway (Miami)
  Bucaneer Trail (Ocean Highway)
  South Dade Expressway
  South Crosstown Expressway (Tampa)

E - Florida Department of Transportation
  & Florida Turnpike Authority
  Florida's Turnpike

F - Florida Department of Transportation
  & Orlando-Orange County Expressway Authority
  Bee Line Expressway
  East-West Expressway

G - Jacksonville Transportation Authority (Florida)
  Jacksonville Toll Road

H - Illinois State Toll Highway Authority
  Northwest Tollway
  Tri-State Tollway
  East-West Tollway

I - Indiana Department of Highways
  Indiana East-West Toll Road

J - Kansas Turnpike Authority
- Kansas Turnpike
- 18th Street Expressway

K - Kentucky Turnpike Authority
- Western Kentucky Parkway
- Western Kentucky Parkway Extension
- Mountain Parkway
- Bluegrass Parkway
- Jackson Purchase Parkway
- Pennyrile Parkway
- Audubon Parkway
- Daniel Boone Parkway
- Cumberland Parkway
- Green River Parkway

L - Maine Turnpike Authority
- Maine Turnpike

M - Maryland Transportation Authority
- John F. Kennedy Memorial Highway

N - Massachusetts Turnpike Authority
- Massachusetts Turnpike

O - New Hampshire Department of Public Works and Highways
- New Hampshire Turnpike
- F. E. Everett Turnpike
- Spaulding Turnpike

P - New Jersey Expressway Authority
- Atlantic City Expressway

Q - New Jersey Highway Authority
- Garden State Parkway

R - New Jersey Turnpike Authority
- New Jersey Turnpike

S - New York State Thruway Authority
- Thomas E. Dewey Thruway (Main Line)
- Berkshire Section
- Niagara Section
- New England Section
- Garden State Parkway Connection

T - Ohio Turnpike Commission
- Ohio Turnpike

U - Oklahoma Turnpike Authority
- Turner Turnpike
- Will Rogers Turnpike
- H. E. Bailey Turnpike
- Indian Nation Turnpike
- Muskogee Turnpike
- Cimarron Turnpike

V - Pennsylvania Turnpike Commission
- Pennsylvania Turnpike
- Northeastern Extension

W - Texas Turnpike Authority
- Dallas North Tollway

X - Harris County Toll Road Authority (Texas)
- Hardy Toll Road
- West Belt Toll Road

Y - Richmond Metropolitan Authority (Virginia)
- Powhite Parkway
- Downtown Expressway

Z - Virginia Department of Highways and Transportation
- Richmond-Petersburg Turnpike
- Norfolk-Virginia Beach Toll Road
- Dulles Toll Road

AA - West Virginia Turnpike/Toll Road Commission
- West Virginia Turnpike/Toll Road

