LONG RUN CHANGES IN DRIVER BEHAVIOR

DUE TO VARIABLE TOLLS

A Thesis

by

KARUN KUMAR KONDURU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2003

Major Subject: Civil Engineering

LONG RUN CHANGES IN DRIVER BEHAVIOR
DUE TO VARIABLE TOLLS

A Thesis

by

KARUN KUMAR KONDURU

Submitted to Texas A&M University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Approved as to style and content by:

Mark W. Burris (Chair of Committee)	Laurence R. Rilett (Member)
Timothy J. Lomax (Member)	Paul N. Roschke (Head of Department)

December 2003

Major Subject: Civil Engineering

ABSTRACT

Long-Run Changes in Driver Behavior due to Variable Tolls.
(December 2003)
Karun K. Konduru, B.S., Sardar Vallabhbhai National Institute of Technology, India
Chair of Advisory Committee: Dr. Mark W. Burris

As many variable pricing projects are still in the implementation stage, long-run driver responses to the variable tolls are largely unknown. This research examined the long-run changes in driver behavior in an existing variable pricing project in Lee County, Florida. Using empirical evidence, it was found that over time the price elasticities of demand on the Lee County toll bridges have decreased from –0.42 to –0.11 (Midpoint Memorial Bridge) and from –0.31 to –0.06 (Cape Coral Bridge) during the early morning discount period. The elasticities have decreased, but to a lesser extent, during the late morning and early afternoon discount periods. A discount period volume spreading ratio was also developed to analyze these changes. The results from this analysis confirmed the elasticity results.

In addition to the empirical analysis of travel patterns discussed above, a telephone survey of drivers was conducted. The survey results indicated that certain driver characteristics such as higher frequency of trips, commute trip purpose, full-time employment status, more people in the household, higher education, and age between 25–34 years, were all indicators that the participant may increase his or her variable pricing usage over time. Other characteristics, including being retired and having a household income less than $16,000, were indicators that the driver may not increase variable pricing participation. Binary logit and semiparametric models were also developed to examine socio-economic and commute characteristics that may influence a driver increasing his or her participation in a variable pricing program.

The results from these two variable toll bridges in Lee County indicated a decrease in variable toll price elasticity over time. However, these results may not be typical for variable pricing projects. Factors such as alternative routes, different traveler demographics, traffic congestion levels, and size of the toll discount may influence the results obtained from other variable pricing projects. However, the methodology developed in this research can be applied to other projects in order to determine those toll price elasticities of demand.

ACKNOWLEDGMENTS

I would like to acknowledge the assistance of the professors in my department in general and members of my committee in particular, in conceptualizing my master's thesis. The chair of my advisory committee, Dr. Burris, worked with me in the precise solution of problems and in providing the theoretical background behind basic concepts in variable pricing and price elasticities of demand. Dr. Rilett reviewed the progress of my thesis at its various stages and gave valuable comments based on his vast experience in transportation planning and modeling. These comments gave me a basis for continually refining my document. Dr. Lomax made available to me vast resources of statistical data and also provided suggestions based on his experience in urban mobility studies and traffic congestion related problems.

This investigation of variable tolls was sponsored by the Department of Civil Engineering at Texas A&M University. The original project sponsors include the Federal Highway Administration's Value Pricing Pilot Program, the Lee County Board of County Commissioners, and the Florida Department of Transportation District 1. The author wishes to thank these agencies for their continued support and guidance throughout this project.

TABLE OF CONTENTS

Page

ABSTRACT……………………………………………………………………..…...iii

ACKNOWLEDGMENTS……………….……………………………………….……v

TABLE OF CONTENTS…………………………………………………………..…vi

LIST OF TABLES……………………………………………………………….….…ix

LIST OF FIGURES…..……………………………………………………………….xi

CHAPTER

I INTRODUCTION…………………………………………………………………..1

OVERVIEW..1
Traffic Congestion Problem 2
PROBLEM STATEMENT 7
PURPOSE AND SCOPE 8
RESEARCH OBJECTIVES 9
THESIS ORGANIZATION...10

II BACKGROUND……………………………………………………………………12

INTRODUCTION...12
PRICE ELASTICITY OF DEMAND..12
Elastic and Inelastic Demand 14
Importance of Price Elasticities of Demand...14
Measurement of Price Elasticity of Demand...15
PRICE ELASTICITY OF TRAVEL DEMAND 17
Components of Price Elasticity of Travel Demand...................................17
Toll Price Elasticities of Travel Demand 19
Empirical Evidence of Variable Toll Price Demand Elasticities 20
Impacts of Variable Tolls 23
Peak Spreading Analysis 24
Factors Affecting Price Elasticities of Travel Demand.............................27
Long-Run and Short-Run Elasticities of Travel Demand 28
SUMMARY 29

III THE LEE COUNTY VARIABLE PRICING PROJECT………………………31

CHAPTER Page

INTRODUCTION....31
PROJECT DESCRIPTION....32
Experimental and Control Groups....34
Changes in Traffic Pattern over Time....35
SUMMARY....49

IV ANALYSIS OF TRAFFIC VOLUME DATA....52

INTRODUCTION....52
TRAFFIC VOLUME DATA....53
Data Collection Effort....53
Data Reduction....53
Data Analysis....54
Traffic Flow Profile Estimation....54
Percentage Changes of Traffic Volume....68
Toll Price Elasticities of Demand....76
Price Elasticities of Demand Method 1....77
Price Elasticities of Demand Method 2....81
Price Elasticities of Demand Method 3....83
Peak Spreading Analysis....91
SUMMARY....100

V ANALYSIS OF TELEPHONE SURVEY DATA....102

INTRODUCTION....102
TELEPHONE SURVEY DATA....102
Data Collection Effort....102
Questionnaire Design....103
Description of Data....103
Description of Independent Variables in the Survey....104
Description of Dependent Variables in the Survey....105
Data Reduction....106
RESEARCH METHODOLOGY....109
Methodology for Explanatory Analysis....109
Discrete Choice Modeling Method....110
Binary Logit Modeling....110
Alternative Methodology....112
Analysis of Responses....114
Demographic Characteristics....117
Household Characteristics....119
Commute Characteristics....119
MODEL ESTIMATION....120

CHAPTER Page

SUMMARY 125

VI CONCLUSIONS AND RECOMMENDATIONS……………………………..127

SUMMARY 127
CONCLUSIONS...129
FUTURE RESEARCH 133

REFERENCES…………………………………………………….……………………..136

APPENDIX A……………………………………………………………….……………142

APPENDIX B……..……………………………………………………………………161

APPENDIX C……………………..……………………………………………………172

VITA……………………….……………………………………………………………..183

LIST OF TABLES

TABLE Page

1 Component shares in total price 19

2 Changes in Cape Coral traffic from 1998 to 2002 36

3 Changes in Midpoint Memorial traffic from 1998 to 2002 36

4 PrePay accounts 37

5 Relative changes of eligible traffic on Cape Coral Bridge 42

6 Eligible and ineligible traffic on Cape Coral Bridge (January-July) 61

7 Eligible and ineligible traffic on Midpoint Memorial Bridge (January-July)....62

8 Eligible and ineligible traffic on Cape Coral Bridge (August-December) 66

9 Eligible and ineligible traffic on Midpoint Memorial Bridge (August-December) 67

10 Percentage change in eligible traffic on Cape Coral Bridge 85

11 Percentage change in eligible traffic on Midpoint Memorial Bridge 86

12 Price elasticities of demand on Cape Coral Bridge....87

13 Price elasticities of demand on Midpoint Memorial Bridge 88

14 Discount period volume spreading model parameters…… 94

15 Discount period volume spreading ratios for January–July discount periods ..97

16 Discount period volume spreading ratios for August–December discount periods 98

17 Comparison between Lee County toll Bridge drivers and population....107

18 Socio-economic and commute characteristics of Lee County toll bridge drivers 115

TABLE Page

19 Variable pricing participation using binary logit model 121

20 Predicted values using binary logit model 123

21 Variable pricing participation using semiparametric model. 124

22 Predicted values using semiparametric model 125

LIST OF FIGURES

FIGURE Page

1 Growth in vehicle miles of travel vs. highway lane miles 3

2 Optimal pricing theory 6

3 Lee County variable pricing setting 33

4 Percentage of half-hourly eligible traffic on Cape Coral Bridge (January-July) 40

5 Percentage of half-hourly ineligible traffic on Cape Coral Bridge (January-July) 41

6 Relative changes of eligible traffic on Cape Coral Bridge (January-July) 43

7 Percentage of half-hourly eligible traffic on Cape Coral Bridge (August-December) 45

8 Percentage of half-hourly ineligible traffic on Cape Coral Bridge (August-December) 46

9 Relative changes of eligible traffic on Cape Coral Bridge (August-December) 48

10 Monthly traffic flow profile of eligible trips on Cape Coral Bridge 56

11 Monthly traffic flow profile of eligible trips on Midpoint Memorial Bridge 57

12 Comparison of eligible user traffic profiles on Cape Coral Bridge (January-July) 59

13 Comparison of eligible user traffic profiles on Midpoint Memorial Bridge (January-July) 59

14 Comparison of ineligible user traffic profiles on Cape Coral Bridge (January-July) 60

15 Comparison of ineligible user traffic profiles on Midpoint Memorial Bridge (January-July) 60

FIGURE Page

16 Comparison of eligible user traffic profiles on Cape Coral Bridge (August-December) ... 64

17 Comparison of eligible user traffic profiles on Midpoint Memorial Bridge (August-December) ... 64

18 Comparison of ineligible user traffic profiles on Cape Coral Bridge (August-December) ... 65

19 Comparison of ineligible user traffic profiles on Midpoint Memorial Bridge (August-December) ... 65

20 Eligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 1999) ... 69

21 Eligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 1999) ... 70

22 Eligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2002) ... 71

23 Eligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2002) ... 72

24 Eligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 1999) ... 73

25 Eligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 1999) ... 73

26 Eligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 2001) ... 74

27 Eligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 2001) ... 74

CHAPTER I
INTRODUCTION

OVERVIEW

The law of demand, which states that the higher the price of a good the less consumers will purchase, has been termed the "most famous law in economics, and the one that economists are most sure of" (*1*). To predict consumer behavior, economists use well-defined techniques to evaluate the sensitivity of consumers to a change in price. Such techniques, pioneered by the great British economist Alfred Marshall (1842–1924) in the early part of the last century, are the foundations of microeconomics. The law of demand addresses the first question related to consumer behavior: what is the relationship between price and quantity demanded for a good? Another important question in consumer behavior is: how much does demand change when the price of good changes by a given amount? The knowledge that quantity demanded decreases when price increases and increases when price decreases is useful for understanding and predicting consumer behavior. However, knowledge of the specific extent of such responses to price changes is even more useful and important. Price elasticity of demand can be used to describe the relationship between change in quantity demanded of a good and change in price.

Understanding and measuring price elasticity of demand has begun to play a more important role in transportation with the implementation of congestion pricing as a means to manage the ever-increasing demand for transportation infrastructure and services. To evaluate impacts of transportation pricing strategies, it is necessary to understand drivers' response to changes in price. Price elasticity of demand is an empirical measure which summarizes demand for a given highway facility at a given point of time in a single number (*2*). Price elasticities of demand are necessary for

---

This thesis follows the style and format of the *Transportation Research Record*.

cost/benefit analyses and are helpful to study motorist behavior. This need was an important motivation for this research.

To understand the importance of price elasticities of demand in transportation planning it is necessary to understand the extent of the traffic congestion problem and how variable pricing can be used to maintain traffic flow at an optimum level from an economical efficiency standpoint. Understanding price elasticity of demand plays a critical role in developing a tolling structure to achieve efficient traffic flow.