# APPENDIX B

# LISTING OF ROUTE SHARE MODEL

## APPENDIX B

## ROUTE SHARE MODEL LISTING

```
      PROGRAM PROTOLL
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS SECTION DIMENSIONS THE VARIABLES
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DIMENSION TOLL(10,10),CATCH(10,10),TVALUE(10)
      DIMENSION CAP(10),SPEED(10),FFTIME(10),TTIME(10)
      DIMENSION PROB(10,10),VOL(10),VOLN(10),DELTA(10)
      DIMENSION REV(10),COST(10,10)USERS(10),VCOST(10)
      DIMENSION ALPHA(10),BETA(10),DIST(10),U(10,10)

C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS SECTION READS THE DATA
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      CHARACTER*20 ID
      OPEN (UNIT=5, FILE='TOLLOUT')
      OPEN (UNIT=6, FILE='DATA')
      READ (6,10) M
      READ (6,10) N
 10   FORMAT(I1)
 11   FORMAT(F3.2)
      DO 100 I=1,M
      DO 100 J=1,N
      READ (6,12) TOLL(I,J)
      READ (6,12) CATCH(I,J)
 12   FORMAT(F4.2)
 100  CONTINUE
      DO 101 I=1,M
      READ (6,13) TVALUE(I)
 13   FORMAT(F5.2)
      READ (6,11) VCOST(I)
      READ (6,14) USERS(I)
 14   FORMAT(F6.0)
 101  CONTINUE
      DO 102 J=1,N
```

```
      READ (6,31) DIST(J)
 31   FORMAT(F4.1)
      READ (6,32) ALPHA(J)
      READ (6,32) BETA(J)
      READ (6,33) CAP(J)
      READ (6,34) SPEED(J)
 32   FORMAT(F3.1)
 33   FORMAT(F6.0)
 34   FORMAT(F3.0)
 102  CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS DO LOOP ECHOES SOME INPUT DATA
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 400 J=1,N
      DO 400 I=1,M
      WRITE (5,316) I,J,TOLL(I,J),CATCH(I,J)
 316  FORMAT(1X,'FOR USER GROUP ',I1,' ON FACILITY ',I1,
     @', THE TOLL IS $',F5.2,/,1X,'AND THE CALIBRATION',
     @' TERM "CATCH" IS $',F5.2)
 400  CONTINUE
      WRITE (5,999)
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS DO LOOP CALCULATES FREE FLOW TRAVEL TIME
C     AND INITIATES THE TRAVEL TIME VARIABLES
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      COUNT=0.
      DO 103 J=1,N
      FFTIME(J)=DIST(J)/SPEED(J)
      TTIME(J)=FFTIME(J)
      VOL(J)=0.
 103  CONTINUE
 1000 COUNT=COUNT+1.
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS DO LOOP CALCULATES THE COST OF TRAVEL
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 104 I=1,M
      DO 104 J=1,N
      COST(I,J)=TVALUE(I)*TTIME(J)+TOLL(I,J)
     @+VCOST(I)*DIST(J)
     @+CATCH(I,J)
 104  CONTINUE
C
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS DO LOOP USES THE LOGIT MODEL TO CALCULATE THE
C     PROBABILITY THAT A USER WILL CHOOSE A CERTAIN
C     FACILITY
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 106 I=1,M
      DO 106 K=1,N
      SUM=0.
      DO 105 J=1,N
      SUM=SUM+EXP(-COST(I,J))
 105  CONTINUE
      PROB(I,K)=EXP(-COST(I,K))/SUM
 106  CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS DO LOOP CALCULATES TRAVEL TIMES AND UPDATES
C     VOLUMES
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 108 J=1,N
      VOLN(J)=0.
      DO 107 I=1,M
      VOLN(J)=VOLN(J)+PROB(I,J)*USERS(I)
 107  CONTINUE
      VOL(J)=VOL(J)+(1/COUNT)*(VOLN(J)-VOL(J))
      TTIME(J)=FFTIME(J)*(1+ALPHA(J)*(VOL(J)/CAP(J))
     @**BETA(J))
 108  CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS DO LOOP CHECKS FOR CONVERGENCE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      IF(COUNT.EQ.1.)GO TO 1000
      DO 109 J=1,N
      DELTA(J)=VOL(J)-VOLN(J)
      D=ABS(DELTA(J))
      IF(COUNT.GT.200.)GO TO 109
      IF(D.GT.1.) GO TO 1000
 109  CONTINUE
C
C
C
C
C
C
C
```

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS SECTION CALCULATES AND PRINTS THE NUMBER OF
C     USERS FROM EACH GROUP ON EACH FACILITY ALONG WITH
C     COSTS OF TRAVEL AND SOME FURTHER ECHOES OF DATA
C     INPUT
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 110 I=1,M
      DO 110 J=1,N
      U(I,J)=PROB(I,J)*USERS(I)
      WRITE (5,200) I,J,U(I,J)
 200  FORMAT(1X,'THE NUMBER OF USERS FROM GROUP ',I2,
     @' ON FACILITY ',I2,' IS ',F6.0,' VPH')
      WRITE (5,203) I,J,COST(I,J)
 203  FORMAT(1X,'THE COST TO USER GROUP ',I1,
     @' ON FACILITY ',I1,' IS ',F5.2)
      WRITE (5,999)
 110  CONTINUE
C
      DO 501 J=1,N
      WRITE (5,502) J,DIST(J),ALPHA(J),BETA(J),CAP(J),
     @SPEED(J),TTIME(J)
 502  FORMAT(1X,'THE LENGTH OF FACILITY ',I1,' IS ',F4.1,
     @' ML., ','ALPHA = ',F3.1,' BETA = ',F3.1,
     @' CAP. = ',F6.0,' VPH, ',/,1X,'AND FREE FLOW',
     @' SPEED' = ',F3.0,' MPH... THE TRAVEL TIME = ',
     @F4.2,' HRS.')
      WRITE (5,999)
 501  CONTINUE
      DO 503 I=1,M
      WRITE (5,504) I,VCOST(I),TVALUE(I),USERS(I)
 504  FORMAT(1X,'FOR USER GROUP ',I1,' OPERATING ',
     @'COSTS = $',F4.2,' PER MILE, TIME VALUE = $',F5.2,
     @' PER HOUR',/,1X,'AND THE',' NUMBER OF USERS',
     @' PER HOUR IS ',F6.0)
      WRITE (5,999)
 503  CONTINUE
 910  CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS STATEMENT INDICATES CONVERGENCE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      WRITE (5,997) COUNT
 997  FORMAT(1X,'THE PROGRAM TOOK ',F6.2,' ITERATIONS',
     @' TO CONVERGE')
      WRITE (5,999)
      IF(COUNT.LT.200)GO TO 1001
      DO 1002 I=1,N
C
```