Traffic Congestion Problem

In the past few decades, traffic congestion in the United States has increased dramatically. The primary cause of this is shown in Figure 1. The growth in vehicle miles of travel (VMT) has far exceeded growth in highway lane miles since 1960. This rapid increase in vehicle miles of travel has caused many problems, primarily traffic congestion and environmental pollution. Potential solutions to the traffic congestion problem fall into two main categories:

1. Increasing capacity of the transportation infrastructure, and
2. Managing demand for the existing transportation infrastructure.

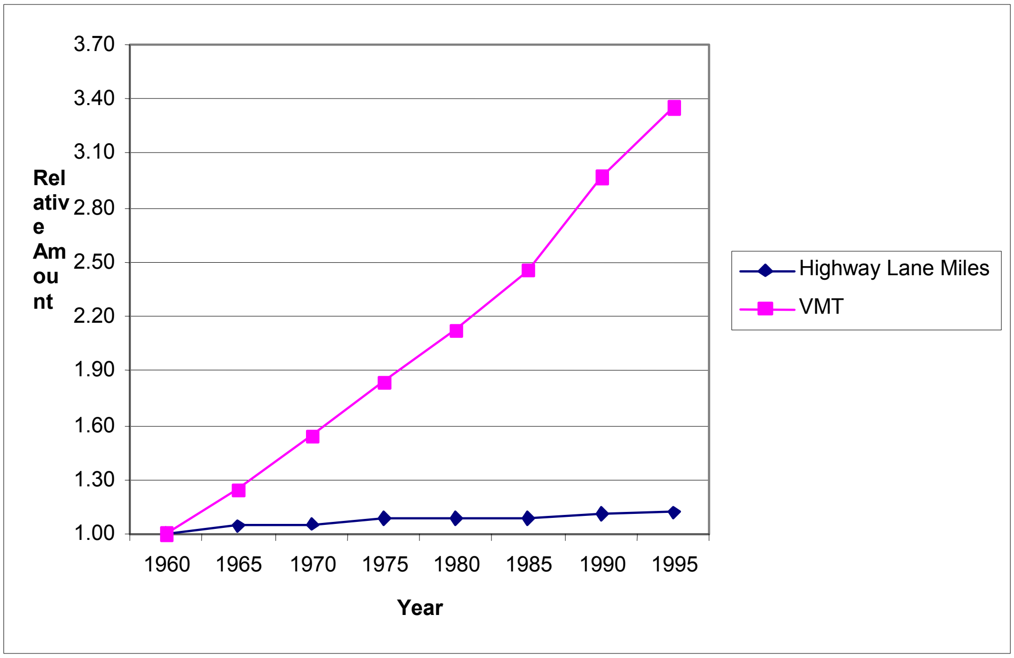

FIGURE 1 Growth in vehicle miles of travel vs. highway lane miles
Note: All values set to 1 in 1960 for comparison. Source: Bureau of Transportation Statistics, National Transportation Statistics

Although the first solution seems obvious, in the long run it may further worsen transportation problems. For example, increasing roadway capacity will result in more vehicles on the road due to induced travel demand, thereby increasing pollution levels and energy consumption (*3*). Also, addressing transportation problems in this manner may result in inefficient allocation of resources, as many roads will have excess capacity outside peak periods. The vast majority of highways in the United States are basically free of congestion for 20 hours of each day and the remaining 4 peak hours contribute to the majority of costs associated with congestion (*4*). In their study on 75 urban areas in the United States, Schrank and Lomax (2002) found that congestion-related costs alone were $68 billion per year in 2002 in these areas during peak periods (*5*). Therefore, the problem is not lack of capacity in the highway system but inefficient use of the available capacity. The above-mentioned problem has caused transportation engineers and planners to put more effort into researching the second option to solve transportation problems: managing demand for the existing transportation infrastructure.

Transportation demand management (TDM) is the combination of different strategies/techniques to increase efficiency of the transportation system by encouraging changes to drivers' travel behavior. TDM strategies are designed to reduce auto travel by encouraging drivers to:

- Switch mode from single-occupancy vehicle (SOV) to high-occupancy vehicle (HOV), transit, walking, or biking,
- Change time of travel to less congested times of day or change trips to less congested routes,
- Telecommute and/or telework, or
- Eliminate certain trips.

These strategies are primarily designed to reduce traffic during peak periods. This will enhance system efficiency by improving the level of service and safety as well as reducing queue length, delay, and peak-period vehicle emissions. However, this could increase some off-peak period vehicle emissions and travel times. But the increase in travel times during off-peak periods will be smaller than the decrease in peak-period travel times, hence resulting in an overall benefit to society as a whole. Thus, by using TDM strategies, policy makers can use available resources in the most efficient manner and either eliminate or postpone the need for costly capacity expansion.

Variable pricing is one of the most effective demand management strategies that target reducing peak-period vehicle trips. It is based on demand-based peak load pricing. Variable pricing is intended to change consumption patterns based on the principle of charging more for goods or services during peak periods and charging less during off-peak periods. For years, variable pricing has been successfully implemented in industry to reduce peak demand. Some of the best examples for variable pricing are ticket prices in the airline industry, differential pricing in the telephone industry, and early-bird specials at some restaurants.

Variable pricing projects on roads have been implemented across the United States. These projects are real-world manifestations of the optimal tolling theory developed in literature. Theoretically, individual drivers can decide whether to use a particular road facility or not by weighing the costs they will have to bear against their expected benefits. Social costs associated with the addition of a new vehicle into the traffic stream are not borne by the new user but by society as a whole. Extensive research has examined optimal pricing theory. In their research, Walters (1968), Small and Gomex-Ibanez (1994), and Hau (1992) attempted to develop an optimal toll by estimating full societal costs associated with a trip (*6, 7, 8*). These societal costs are primarily associated with the amount of time spent in congestion, and environmental costs, which are borne by society as a whole rather than by the individual user. To optimize net social benefits, the toll would be set to the difference in total societal costs caused by the trip and costs borne by individual driver, which is known as marginal cost pricing (*9, 10, 11*).

In Figure 2, OA is the fixed cost associated with a trip. At q_o total cost associated with the trip is OB. Below q_o (see Figure 2) the majority of all costs are borne by the user. However, when traffic volumes exceed this level, vehicles will impose costs on one another and also on society. In the absence of a toll, travel demand will increase to point q, and societal costs associated with this traffic level are indicated by point H and costs borne by individual driver is indicated by point G. Optimal traffic flow, q_{opt}, occurs at a point where the demand curve D-D intersects the marginal cost curve. At q_{opt} the total cost associated with the trip is P_2, whereas the costs borne by individual driver is P_1. At q_{opt} flow, any increase or decrease in traffic volume would decrease net societal benefits (*9*). To maintain traffic at q_{opt}, a toll (EF in Figure 2) would have to be levied on the driver. By charging this toll the user would bear the entire social costs associated with their trip.

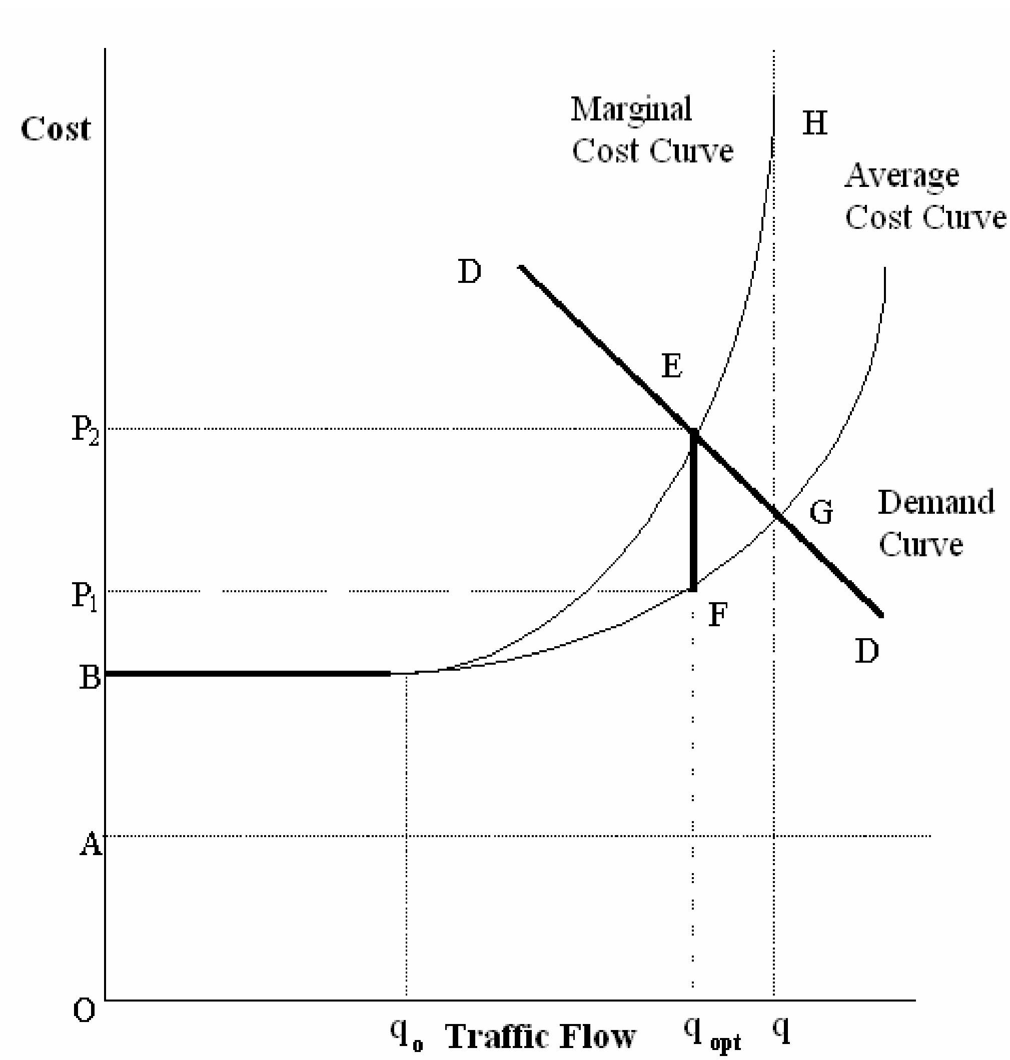

FIGURE 2 Optimal pricing theory

Variable pricing generally involves a toll that varies by the amount of traffic on the highway, with higher tolls during peak periods and lower tolls during off-peak periods. This variable toll can be set based on time of day targeting traditional peak hours based on a fixed daily and weekly schedule or they can be set based on the level of congestion that exists on a particular network at a particular point of time (in Figure 2 tolls are set based on the level of traffic). Recent technological advances have made both forms of variable tolling practical and cost efficient for implementation.

To determine the optimal size of the variable toll, which may vary by either time of day or level of congestion, information is required on drivers' willingness to pay and their responsiveness to price changes (*2, 3, 4, 7, 8, 9*). Drivers' responsiveness to price changes can be quantified in terms of their price elasticity of travel demand. An extensive amount of research has been conducted to estimate driver price elasticities of demand for such things as fuel, mode choice, and even flat-rate tolls (*2, 3, 7, 9*). However, limited research has been done to determine price elasticity of demand of variable tolls, whether it changes over time, and, if so, how it changes over time. This research analyzed how price elasticities of demand of drivers participating in a variable pricing program changed over time.

PROBLEM STATEMENT

Evaluation of any transportation project requires estimation of its expected impacts. Variable tolls can be effective in reducing congestion during peak periods, especially on congested urban highways. A variable pricing program may help reduce congestion by changing driver behavior.

One of the important objectives of any variable pricing project is to encourage some peak-period traffic to travel during off-peak periods. This change in time of travel from peak to off-peak periods that can be attributed to the variable toll often results in more efficient use of the highway.