```
      WRITE (5,998) I,DELTA(I)
 998  FORMAT(1X,'DELTA ',I1,' = ',F10.5,'THE PROGRAM',
     @' DID NOT CONVERGE')
 1002 CONTINUE
      WRITE (5,999)
 1001 CONTINUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C     THIS SECTION CALCULATES AND PRINTS EXPECTED HOURLY
C     REVENUE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
      DO 60 J=1,N
      SUM=0.
      DO 70 I=1,M
      SUM=SUM+TOLL(I,J)*U(I,J)
 70   CONTINUE
      REV(J) = SUM
      WRITE (5,202) J,REV(J)
 202  FORMAT(1X,'THE EXPECTED REVENUE FOR FACILITY ',
     @I1,' IS $',F10.0)
  60  CONTINUE
      WRITE (5,999)
 999  FORMAT(1X)
      END
```

# APPENDIX C

## DATA SET USED TO APPROXIMATE CONDITIONS AT THE DALLAS NORTH TOLLWAY, 1981

## APPENDIX C

## DATA SET USED TO APPROXIMATE CONDITIONS AT THE DALLAS NORTH TOLLWAY, 1981

```
3         = # OF USER GROUPS
6         = # OF FACILITIES

.35       = TOLL(1,1)
0.        = CATCH(1,1)
0.        = TOLL(1,2)
0.        = CATCH(1,2)
0.        = TOLL(1,3)
0.        = CATCH(1,3)
0.        = TOLL(1,4)
0.        = CATCH(1,4)
0.        = TOLL(1,5)
0.        = CATCH(1,5)
0.        = TOLL(1,6)
0.        = CATCH(1,6)

.35       = TOLL(2,1)
0.        = CATCH(2,1)
0.        = TOLL(2,2)
0.        = CATCH(2,2)
0.        = TOLL(2,3)
0.        = CATCH(2,3)
0.        = TOLL(2,4)
0.        = CATCH(2,4)
0.        = TOLL(2,5)
0.        = CATCH(2,5)
0.        = TOLL(2,6)
0.        = CATCH(2,6)