However, due to lack of experience with variable pricing projects in the United States, there has been limited research conducted on changes in variable pricing program participation over time. Therefore, little is known with regards to the long-term impacts of price elasticities of demand associated with variable pricing programs. Some models have been developed that predict variable pricing participation based on socio-economic and commute characteristics (*4, 9, 12*). However, these models assumed driver behavioral responses to a change in price remain unchanged over time. If behavioral response does change over time then the accuracy of these estimates is in question. No model could be found in the literature that predicts variable pricing participation over time.

Proper evaluation of any variable pricing project requires examining individual variability in drivers' variable pricing participation over time by answering the following questions:

- Do drivers completely stop using the variable pricing program?
- Has a driver's participation increased/decreased/remained the same over time?
- Does the variable toll influence employment and housing locations?

Research described in this thesis will estimate changes in price elasticities demand over time and the influence of drivers' socio-economic and commute characteristics in changing their variable pricing participation over time. This understanding will improve the accuracy of variable pricing project evaluation.

PURPOSE AND SCOPE

The focus of this thesis is to assess long-run changes in driver behavior due to variable tolls, holding socio-economic and commute characteristics constant. It can be expected that a driver may change his/her participation in a variable pricing program due to the following:

- Changes in socio-economic and commute characteristics of drivers over time (like change in employment or housing location),
- Change in driver reaction to the variable pricing program over time without any significant change in other characteristics of a driver.

Considering the above factors it can be reasonably expected that a commuter may adjust his/her travel behavior over time to gain maximum benefits of a variable pricing program. The scope of this research was limited to analyzing how drivers reaction to variable pricing changes over time.

RESEARCH OBJECTIVES

This research had four objectives that were examined using data from the Lee County variable pricing program:

1. Calculate and compare price demand elasticities over time to ascertain whether there was any change in variable pricing participation over time.
2. Construct a model similar to a peak spreading model to evaluate impacts of variable pricing over time.
3. Identify variables that may impact changes in price elasticities of demand over time.
4. Develop a mathematical model to predict the impact of variable pricing on travel demand over time. The model will be based on the socio-economic and commute characteristics of drivers.

THESIS ORGANIZATION

Chapter I of this thesis introduces the concepts of price elasticity of demand, and the increasing role of elasticities in the context of variable pricing is discussed.

Chapter II presents a comprehensive review of literature related to the problem of traffic congestion and examines congestion/variable pricing projects. Literature specific to traffic congestion, variable pricing as an important transportation demand management strategy in reducing congestion, the impact of variable pricing program on travel demand, price elasticities of demand, peak spreading, and behavioral responses to price changes that occur over time were researched.

Chapter III includes an extensive description of the Lee County variable pricing project and preliminary analysis of changes in traffic patterns over time caused by the variable pricing project. This includes different payment options available to Lee County toll bridge drivers, description of eligible and ineligible patrons based on payment type, and a detailed description of different discount periods available to Lee County drivers.

In Chapter IV, traffic volume data collection procedures are introduced and a detailed description of the data is provided. Half-hourly traffic flow profiles are developed using data collected from 1998 to 2002 for the Lee County variable pricing project. In this chapter the percentage changes in half-hour traffic volumes are estimated using the traffic volume data. Different methods to calculate price elasticity of demand are discussed and elasticities over time are estimated using these methods and real-world data obtained from Lee County toll bridges. Also, a model similar to the peak spreading model is developed to evaluate the variable pricing project. Finally, results based on this analysis are presented.

Chapter V introduces the reader to the telephone survey data collected to gain additional insight into changes in driver participation in variable pricing program over time. The study included questionnaire design, categorization of data into different groups, and descriptive analysis to identify variables that may impact driver participation in a variable pricing program over time. Using standard statistical tests, variables which may influence changes in driver participation in a variable pricing program are identified. Next, a binary logit model and a semiparametric model are developed to predict changes in driver participation in a variable pricing program over time. Finally, results based on these models are discussed.

Chapter VI summarizes results, and important findings in this research are discussed in this chapter. Also in this chapter, recommendations for future research are presented.

CHAPTER II
BACKGROUND

INTRODUCTION

The success of any variable pricing project partially depends on the amount of traffic it diverts from peak periods to off-peak periods, the number of forgone trips, and trips changed to other modes and routes (*9, 13, 14*). Important questions remain regarding changes in driver response to variable tolls and the extent of his or her participation in a variable pricing program over time. The impact of variable pricing on driver behavior can be quantitatively measured using toll price elasticities of travel demand. Price elasticities can be used to evaluate the effectiveness of a variable pricing program. To successfully predict driver participation in any variable pricing project, it is important to understand the intricacies of driver behavioral responses. This chapter reviews the following information from past research projects:

- Concepts of price elasticity of demand,
- Price elasticities of demand in transportation,
- Important features of toll price elasticity of travel demand,
- Empirical evidence of variable toll price elasticities of demand in variable pricing projects implemented in the United States, and
- Change in driver behavioral response over time to a change in price.

PRICE ELASTICITY OF DEMAND

Price elasticity of demand is used to measure the change in price of a good to the change in quantity of the good demanded. It is defined as percentage change in quantity demanded divided by percentage change in price. In general, elasticity is denoted by 'E'. Equation 1 is the general equation for calculating price elasticity of demand.

$$E = \frac{dq}{dp} * \frac{p}{q} \qquad (1)$$

where,

dq = change in quantity demanded,

dp = change in price,

p = original price, and

q = original quantity demanded.

In calculating price elasticities of demand there is a difference in opinion about whether change in price and quantity are divided by initial price and quantity or by final price and quantity. Depending upon initial price and quantity and magnitude of change relative to these amounts, it is possible to obtain considerably different elasticity values. To offset this effect, some economists suggest using the average of initial and final price and quantity to calculate price elasticities of demand. In calculating elasticities in this research, initial values of price and quantity were used so that elasticity estimates were not artificially inflated, yielding more conservative elasticity estimates.

The slope of the demand curve is almost always negative, as price and quantity are inversely related. Hence, price elasticities of demand are almost always negative. However, they are generally denoted by their absolute value. Elasticity is a ratio and is dimensionless. This property allows us to compare elasticities among various goods and services. Elasticity can be classified as elastic ($|E| > 1$), inelastic ($|E| < 1$), and unitary elastic ($|E| = 1$), based on relative responsiveness of the good to price (*14, 15*).

Elastic and Inelastic Demand

If the demand for a good is price elastic then a percentage change in price will lead to an even larger percentage change in quantity demanded. For example, if a 10 percent rise in the price of a good leads to a 20 percent fall in demand, then price elasticity of demand is $20\% / 10\% = 2$. If a fall in price would lead to an infinite increase in quantity demanded or an increase in price would lead to quantity demanded falling to zero, then demand is infinitely elastic. If demand is price inelastic then a percentage change in price will lead to an even smaller percentage change in quantity demanded. Demand is infinitely inelastic if any change in price would have no effect on quantity demanded (*15, 16, 17*).

Importance of Price Elasticities of Demand

Based on toll price elasticity, tolls can be set in a variable pricing project to maximize toll revenue. However, in most of the implemented variable pricing projects, revenue maximization was not the primary objective. In the Lee County variable pricing program, the goal was to reduce the number of vehicles using toll bridges during rush hours and thereby use the bridges more efficiently (*18*). As travel demand on Lee County toll bridges is inelastic (*9*), reducing tolls during off-peak periods reduces total revenue. This loss in revenue can be weighed against travel time savings to those drivers who drive during peak periods. Also, using toll bridges more efficiently will either postpone or eliminate the need for costly capacity expansion.

Charging different customers different prices for the same good or service when price differences are not justified based on cost differences is known as price discrimination (*15, 19, 20*). Firms attempt to discriminate price because willingness to pay for service and price elasticities varies across consumers and raising price to some consumers while lowering it for others may increase total revenue. For price discrimination, firms should able to separate people with less elastic demand from those with more elastic demand. Airline pricing strategy is one of the best examples of price discrimination practice in industry (*19, 20*). The objective of this price discrimination in this project is to increase total system efficiency by diverting some peak-period trips to off-peak periods.

Measurement of Price Elasticity of Demand

Based on the method of measurement, price demand elasticities can be classified into different categories (*1, 2, 14, 16, 21*).

Elasticity can be measured as:

1. Arc Elasticity: Arc elasticity of demand calculates the ratio of percentage change in quantity demanded $\left(\left((q_1 - q_0)/q_0\right) \times 100\right)$ to percentage change in price $\left(\left((p_1 - p_0)/p_0\right) \times 100\right)$ using initial and final observations on price and quantity demanded. Equation 2 can be used to calculate arc elasticity of demand.

$$E_{Arc} = \frac{(q_1 - q_0)/q_0}{(p_1 - p_0)/p_0} \qquad (2)$$

where,

p_o= initial price,

q_o= initial quantity demanded,

p_1 = final price, and

q_1 = final quantity demanded.

2. Point Elasticity: Point elasticity of demand calculates the ratio of percentage change in quantity demanded to percentage change in price using observations at a single point on the demand curve (see Equation 3).

$$E_{Point} = \frac{dq}{dp} \times \frac{p_o}{q_o} \tag{3}$$

Elasticity with respect to time can be measured as:

1. Long-Run Price Elasticity of Demand: Economists define time period to calculate long-run elasticity as that in which a consumer can adjust all of his or her items of consumption or usage. Usually long-run elasticities in transportation are estimated for three to five years (*2, 9, 14, 21*).

2. Short-Run Price Elasticity of Demand: Economists define time period to calculate short-run elasticity as that in which a consumer cannot change all of his or her items of consumption. Usually, short-run elasticities in transportation are estimated for one to one and a half years (*2, 9, 14, 21*).

Elasticities with respect to change in demand of one good due to the change in price of another good can be measured as the cross-price elasticity of demand. It is defined as percentage change in demand of one good divided by percentage change in price of another good.

Proportional Elasticity: In case of transportation, increase or decrease in number of trips cannot be entirely attributed to the change in price of travel components. To account for overall growth in traffic the percentage of traffic during each half-hour can be examined from year to year. It should be noted that using the percentage of traffic during each half-hour provides the same results as using raw traffic volumes and factoring overall growth in traffic. Equation 4 was the general form of the equation used to calculate proportional elasticities in this thesis.

$$E_{\Pr oportional} = \frac{\left(\left(\left(V_x / V \right)_j - \left(V_x / V \right)_i \right) \Big/ \left(V_x / V \right)_i \right) \times 100}{\left(\left(p_j - p_i \right) / p_i \right) \times 100} \tag{4}$$

where;

V_x = Average daily traffic volume during a particular half hour period x,

V = Total average daily traffic volume,

p_i = Toll price during the analysis year i,

P_j = Toll price during the analysis year j.

PRICE ELASTICITY OF TRAVEL DEMAND

Components of Price Elasticity of Travel Demand

The total cost of a trip consists of several individual cost components, some of which cannot be measured directly in monetary costs, yet will significantly influence travel decisions. For example, travel time is an important component in the total cost of the trip and many times it will influence travel decisions more than the cost of fuel or tolls. These costs can be treated as disutilities and then be converted to an equivalent dollar price (*2*). By converting all the components to an equivalent dollar price, price elasticity of demand of individual components can be estimated. Total price elasticity of demand for highway travel can be estimated from price elasticity demands of individual travel components (*2*).

Drivers may react differently to changes in price for each component, which suggests that each component will have a different price elasticity of travel demand based on the share of the component in the total price of the trip and available substitutes or alternatives. The Highway Economic Requirements System (HERS) Technical Report, Appendix C (*2*) estimates the component shares of the trip in total cost (see Table 1).