.60       = TOLL(3,1)
0.        = CATCH(3,1)
0.        = TOLL(3,2)
0.        = CATCH(3,2)
0.        = TOLL(3,3)
0.        = CATCH(3,3)
0.        = TOLL(3,4)
0.        = CATCH(3,4)
0.        = TOLL(3,5)
0.        = CATCH(3,5)
0.        = TOLL(3,6)
0.        = CATCH(3,6)
```

| | |
|---|---|
| 5.00 | = TIME VALUE OF USER GROUP 1 |
| .06 | = OPERATING COSTS OF USER GROUP 1 |
| | = # OF USERS IN USER GROUP 1 (SEE BELOW) |
| 3.50 | = TIME VALUE OF USER GROUP 2 |
| .06 | = OPERATING COSTS OF USER GROUP 2 |
| 5330. | = # OF USERS IN USER GROUP 2 (SEE BELOW) |
| 25.00 | = TIME VALUE OF USER GROUP 3 |
| .15 | = OPERATING COSTS OF USER GROUP 3 |
| 615. | = # OF USERS IN USER GROUP 3 (SEE BELOW) |
| 10. | = LENGTH OF FACILITY 1 |
| 1.1 | = ALPHA PARAMETER FOR FACILITY 1 |
| 6.9 | = BETA PARAMETER FOR FACILITY 1 |
| 6000. | = CAPACITY OF FACILITY 1 |
| 55. | = FREE FLOW SPEED FOR FACILITY 1 |
| 10. | = LENGTH OF FACILITY 2 |
| 1.0 | = ALPHA PARAMETER FOR FACILITY 2 |
| 6.6 | = BETA PARAMETER FOR FACILITY 2 |
| 2400. | = CAPACITY OF FACILITY 2 |
| 40. | = FREE FLOW SPEED FOR FACILITY 2 |
| 10. | = LENGTH OF FACILITY 3 |
| 1.0 | = ALPHA PARAMETER FOR FACILITY 3 |
| 6.6 | = BETA PARAMETER FOR FACILITY 3 |
| 2400. | = CAPACITY OF FACILITY 3 |
| 40. | = FREE FLOW SPEED FOR FACILITY 3 |
| 10. | = LENGTH OF FACILITY 4 |
| 1.0 | = ALPHA PARAMETER FOR FACILITY 4 |
| 6.6 | = BETA PARAMETER FOR FACILITY 4 |
| 2400. | = CAPACITY OF FACILITY 4 |
| 40. | = FREE FLOW SPEED FOR FACILITY 4 |
| 10. | = LENGTH OF FACILITY 5 |
| 1.0 | = ALPHA PARAMETER FOR FACILITY 5 |
| 6.6 | = BETA PARAMETER FOR FACILITY 5 |
| 2400. | = CAPACITY OF FACILITY 5 |
| 40. | = FREE FLOW SPEED FOR FACILITY 5 |
| 10. | = LENGTH OF FACILITY 6 |
| 1.1 | = ALPHA PARAMETER FOR FACILITY 6 |
| 6.9 | = BETA PARAMETER FOR FACILITY 6 |
| 8000. | = CAPACITY OF FACILITY 6 |
| 55. | = FREE FLOW SPEED FOR FACILITY 6 |

NUMBER OF USERS FROM EACH USER GROUP

PEAK PERIOD (2 HOURS PER DAY - WEEKDAY ONLY)

| HEAVY DIRECTION - 70% | LIGHT DIRECTION - 30% |
|---|---|
| 1) 14555. | 1) 6238. |
| 2) 5330. | 2) 2284. |
| 3) 615. | 3) 264. |

DAY PERIOD (10 HOURS PER DAY)

| HEAVY DIRECTION - 70% | LIGHT DIRECTION - 30% |
|---|---|
| 1) 9230. | 3) 3956. |
| 2) 3380. | 2) 1449. |
| 3) 390. | 3) 167. |

NIGHT PERIOD (12 HOURS PER DAY)

| HEAVY DIRECTION - 70% | LIGHT DIRECTION - 30% |
|---|---|
| 1) 2556. | 3) 1095. |
| 2) 926. | 2) 401. |
| 3) 108. | 3) 46. |

# APPENDIX D

# EXAMPLE TOLL FACILITY FINANCIAL DATA

## APPENDIX D

## EXAMPLE TOLL FACILITY FINANCIAL DATA

TOLL AUTHORITY: MAINE TURNPIKE AUTHORITY (22)
FACILITY NAME: MAINE TURNPIKE
YEAR OPENED: 1947
LENGTH IN MILES: 100

EXPENDITURES
(IN 1985 $ PER MILE)

| | P | C | M |
|---|---|---|---|
| '84 | $69,961 | $6,812 | $128,549 |
| '83 | 58,598 | 8,347 | 28,294 |
| '82 | 59,259 | 5,812 | 33,325 |
| '81 | 64,258 | 4,606 | 47,038 |
| '80 | 63,732 | 7,159 | 50,712 |
| '79 | 66,010 | 9,806 | 70,550 |
| AVG | 63,636 | 7,090 | 59,745 |

REVENUES
(IN 1985 $ PER MILE)

| | T | Cp | Cm | I | O |
|---|---|---|---|---|---|
| '84 | $226,207 | $25 | $5,184 | $13,959 | $3,168 |
| '83 | 218,548 | 40 | 5,184 | 7,146 | 3,006 |
| '82 | 198,094 | 44 | 7,747 | 6,947 | 3,784 |
| '81 | 165,682 | 43 | 7,465 | 10,308 | 5,101 |
| '80 | 175,633 | 54 | 8,970 | 7,568 | 3,737 |
| '79 | 196,633 | | 11,354 | 6,468 | 1,910 |
| AVG | 196,799 | 41 | 8,060 | 8,733 | 3,451 |

AVERAGE TOTAL REVENUE = $217,043 (1985 $ PER MILE)
AVERAGE TOTAL EXPENDITURES = $130,471 (1985 $ PER MILE)
AVERAGE R/E = 1.66
AVERAGE P/E = .49
AVERAGE (P+M)/E = .95
AVERAGE (P+C)/E = .54

P = OPERATING COSTS
C = ORIGINAL CONSTRUCTION COSTS
M = MAINTENANCE COSTS

T = TOLL REVENUES
Cp = CONCESSIONS PER 1000 VEH.
Cm = CONCESSIONS PER MILE
I = INCOME FROM INVESTMENTS
O = OTHER INCOME

TOLL AUTHORITY: ILLINOIS STATE TOLL HIGHWAY AUTHORITY (23)
FACILITY NAME: ILLINOIS TOLL HIGHWAY SYSTEM
YEAR OPENED: 1956
LENGTH IN MILES: 256

EXPENDITURES
(IN 1985 $ PER MILE)

| | P | C | M |
|---|---|---|---|
| '84 | $141,050 | $112,397 | $327,397 |
| '83 | 130,104 | 63,387 | 409,948 |
| '82 | 124,705 | 68,362 | 273,456 |
| '81 | 121,274 | 47,657 | 266,750 |
| '80 | 129,487 | 85,679 | 269,762 |
| AVG | 129,324 | 80,896 | 309,463 |

REVENUES
(IN 1985 $ PER MILE)

| | T | Cp | Cm | I | O |
|---|---|---|---|---|---|
| '84 | $639,143 | $4 | $6,088 | $35,555 | $4,990 |
| '83 | 494,554 | 7 | 8,482 | 43,200 | 2,923 |
| '82 | 433,790 | 6 | 6,908 | 72,415 | 5,161 |
| '81 | 455,166 | 6 | 7,624 | 76,737 | -3,565 |
| '80 | 488,449 | 7 | 8,570 | 47,007 | 1,551 |
| AVG | 502,220 | 6 | 7,534 | 54,983 | 2,212 |

AVERAGE TOTAL REVENUE = $566,950 (1985 $ PER MILE)
AVERAGE TOTAL EXPENDITURES = $519,683 (1985 $ PER MILE)
AVERAGE R/E = 1.09
AVERAGE P/E = 0.25
AVERAGE (P+M)/E = 0.84
AVERAGE (P+C)/E = 0.40

P = OPERATING COSTS
C = ORIGINAL CONSTRUCTION COSTS
M = MAINTENANCE COSTS

T = TOLL REVENUES
Cp = CONCESSIONS PER 1000 VEH.
Cm = CONCESSIONS PER MILE
I = INCOME FROM INVESTMENTS
O = OTHER INCOME

TOLL AUTHORITY: NEW JERSEY TURNPIKE AUTHORITY (24)
FACILITY NAME: NEW JERSEY TURNPIKE
YEAR OPENED: 1951
LENGTH IN MILES: 131

EXPENDITURES
(IN 1985 $ PER MILE)

| | P | C | M |
|---|---|---|---|
| '84 | $481,904 | $445,651 | $196,349 |
| '83 | 448,732 | 335,401 | 193,037 |
| '82 | 409,220 | 357,549 | 195,459 |
| '81 | 377,735 | 387,556 | 188,000 |
| '80 | 376,868 | 440,188 | 192,486 |
| AVG | 418,892 | 393,269 | 193,066 |

REVENUES
(IN 1985 $ PER MILE)

| | T | Cp | Cm | I | O |
|---|---|---|---|---|---|
| '84 | $1,206,030 | $48 | $57,967 | $94,375 | $5,791 |
| '83 | 1,153,332 | 49 | 53,762 | 77,640 | 5,198 |
| '82 | 1,110,785 | 50 | 51,154 | 117,514 | 4,381 |
| '81 | 1,136,655 | 56 | 53,412 | 119,789 | 4,401 |
| '80 | 1,186,139 | 64 | 60,140 | 62,590 | 4,418 |
| AVG | 1,158,588 | 53 | 55,287 | 94,382 | 4,838 |