The HERS Technical Report Appendix C and the *Transportation Demand Encyclopedia* by the Victoria Transport Policy Institute summarized the empirical evidence of price elasticities of various components of travel (*2, 14*). Hirschman (1995), Harvey (1994), and Mekky (1999) also estimated price elasticities of demand of automobiles and trucks (*22, 23, 24*). Burris (2003) summarized various studies related to price elasticities of travel components and found that elasticity estimates vary from –0.05 to –0.33 for various travel components (*9*).

TABLE 1 Component shares in total price

Component	Low Share* (%)	High Share* (%)
Fuel	8	36
Maintenance	9	48
Accidents and Insurance	7	37
Vehicle Ownership	18	54
Tolls	0	10
Parking	1	10
Travel Time	40	62

Low Share* and High Share* are estimated based on four different estimates used to measure total cost (Back-of-Envelope, Delucchi, Runzheimer, and FHWA). Source: Highway Economic Requirements System (HERS) Technical report Appendix C.

Toll Price Elasticities of Travel Demand

Two types of toll price elasticities of travel demand were discussed in available literary sources. Available literature on toll price elasticities of travel demand mainly dealt with elasticities based on a fixed toll, which does not vary by time of day or congestion level. Based on review of nine studies, Burris (2003) found that fixed toll price elasticity travel demand generally varied from –0.03 to –0.35 (*9*).

Given the lack of experience with variable pricing on toll roads or bridges, there was limited research available on variable toll price elasticity of travel demand based on empirical evidence. Burris (2003) reviewed four studies which estimate variable toll price elasticities and found that they varied from –0.16 to –1.0 (*9*). He also found that the absolute values of price demand elasticities were greater for tolls that vary by time of day or traffic level as compared to fixed-price tolls, as drivers have an added incentive to explore more options in scheduling their time of travel.

Empirical Evidence of Variable Toll Price Demand Elasticities

Under the Transportation Equity Act for the 21st Century (TEA-21), the Federal Highway Administration (FHWA) supported value/variable pricing project costs (*25*). Variable pricing projects in the United States can be broadly classified into three categories (*25*).

1. Higher peak-period tolls or lower shoulder peak-period tolls on existing toll facilities,
2. Conversion of HOV lanes to high-occupancy toll (HOT) lanes, and
3. Variable pricing on newly constructed lanes which also include HOT lanes.

Variable pricing was implemented for 3 months on the Hardy Toll Road in Houston, Texas, in 1990. In this variable pricing project, a 50 percent toll discount was offered from 10:00 a.m. to 2:00 p.m. The objective of this variable pricing project was to encourage traffic during off-peak hours. During this testing period, off-peak traffic (10:00 a.m. to 2:00 p.m.) increased by 20 to 40 percent (*9, 26*). Estimated elasticities were –0.4 to –0.8. As this project involved reduced tolls, it was unlikely that these elasticity values would include any abandoned trips (*9*). The increase in off-peak period traffic may have been due to changing time of travel of trips or, possibly, by induced travel. Although discounted tolls increased traffic volumes during the discount period, toll revenue fell by 28 to 41 percent (*26*) and was discontinued after 3 months.

Variable pricing was introduced in August 1998 on Cape Coral and Midpoint Memorial Bridges in Lee County, Florida. The variable toll offers a 50 percent discount during shoulder periods (6:30 a.m. to 7:00 a.m., 9:00 a.m. to 11:00 a.m., 2:00 p.m. to 4:00 p.m., and 6:30 p.m. to 7:00 p.m.) just before and after peak periods. These bridges did not have severe traffic congestion problem, but variable pricing was introduced as a proactive measure to reduce growth in peak-period traffic volumes (*27*). Initial research on this project showed that variable pricing had a positive impact in increasing traffic during the discount periods (*4, 9, 28, 29*). The increase in traffic during toll discount periods is primarily due to change of time of travel from peak period and non-shoulder periods of the day (*9*).

The Port Authority of New York/New Jersey introduced variable tolls in March 2001. Variable tolls offer motorists using E-Z pass a discount of $1.00 during off-peak periods. Peak periods are defined as 6:00 a.m. to 9:00 a.m. and 4:00 p.m. to 7:00 p.m. during weekdays and 12:00 noon to 8:00 p.m. on weekends. All other times, including public holidays, were considered off-peak periods (*30*). For automobiles the original toll schedule was $5.00 and from March 2001 they can drive for $4.00 during off-peak periods. According to the port authority, motorists responded well to variable tolls by reducing morning peak trips by 7 percent and evening peak trips by 4 percent while increasing the number of trips during off-peak periods (*31*). Estimated elasticities for morning and evening peak periods were –0.35 and –0.20, respectively.

The San Diego Association of Governments (SANDAG) board passed a resolution for a pilot program that allowed conversion of a high occupancy vehicle (HOV) lane to a high occupancy toll (HOT) lane. The project was implemented in two phases (*32*). In phase 1, which operated from December 1996 to March 1998, single occupant vehicles (SOVs) were allowed to use the existing HOV lanes on the I-15 express lanes for a monthly fee. This fee was initially $50.00 per month but later increased to $70.00 per month. In the second phase of the project, which commenced in March 1998, SANDAG implemented the FasTrak™ program. Under this program tolls vary dynamically from $0.50 to $4.00 in response to traffic conditions on the HOV lanes. On August 31, 1998, the maximum allowable tolls during off-peak periods were reduced between $0.75 and $2.00 in order to encourage FasTrak users to drive outside peak hours. Off-peak periods are defined as 5:45 a.m. to 7:00 a.m., 8:00 a.m. to 9:15

a.m., 3:00 p.m. to 4:30 p.m., and 5:30 p.m. to 7:00 p.m. time periods. The maximum toll during peak periods remained at the same level ($4.00). On the I-15 express lanes, drivers have several options: they may use the toll road, use the parallel free road, carpool, or avoid the trip altogether, which made calculation of toll price elasticities of demand complicated (*9*). SANDAG attempted to estimate price elasticities of demand related to FasTrak user time of travel. These elasticities were estimated based on the change in traffic volume at the maximum allowable toll. They found that for the morning peak period price change has significant impact on FasTrak users' time of travel, whereas for evening peak period there was minimal impact of price change on time of travel (*33*). Estimated elasticities for morning peak periods vary from –0.34 (9:00 a.m. to 9:15 a.m. time period) to –0.42 (8:30 a.m. to 9:00 a.m. time period).

In January 1998, in Houston, Texas, the HOV3+ (three or more passengers per vehicle required) lanes were converted to HOT lanes during peak periods. This value pricing program was known as the QuickRide program. Under this program, HOV2 (two or more passengers per vehicle) vehicles can use HOV3+ lanes during peak periods for a $2.00 toll (*34*). The objective of this program was to use excess capacity available in HOV3+ during peak periods, thereby increasing efficiency. For the QuickRide program, initially 180 users signed up and there was an increase of 25 percent in participation within a few months. As of April 2003, 1476 users were enrolled in the program. In this case price demand elasticities cannot be estimated, as initially the price was zero and percentage change in price is infinity (*9*). However, in April 2003, a discount of 50 percent in QuickRide toll was offered. This toll reduction increased the number of QuickRide trips by 17.6 percent. The estimated variable toll price elasticity of travel demand was –0.35.

In the median of State Route 91 (SR91) in Orange County, California, a four-lane toll facility was opened on December 27, 1995. Initially, SR91 was a privately funded project managed by the California Private Transportation Company (CPTC). On

January 10, 2003, the project was taken over by the Orange County Transportation Authority (OCTA). This is the first variable pricing electronic tolling project in the United States. The toll on this facility varies based on time of day and vehicle occupancy. Drivers traveling on SR91 have the option of using the express lanes or free lanes (*35*). On SR91 drivers have several options: they may use the toll road, change the route, mode, or time of travel, or they can eliminate the trip altogether. This choice gives rise to various components of toll price elasticities of travel demand. In his research report evaluating impacts of SR91 value pricing toll lanes, Sullivan (2000) estimated elasticities for time of travel and route choice using the logit model and elasticities for mode choice using the nested logit model (*12*). He estimated that price elasticities of demand for choice of route for a small increase in toll is approximately –0.7, for altering time of travel on express lanes is –0.9 to –1.0, and for change in mode from SOV to HOV is –0.05.

Impacts of Variable Tolls

Variable tolls can be effective in reducing congestion during peak periods, especially on congested urban highways. In a variable pricing project, any one of the following changes in traffic patterns or a combination of the following changes in traffic patterns can be observed (*9, 10, 36*):

- Change in route taken,
- Change in time of travel,
- Change in mode of travel,
- Elimination of trips that are valued less than costs associated with the trip,
- Linking of trips by combining more errands on a single trip,
- Change in destination, or
- Change in home/work location

On Lee County toll bridges, options are very limited to drivers, and changes in travel patterns are mainly due to the change in time of travel from peak periods to off-peak periods. Hence, these changes can be used to help evaluate effectiveness of the Lee County variable pricing project.

One of the main objectives in most of the variable pricing projects is to reduce peak-period traffic. The natural phenomenon of expansion of peak-period traffic to shoulders of peak periods as the level of congestion increases on the highway is known as peak spreading (*37*). Thus, the similarities warrant investigation of peak spreading analysis techniques for their applicability in estimating variable pricing program impacts.

Peak Spreading Analysis

The effectiveness of the Lee County variable pricing program in diverting peak-period traffic to shoulder peak periods may be analyzed using peak spreading equations. This analysis can be performed by comparing traffic volume changes of eligible and ineligible users in time periods adjacent to toll discount periods.

In 1998, Loudon et al. developed a peak spreading model that predicts reduction of peak-hour volumes on congested urban highways (*38*). This model was based on hourly volumes collected from 33 freeways and 16 arterials in 3 different states. Each of these locations had a 20 percent increase in traffic volume. The primary objective of this research is to incorporate the model developed into a large-scale traffic assignment and equilibrium system and use its results to produce more accurate peak-hour volume and speed estimates.

The model developed by Loudon et al. has two modeling components (*38*). The first component estimates percentage of travel that occurs by trip type during a 3-hour peak period. It is hypothesized that traffic level within this 3-hour peak period is relatively stable with respect to different levels of congestion. The second component estimates percentage of the 3-hour peak period volume that occurs during the peak hour. Data from 45 facilities were used in regression analysis to estimate the relationship between the peak hour to 3-hour peak-period volume ratio and volume to capacity (V/C) ratio of the 3-hour peak period. The peak spreading relationship was represented by the exponential equation:

$$P = 1/3 + A \times e^{B*(V/C)} \tag{5}$$

where,

P = the ratio of peak-hour volume to peak-period volume,
V = volume during the 3-hour period,
C = capacity, and
A, B = model parameters.

In the above equation, P is always greater than or equal to 1/3 and values for P can be calculated for demand to capacity ratios greater than one. The model parameters for collected data can be estimated through a transformation of the equation and an ordinary least-square regression.

In their research Ramsey and Hayden (1995) proposed a ratio to represent the degree of peak spreading on a roadway. This ratio is known as the peak spreading road efficiency percentage (PSREP). This ratio is similar to the peak-hour factor that can be applied to peak-period analysis (*39*). The calculation of PSREP for consecutive years indicates the peak spread over time (*39*).

Goodwin and Coombe (1996) developed a simple peak spreading model that can be applied iteratively in development of peak-hour trip matrices (*40*). In this model coefficients calculated for morning and afternoon peak periods were each derived from only six data points. Although both coefficients were statistically significant at a 95 percent confidence interval, the author suggests that more data be collected for further data points (*40*). The model developed by Goodwin and Coombe is represented by the following equation:

$$R = 1 - K * V^2 \tag{6}$$

where,

R = ratio of flow in the adjacent two half-hour periods to flow in the peak hour,

K = a calibrated coefficient specific to the chosen peak period (morning or evening), and

V = average peak-hour speed.

Barnes (1998) in her analysis developed several short-term and long-term approaches for developing a peak spreading model for the Seattle metropolitan area (*37*). She suggested that for the short term, a stand-alone static model that will estimate more realistic traffic profiles for congested conditions based on historical trends but not sensitive to characteristics of the driver is preferable. Bacquie and Wang (1997) developed a functional relationship between peak spreading and traffic congestion using the Greater Toronto area (GTA) (*41*). To develop a functional relationship, the ratio of peak-hour traffic to peak 3-hour traffic was observed for 11 years at screen lines and then this ratio was compared to the trend in traffic congestion at the screen lines.

The peak spreading model developed by Ramsey and Hayden was developed independent of the four-step modeling process. In this model, historical traffic volume data was used to calculate PSREP. This factor represents the traffic remaining on the highway during the peak periods for respective years. The decrease in value of PSREP for respective years indicates that there was natural diversion in time of travel from the peak periods to the adjacent time periods. Hence, this ratio represents how the peak spread over time. By applying similar methodology it was possible to calculate eligible traffic remaining during the adjacent discount periods over time.

Factors Affecting Price Elasticities of Travel Demand

Almost all available estimates in the literature suggest that price elasticities of travel demand for many travel components are less than one and are therefore inelastic. In transportation, total elasticity for travel demand is built from component elasticities, hence, a component price elasticity demand less than one can also be considered quite significant. Component price elasticities of demand in transportation are inelastic for the following reasons (*42, 43, 44*):

- There are not many substitutes available in transportation.
- In transportation, supply cannot be changed according to demand, in contrast to the putty model, where supply can be stretched according to demand (*42*).
- Demand for transportation is a derived demand, and is partially derived from land use patterns. Traveling itself many times is not an activity but is a means of achieving other activities. Elasticities are lower because there will be trade off between the utility of the trip purpose and disutility of the trip itself.
- In the short run a driver cannot change any of his input travel variables, whereas drivers have more opportunities to adjust their travel behavior over a period of time. Hence, long-run elasticities are, in general, more elastic than those of the short run (*2, 9, 10, 11, 16*).

Although transportation demand is a derived demand, drivers have several options. They may change their route to a free alternative route if one is available, carpool to avoid or reduce the toll, or change their time of travel. These options will lead to a wide range of price elasticities of demand. Depending upon the desired level of peak-period traffic flow, a toll that could reduce peak-period traffic by even 7 to 10 percent could be considered effective (*3, 45*). Also, price elasticities of demand of components tend to change over time (*9, 14, 21*), as drivers have more opportunities to adjust their travel input variables over a period of time.

Long-Run and Short-Run Elasticities of Travel Demand

As previously mentioned, in the long run drivers have more opportunities to change their travel behavior in response to a change in price. Hence, long-run elasticities tend to be higher than short-run elasticities. Economists consider the long-run period as the time in which a driver can change all of his/her input travel variables and the short run as the time period in which he/she cannot change all of his/her travel input variables (*14, 21*). However, in the reviewed literature, the time required to change travel input variables was determined by the individual author's discretion. In general, short-run elasticities were considered within one year of price changes and long-run elasticities were considered with in a span of three to five years (*2, 15*). Almost all available estimates in the reviewed literature suggest that long-run elasticities were at least twice those of short-run elasticities (*2, 7, 43, 46*). However, some authors suggest that research is needed to identify the impact of long-term travel behavior for variable pricing projects (*46*), as they are relatively new and there are few variable pricing projects implemented in the United States and worldwide.

The change in price elasticities of demand is not only due to travelers adjusting their travel input variables over time but may also be due to the change in driver response over time without any other changes. Several studies on driver behavior concluded that there is high variability in driver behavior over time and driver response to change in price may change over time, without changing any of his or her travel characteristics (*47, 48, 49*). This is in line with this research proposal's hypothesis that how drivers perceive variable tolls may vary over time even though socio-economic and commute characteristics remain constant.

SUMMARY

There are some studies in the reviewed literature that attempted to predict variable pricing program participation based on socio-economic and commute characteristics of drivers. Although these studies provide valuable insight into variable pricing program participation, ignoring long-term impacts of variable tolls on driver behavior may understate/overstate potential long-term impacts of a variable pricing program. This may in turn affect the cost benefit analysis of any variable pricing project. Long-run price elasticity of demand models can be developed by incorporating location choice and mode choice decisions in transport demand. As drivers may change their mode of travel or housing or employment location over time in order to take advantage of a variable pricing program, these factors may contribute significantly to model development. One more aspect that needs to be considered in developing any long-run model is variability in driver response to tolls. Over time, drivers' reaction to variable tolls may change without any change in either exogenous or endogenous variables of travel characteristics. Several behavioral studies support this notion (*47, 48, 49*).

The Lee County variable pricing project is a unique project, as congestion on the toll bridges was not excessive and driver participation in the variable pricing program primarily depended on the economic incentive of toll discounts. Toll discounts in the Lee County project were not sufficient to cause a significant change in mode of travel, location of housing, or employment location (*4, 9*). Hence, the change in driver participation in variable pricing programs over time can be primarily attributed to a change in driver perception toward toll discounts.

Prior to this research effort, it was not known how driver reactions to variable tolls change over time and what factors may influence these changes. This thesis examined changes in driver participation in variable pricing program over time and the influence of socio-economic and commute characteristics on changing variable pricing program participation. Results of this thesis should be beneficial in predicting the impact of variable tolls on driver behavior over time.

However, directly applying these results to any congested urban highway and/or highway with parallel free routes may understate potential impacts of variable pricing over time. Therefore, before applying these results to any variable pricing program, traffic congestion problem and the influence of parallel free routes needs to be considered. Nevertheless, this study may provide potentially useful insight for development of hypotheses that might explain changes in driver response over time to variable tolls in a variable pricing project.

CHAPTER III
THE LEE COUNTY VARIABLE PRICING PROJECT

INTRODUCTION

Data used in this thesis were obtained as a part of the Lee County variable pricing project. The Lee County variable pricing project is one of the few operational projects under FHWA's value pricing pilot program. Therefore, data used in this thesis were based on real-world responses of drivers to variable tolls.

The Intermodal Surface Transportation Efficiency Act (ISTEA) and subsequent legislation, TEA-21, provided funding for the study and development of programs pursuing alternative means of managing roadway congestion. In 1991, ISTEA started the congestion pricing pilot program, supporting the costs for implementing a small number of actual road pricing projects.

In an effort to both manage traffic congestion and better understand driver responses to variable tolls, variable pricing, a form of value pricing, was introduced on August 3, 1998, on two heavily traveled toll bridges in Lee County, Florida. In an effort to limit congestion during peak hours, drivers were charged a fee that varied with time of day. To help judge the success of this variable pricing project, driver response to this variable toll was continuously monitored and evaluated.

This chapter briefly describes different aspects of the Lee County variable pricing project. First, the variable pricing project setting is discussed briefly. Next, different groups of drivers, those who are eligible to get toll discounts (*eligible drivers*) and those who are not eligible to get discount tolls (*ineligible drivers*), were identified. Also, the impact of variable pricing on traffic volume over time was discussed.

PROJECT DESCRIPTION

Lee County is located along Florida's southwest coast. The population of Lee County is approximately 441,000 (*50*). The majority of the population resides in or near the cities of Cape Coral and Fort Myers. These two cities are separated by the Caloosahatchee River (see Figure 3). The majority of employment is in Fort Myers, and four bridges, Edison Bridge, Caloosahatchee Bridge, Midpoint Memorial Bridge, and Cape Coral Bridge, connect these two cities. Two of these bridges, Cape Coral and Midpoint Memorial, are tolled, and variable pricing was implemented on these two bridges only.

The current variable pricing program entitles Cape Coral and Midpoint Memorial Bridge users to receive a 50 percent toll discount during shoulder periods. These discount periods were chosen so that drivers traveling during peak periods could change their time of travel to shoulder periods to obtain toll discounts. Discount periods are from 6:30 a.m. to 7:00 a.m., 9:00 a.m. to 11:00 a.m., 2:00 p.m. to 4:00 p.m., and 6:30 p.m. to 7:00 p.m. Discount periods are limited to off-peak periods just before and just after peak periods but not during all off-peak periods. This minimizes revenue loss while encouraging drivers traveling in peak periods to change their time of travel. A discount toll during all off-peak periods was not economical and did not serve the purpose of reducing peak-period traffic. For example, drivers who normally traveled at 7:15 a.m. could have altered their time of travel to 6:45 a.m. to obtain the toll discount. However, it was unlikely that they would have changed their time of travel to a time earlier than 6:30 a.m. for a toll discount. The late morning and late afternoon discount periods are 2 hours in length, offering drivers more flexibility in scheduling their trip outside the peak period. However, to obtain these toll discounts drivers must pay tolls electronically.

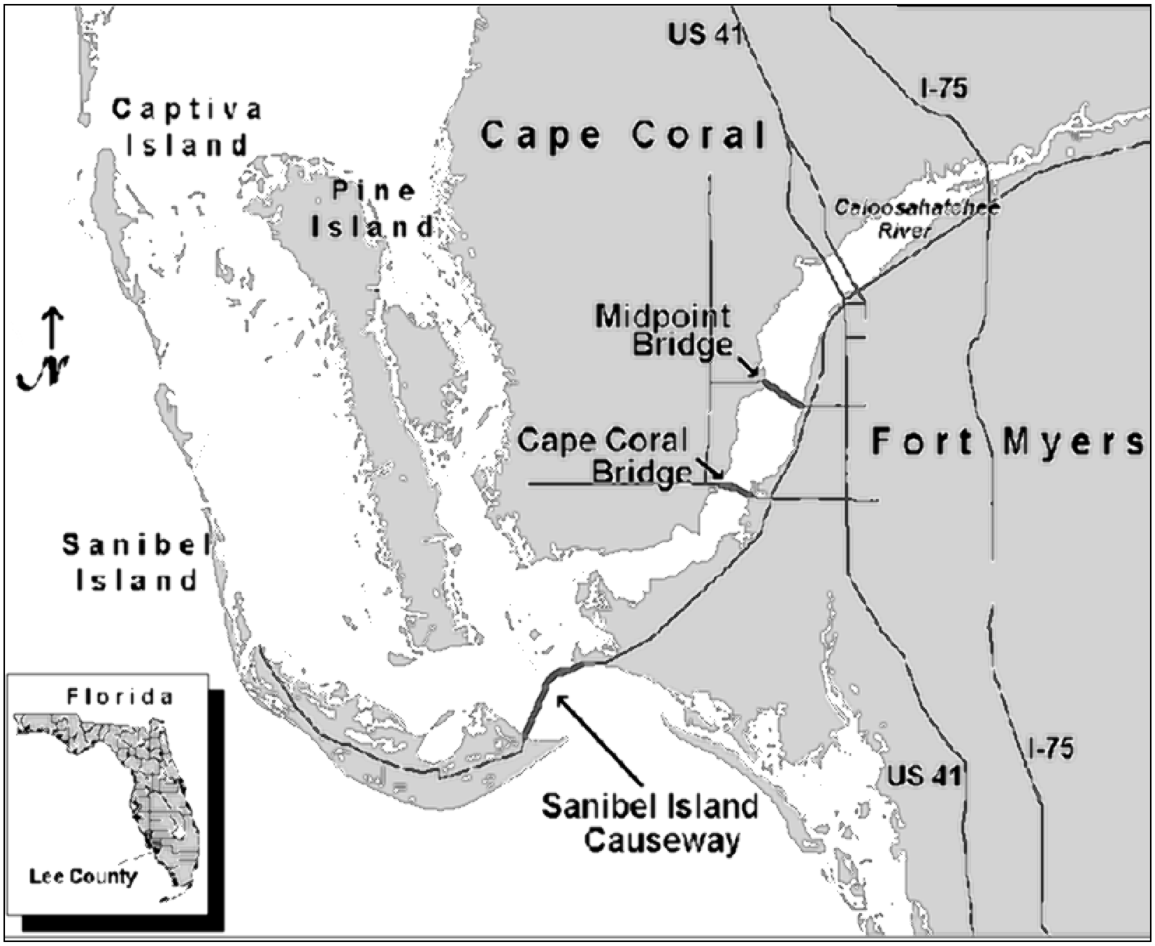

FIGURE 3 Lee County variable pricing setting
Source: Lee County Variable Pricing Project: Evaluation Report (*28*)

To pay tolls electronically, drivers must have a transponder, a small electronic device, on the windshield inside the vehicle. The transponder emits a low-frequency radio signal that is read by a receiver at the tollbooth. As the vehicle passes the tollbooth, the toll fee is electronically debited from the prepaid account (PrePay) administered by the tolling facility (LeeWay).