AVERAGE TOTAL REVENUE = $1,313,094 (1985 $ PER MILE)
AVERAGE TOTAL EXPENDITURES = $1,005,227 (1985 $ PER MILE)
AVERAGE R/E = 1.31
AVERAGE P/E = 0.42
AVERAGE (P+M)/E = 0.61
AVERAGE (P+C)/E = 0.81

P = OPERATING COSTS
C = ORIGINAL CONSTRUCTION COSTS
M = MAINTENANCE COSTS

T = TOLL REVENUES
Cp = CONCESSIONS PER 1000 VEH.
Cm = CONCESSIONS PER MILE
I = INCOME FROM INVESTMENTS
O = OTHER INCOME

TOLL AUTHORITY: OHIO TURNPIKE COMMISSION (25)
FACILITY NAME: OHIO TURNPIKE
YEAR OPENED: 1956
LENGTH IN MILES: 241.2

EXPENDITURES
(IN 1985 $ PER MILE)

| | P | C | M |
|---|---|---|---|
| '84 | $106,859 | $21,861 | $263,898 |
| '83 | 103,181 | 22,614 | 188,604 |
| '82 | 97,274 | 24,122 | 145,164 |
| '81 | 93,941 | 32,535 | 146,695 |
| '80 | 98,549 | 38,760 | 138,771 |
| '79 | 101,084 | 76,149 | 119,403 |
| AVG | 100,148 | 36,007 | 167,089 |

REVENUES
(IN 1985 $ PER MILE)

| | T | Cp | Cm | I | O |
|---|---|---|---|---|---|
| '84 | $294,823 | $177 | $18,762 | $18,365 | $10,505 |
| '83 | 288,917 | 183 | 18,846 | 15,850 | 10,796 |
| '82 | 274,915 | 216 | 21,213 | 15,031 | 11,896 |
| '81 | 219,358 | 192 | 19,838 | 15,707 | 5,642 |
| '80 | 228,844 | 317 | 30,624 | 16,154 | 6,928 |
| '79 | 273,574 | | 40,463 | 12,840 | 5,389 |
| AVG | 263,405 | 217 | 24,958 | 15,658 | 8,526 |

AVERAGE TOTAL REVENUE = $312,547 (1985 $ PER MILE)
AVERAGE TOTAL EXPENDITURES = $303,244 (1985 $ PER MILE)
AVERAGE R/E = 1.03
AVERAGE P/E = 0.33
AVERAGE (P+M)/E = 0.88
AVERAGE (P+C)/E = 0.45

P = OPERATING COSTS
C = ORIGINAL CONSTRUCTION COSTS
M = MAINTENANCE COSTS

T = TOLL REVENUES
Cp = CONCESSIONS PER 1000 VEH.
Cm = CONCESSIONS PER MILE
I = INCOME FROM INVESTMENTS
O = OTHER INCOME

TOLL AUTHORITY: TEXAS TURNPIKE AUTHORITY (26)
FACILITY NAME: DALLAS NORTH TOLLWAY
YEAR OPENED: 1969
LENGTH IN MILES: 10 (7 More under construction)
(Use 17 for C calculations after 1981)

EXPENDITURES
(IN 1985 $ PER MILE)

| | P | C | M |
|---|---|---|---|
| '84 | $267,606 | $1,071,145 | $62,442 |
| '83 | 245,544 | 1,112,343 | 55,296 |
| '82 | 232,522 | 1,176,351 | 59,272 |
| '81 | 220,578 | 302,769 | 52,284 |
| '80 | 214,251 | 284,969 | 49,699 |
| AVG | 236,100 | 789,516 | 55,799 |

REVENUES
(IN 1985 $ PER MILE)

| | T | Cp | Cm | I | O |
|---|---|---|---|---|---|
| '84 | $1,418,641 | 0 | 0 | $1,821,697 | $ 67 |
| '83 | 1,405,862 | 0 | 0 | 2,019,273 | 409 |
| '82 | 986,334 | 0 | 0 | 658,272 | 138 |
| '81 | 844,838 | 0 | 0 | 67,646 | 59 |
| '80 | 861,337 | 0 | 0 | 58,278 | 86 |
| AVG | 1,103,397 | 0 | 0 | 925,033 | 152 |

AVERAGE TOTAL REVENUE = $2,028,582 (1985 $ PER MILE)
AVERAGE TOTAL EXPENDITURES = $1,081,415 (1985 $ PER MILE)
AVERAGE R/E = 1.88
AVERAGE P/E = 0.22
AVERAGE (P+M)/E = 0.27
AVERAGE (P+C)/E = 0.95

P = OPERATING COSTS
C = ORIGINAL CONSTRUCTION COSTS
M = MAINTENANCE COSTS

T = TOLL REVENUES
Cp = CONCESSIONS PER 1000 VEH.
Cm = CONCESSIONS PER MILE
I = INCOME FROM INVESTMENTS
O = OTHER INCOME