Experimental and Control Groups

Drivers in Lee County effectively have three methods of toll payment available to them. The entire range of payment options is rather complex. Drivers without a transponder and PrePay account must pay cash. Drivers with a transponder but no PrePay account must also pay in cash; however, if these drivers have enrolled in a frequent bridge user discount program they are eligible for a discount of 50 percent of their normal toll charge. To join frequent-user discount programs drivers must pay a fee of $40.00 per year, which allows them to pay only $0.50 instead of the regular $1.00 toll to cross either Cape Coral or Midpoint Memorial Bridges. For a fee of $330.00 per year drivers could purchase an unlimited trip program and can cross either of these bridges without paying any toll for one year.

The third payment method consists of drivers having both transponder and PrePay account (LeeWay PrePay). It is only these drivers that are eligible for variable pricing discount tolls. As long as there is a credit balance in their PrePay account, these drivers need not stop at the tollbooth for toll payment. As the vehicle passes through the tolling facility, toll fees are electronically debited from their PrePay account. Once an account balance falls to a predetermined level, a caution (yellow) light is displayed as the driver passes through the toll plaza. If there are insufficient funds a red light is displayed and drivers must stop and pay by cash for their trip.

PrePay account holders may also enroll in frequent bridge user discount programs. These drivers then receive a 50 percent discount on their program if they drive during variable pricing discount time periods. That is, drivers who have enrolled in a frequent user discount program and drive during discount periods save an extra $0.25 and drivers who have not enrolled in a frequent user discount program can get a $0.50 discount by driving during discount periods.

By limiting the variable pricing program to those users who pay tolls electronically, users were divided into two main groups. The first group was a control group that included drivers not eligible for variable pricing toll discount. The second group was an experimental group that included drivers eligible for variable pricing toll discount. Those drivers who have enrolled in an unlimited trip program were also included in the ineligible group (the control group), as the variable pricing program does not impact their toll rate and they are not likely to change their time of travel due to the toll discount.

The categorization of drivers into control and experimental groups helped in comparing changes in traffic patterns after the introduction of the variable pricing program. While analyzing the data, changes in traffic patters of eligible drivers (the control group) were compared to changes in traffic patterns of ineligible drivers (the experimental group). This comparison helps to control for traffic pattern changes caused by factors other than the variable pricing program.

Changes in Traffic Pattern over Time

If a variable pricing program could be considered successful, a large number of eligible drivers would shift their time of travel from peak periods to discount periods. In the Lee County variable pricing project there was a change in eligible patron traffic flow during the analysis period (1998–2002). Although, eligible users comprised only a small percentage (approximately 25 percent in 1998 and over 33 percent in 2002) of total traffic, their percentage during the analysis period gradually increased. As shown in Tables 2 and 3, percentage increase in trips by eligible drivers during the analysis period is much higher than percentage increase in total traffic and percentage of trips by ineligible users gradually decreased over time on Cape Coral Bridge and slightly increased on Midpoint Memorial Bridge.

TABLE 2 Changes in Cape Coral traffic from 1998 to 2002

Cape Coral Bridge						
Year	**# Crossings per Day**			**% Change w.r.t. to 1998**		
	Eligible	**Ineligible**	**Total**	**Eligible**	**Ineligible**	**Total**
1998	7,234	31,071	38,305	n/a	n/a	n/a
1999	9,769	30,284	40,053	35.0	-2.5	4.6
2000	11,322	30,498	41,820	56.5	-1.8	9.2
2001	13,718	30,360	44,078	89.6	-2.3	15.1
2002	16,730	29,206	45,935	131.3	-6.0	19.9

Average daily traffic was calculated using all weekday traffic.
Weekday traffic is calculated excluding weekends and public holidays.
For 2002, only January to July traffic was used to calculate average daily traffic

TABLE 3 Changes in Midpoint Memorial traffic from 1998 to 2002

Midpoint Memorial Bridge						
Year	**# Crossings per Day**			**% Change w.r.t. to 1998**		
	Eligible	**Ineligible**	**Total**	**Eligible**	**Ineligible**	**Total**
1998	5,920	25,725	31,645	n/a	n/a	n/a
1999	8,801	27,696	36,497	48.6	7.7	15.3
2000	10,631	29,408	40,039	79.6	14.3	26.5
2001	12,918	29,761	42,679	118.2	15.7	34.9
2002	15,830	29,923	45,753	167.4	16.3	44.6

Average daily traffic was calculated using all weekday traffic.
Weekday traffic is calculated excluding weekends and public holidays.
For 2002, only January to July traffic was used to calculate average daily traffic

This increase in number of trips over time may be result of one or combination of several factors:

1. An increase in number of trips taken by existing eligible users,
2. New bridge travelers obtaining a PrePay account and/or joining frequent-user

discount programs, and/or

3. Existing ineligible drivers enrolling in the toll discount programs, thus becoming eligible drivers.

As shown in Table 4, the increase in percentage of prepaid accounts in the analysis period suggests that the increase in trips by eligible users is partly due to new users enrolled in the toll discount programs. But as shown in Tables 2 and 3, the decrease in number of trips by ineligible users suggests that some existing drivers who did not have PrePay accounts may have obtained a PrePay account to take advantage of toll discounts and other values of ETC.

TABLE 4 PrePay accounts

Year	**Electronic Toll Collection Accounts (End of December)**		
	PrePay[A]	**Total[B]**	**PrePay (%)**
1998	21,081	44,349	47.5
1999	25,577	50,423	50.7
2000	29,727	56,321	52.8
2001	43,396	61,358	70.7
2002	47,151	61,664	76.5

[A] PrePay accounts are active accounts as of the respective month.
[B] Total number of accounts included unlimited trip program accounts, and non-PrePay accounts.

From the above discussion it can be concluded that the percentage of eligible patrons in total traffic is increased over time. However, this increase cannot be directly attributed to the variable pricing program. As mentioned previously, there are three subsets of drivers in the eligible drivers group (the experimental group):

1. Drivers obtaining a $0.50 discount by enrolling in a frequent-user discount program,
2. Drivers obtaining a $0.75 discount by enrolling in a frequent-user discount program and by changing time of travel to discount periods, and
3. Drivers obtaining a $0.50 discount by changing their time of travel to discount periods.

This thesis focuses on drivers who have changed their variable pricing participation during the analysis period (1998–2002) and examines how changes in variable pricing program participation differs by socio-economic and commute characteristics. To ascertain the impact of the variable pricing program on driver behavior, changes in traffic patterns of both eligible and ineligible drivers were compared. In particular, changes in traffic patterns during toll discount periods and peak periods were compared. Earlier research on this project proved that variable tolls had a effect on traffic (shifting peak period travelers to discount periods) in the year following introduction of the variable pricing program. If the impact of the variable pricing program has changed over time, changes in travel patterns of eligible drivers should be different from those of ineligible drivers over the period 1998 to 2002.

This analysis was accomplished by developing half-hour traffic flow profiles for the analysis period. For this analysis, traffic volumes from 1998 to July 2002 were compared. As the variable pricing program was introduced in August 1998, specific comparisons of traffic were made separately using data from January to July and from August to December. The shift in time of travel can be readily observed in Figures 4–9.

As 86 to 87 percent of total average daily trips on both Cape Coral and Midpoint Memorial Bridges occurred between 6:00 a.m. and 8:00 p.m., and variable pricing is intended to change time of travel of these trips, only these time periods were shown in the analysis. Moreover, comparison of January to July traffic during the analysis period is a comparison between traffic after introducing the variable pricing program and traffic prior to the variable pricing program, whereas all August to December comparisons are comparisons after introducing the variable pricing program.

Figures 4 and 5 show percentage of eligible and ineligible trips during each half-hour of the day for the January to July analysis period on the Cape Coral Bridge. It can be seen that eligible traffic increased during each discount period immediately after introducing the variable pricing program in January to July 1999. Eligible traffic decreased during many time periods adjacent to discount periods, which indicates that there is a shift in time of travel from these time periods to discount periods. Additionally, during January to July 1999, there were no changes found in ineligible traffic in discount periods. Indeed in some discount periods percentage of ineligible traffic decreased in comparison to January to July 1998 (see Figure 5).

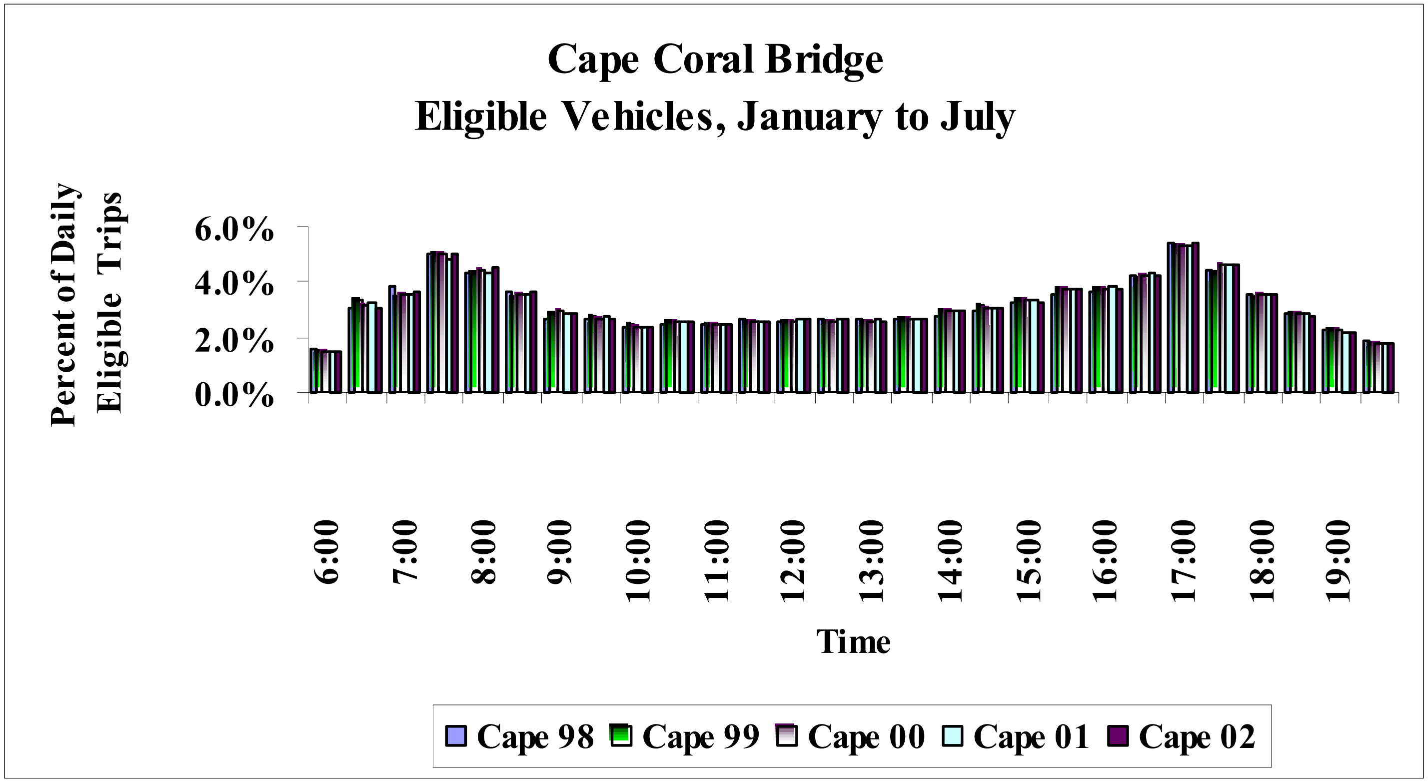

FIGURE 4 Percentage of half-hourly eligible traffic on Cape Coral Bridge (January-July)

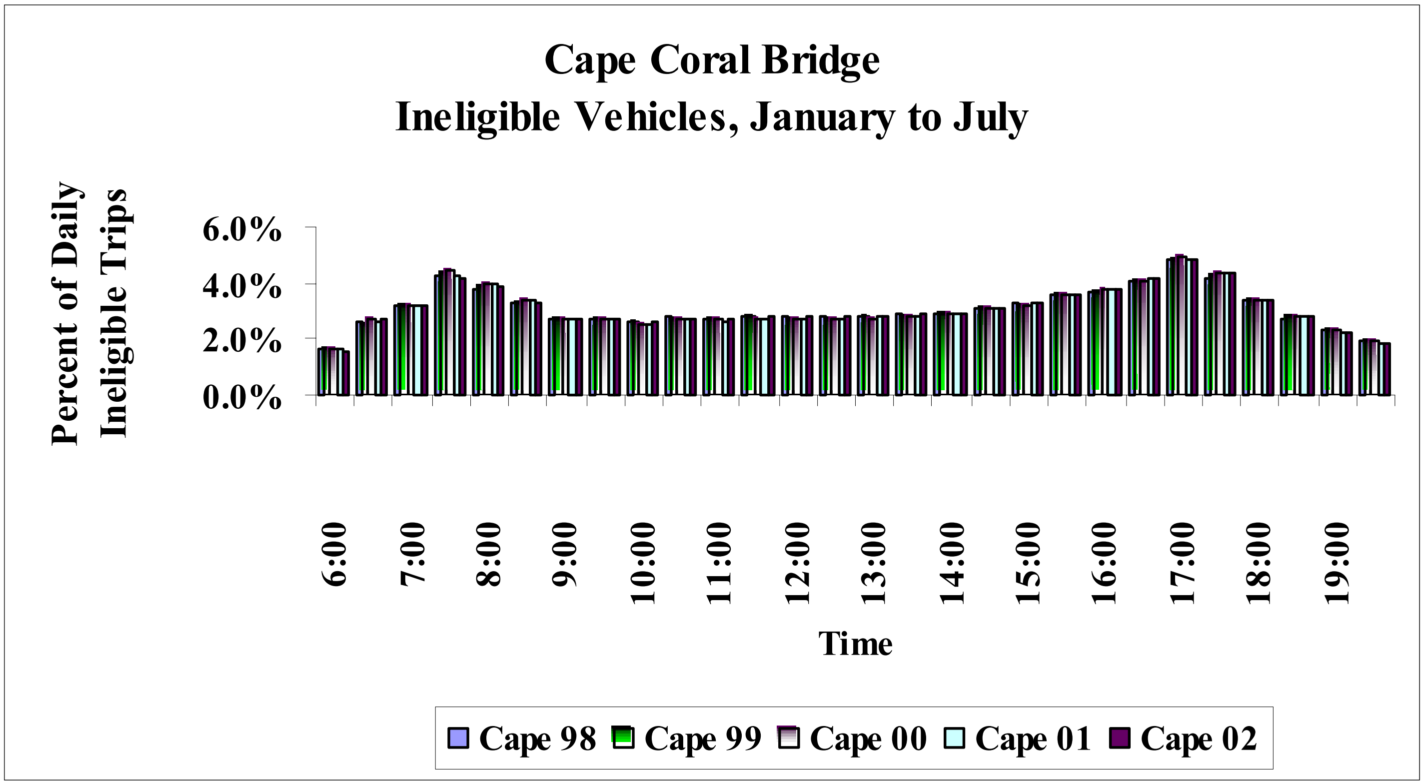

FIGURE 5 Percentage of half-hourly ineligible traffic on Cape Coral Bridge (January-July)

However, in many discount periods, the percentage of traffic gradually decreased after January to July 1999. To better illustrate how variable pricing impacts changed over time, relative percentage changes of eligible traffic over time were compared. Table 5 indicates relative percentage changes of eligible traffic on Cape Coral Bridge.

TABLE 5 Relative changes of eligible traffic on Cape Coral Bridge

Analysis Period	Cape Coral Bridge				
	Time Period	Relative Change of Eligible Traffic w.r.t. 1998			
		1999	2000	2001	2002
January–July	6:30-7:00 a.m.	13.7	4.3	6.5	0.7
	9:00-11:00 a.m.	5.9	6.8	6.5	4.6
	2:00-4:00 p.m.	6.8	5.2	5.1	3.6
	6:30-7:00 p.m.	-0.7	-0.5	-1.3	-4.0
August–December	6:30-7:00 a.m.	-8.1	-9.6	-16.0	n/a
	9:00-11:00 a.m.	-0.8	-0.7	-1.8	n/a
	2:00-4:00 p.m.	2.0	0.4	-1.0	n/a
	6:30-7:00 p.m.	-1.8	-1.8	-1.1	n/a

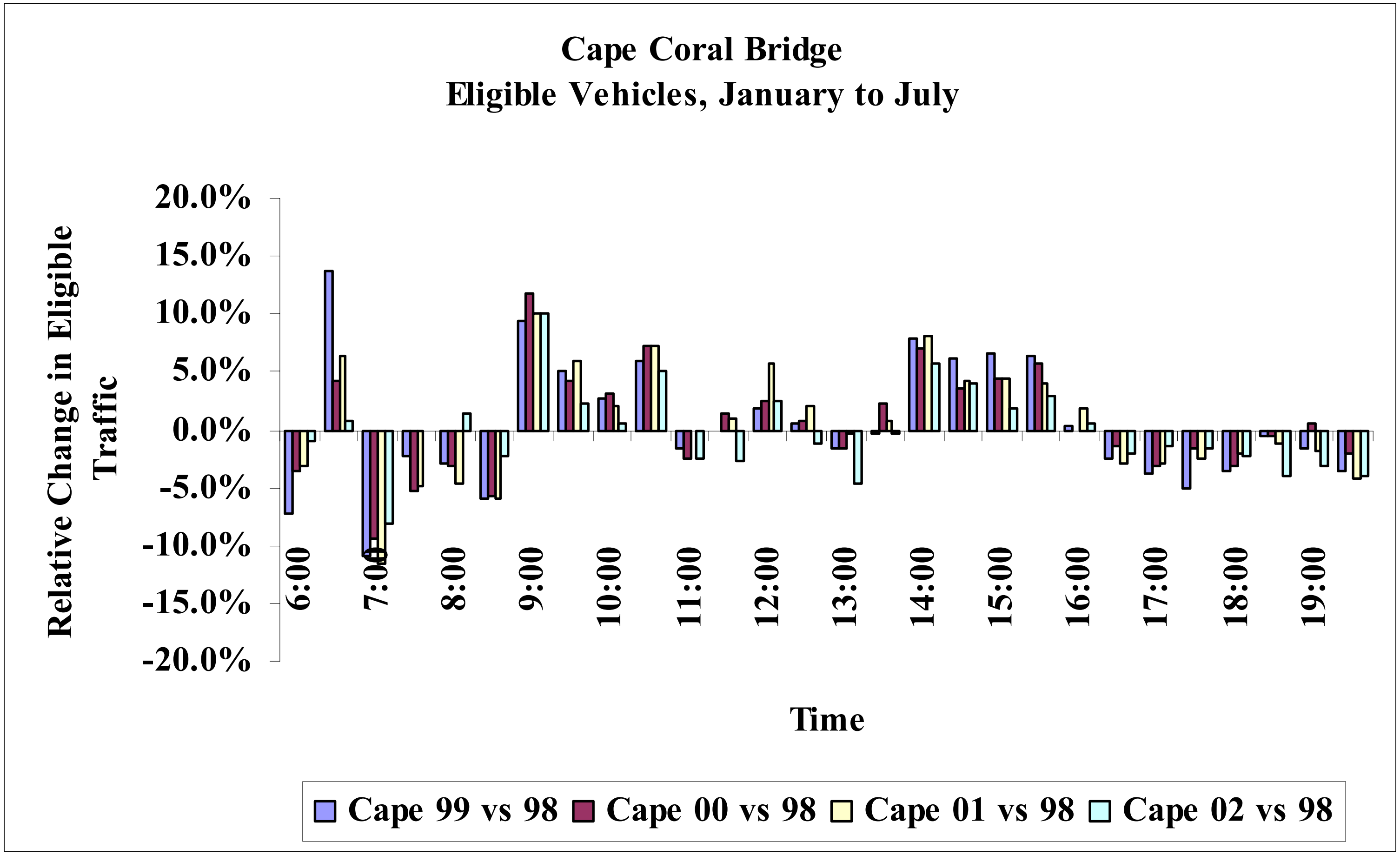

FIGURE 6 Relative changes of eligible traffic on Cape Coral Bridge (January-July)

These relative changes were calculated by subtracting the percentage change of ineligible traffic from the percentage change of eligible traffic. These percentage changes in eligible traffic were also graphically represented in Figure 6.

From Table 5 and Figure 6 it can be clearly seen that impact of variable pricing in changing time of travel decreased from 13.7 percent to 0.7 percent from January to July 1999 to 2002 during the 6:30 a.m. to 7:00 a.m. discount period. The discount toll did not have much impact during the 6:30 p.m. to 7:00 p.m. discount period. The impact during the 9:00 a.m. to 11:00 a.m. time period increased over time except for January to July 2002. The impact of variable pricing in encouraging off-peak traffic decreased during the 2:00 p.m. to 4:00 p.m. time period. In the January to July 2002 analysis period it can be clearly observed that there is a still 4.6 to 3.6 percent change in eligible traffic during the 9:00 a.m. to 11:00 a.m. and 2:00 p.m. to 4:00 p.m. discount periods respectively.

Figures 7 and 8 indicate the percentage of eligible and ineligible trips during each half-hour of the day on Cape Coral Bridge for the August to December time frame. As comparisons do not include a time frame prior to variable pricing program implementation, these graphs only represent variable pricing usage over time.

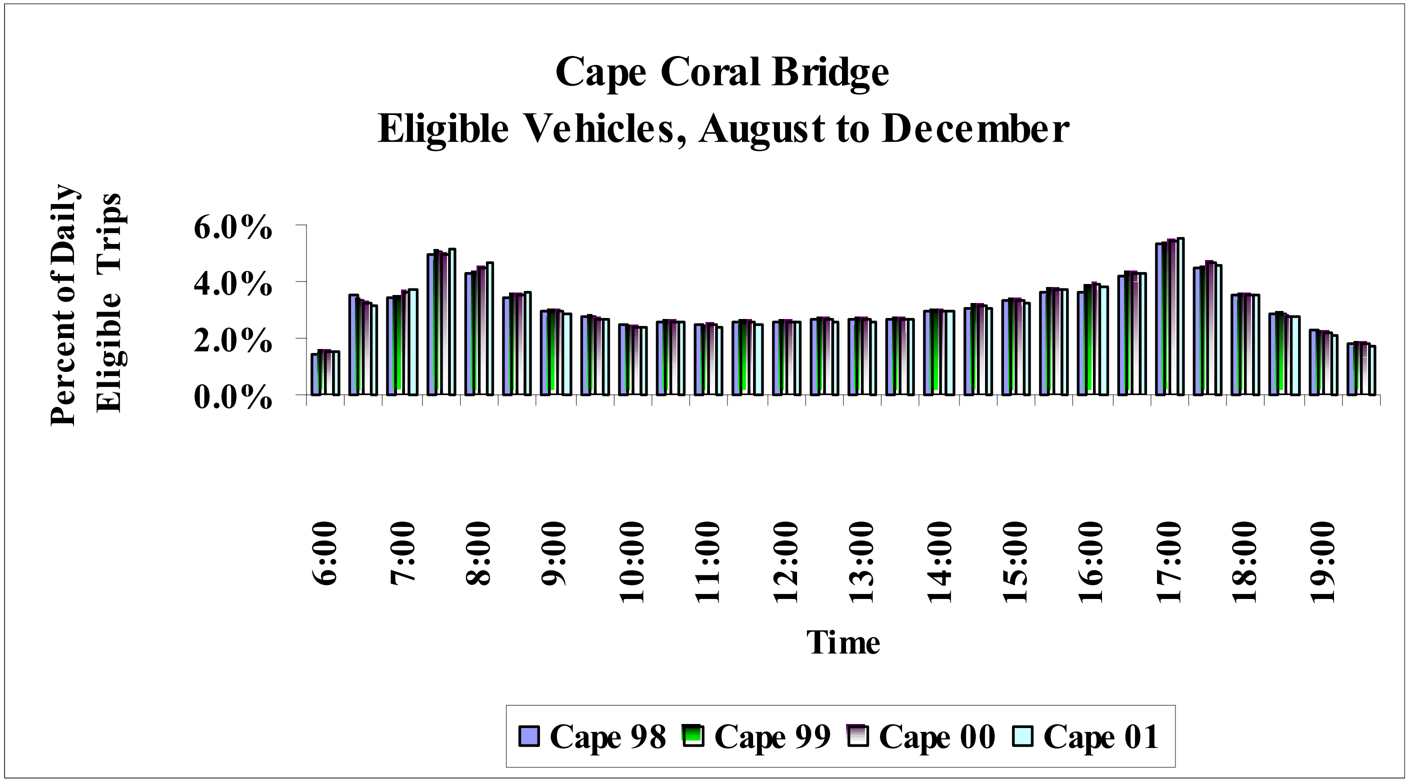

FIGURE 7 Percentage of half-hourly eligible traffic on Cape Coral Bridge (August-December)

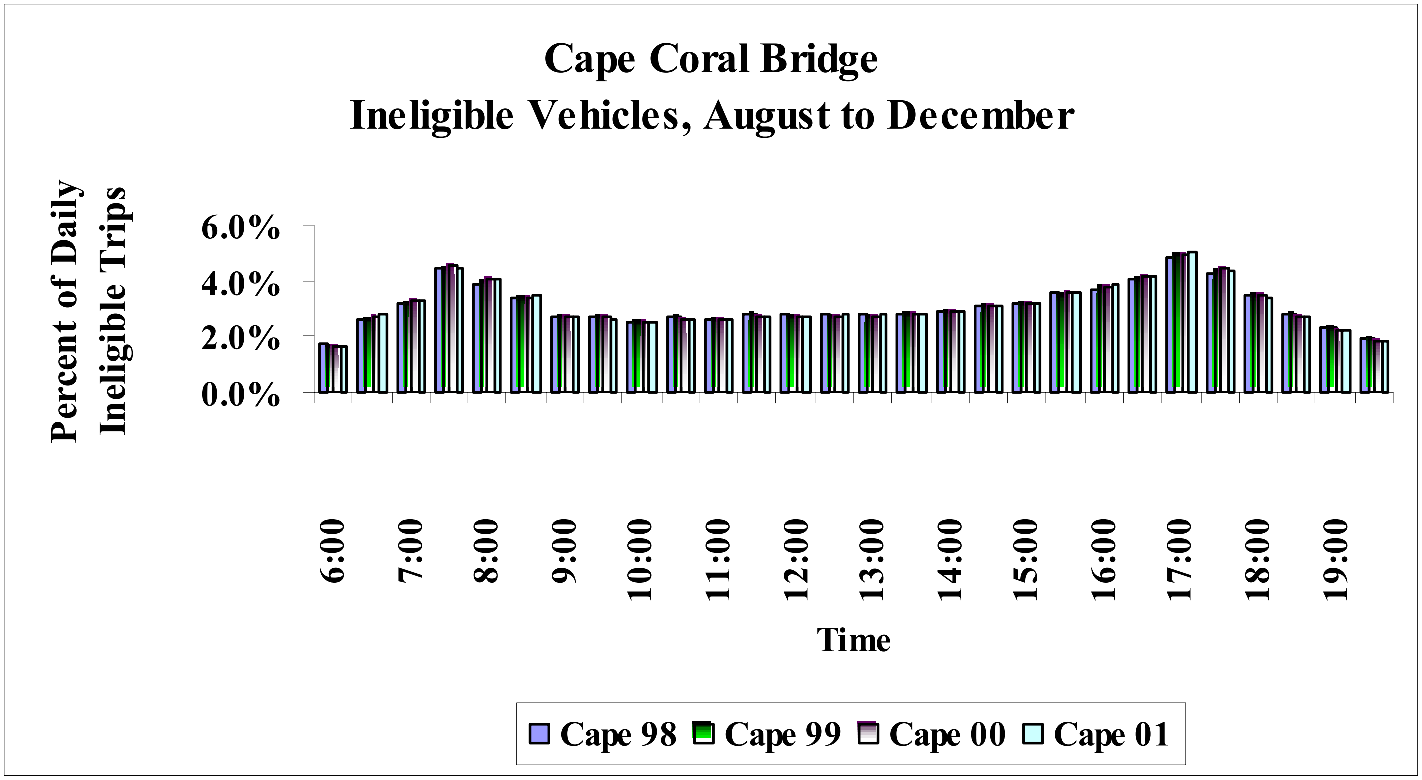

FIGURE 8 Percentage of half-hourly ineligible traffic on Cape Coral Bridge (August-December)

From these graphs it can be seen that eligible traffic decreased during the 6:30 a.m. to 7:00 a.m. discount period. In this discount period eligible traffic decreased from 3.6 percent in August to December 1998 to 3.2 percent in August to December 2001 (indicating 11.1 percent decrease). It is possible that drivers responded positively immediately after introducing the variable pricing program but subsequently decreased their participation. During August to December 1999, compared to 1998, the percentage of eligible traffic increased only during the 2:00 p.m. to 4:00 p.m. time period but these percentages decreased for subsequent years. The percentage of ineligible traffic during the 6:30 a.m. to 7:00 a.m. time period increased during August to December 2002.

These changes can be better represented by calculating relative percentage changes of eligible traffic over time. Table 5 indicates relative percentage changes of eligible traffic for the August to December time frame. These percentage changes were also graphically illustrated in Figure 9.

From Table 5 and Figure 9 it can be clearly seen that the impact of variable pricing decreased during the 6:30 a.m. to 7:00 a.m. time period on Cape Coral Bridge during the August to December time frame. Especially during the August to December 2001 analysis period eligible traffic decreased by 16 percent compared to August to December 1998. As these trips were during early morning, they were likely to be commute trips. It is possible that home to workplace trips have less flexibility in changing time of travel. The relative percentage change in eligible traffic is within the range of 2 percent for all other discount periods. This supports the earlier finding that the impact of variable pricing was not decreased during the 9:00 a.m. to 11:00 a.m. and 2:00 p.m. to 4:00 p.m. time periods in comparison to the 6:30 a.m. to 7:00 a.m. time period.

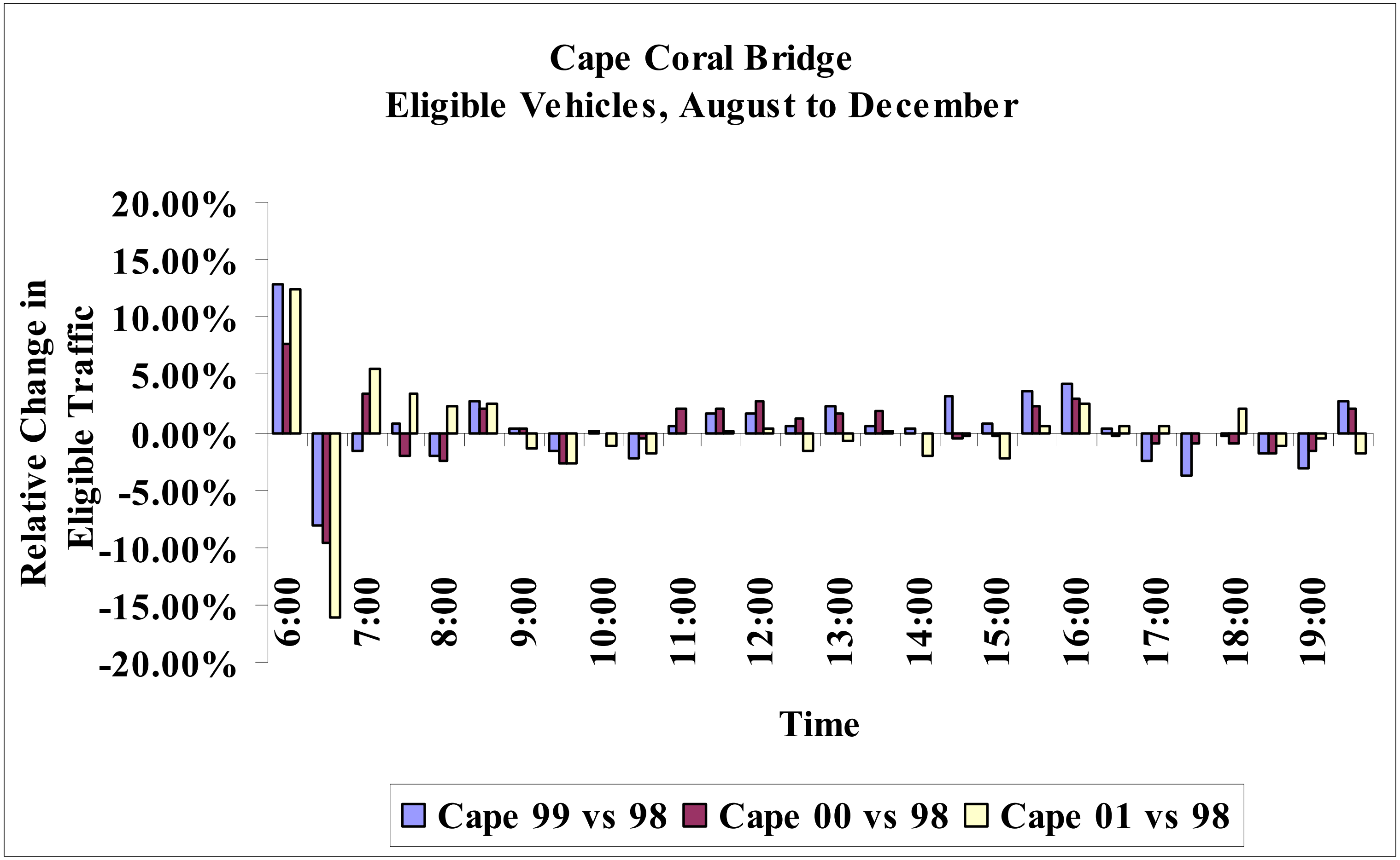

FIGURE 9 Relative changes of eligible traffic on Cape Coral Bridge (August-December)

Traffic pattern on Midpoint Memorial Bridge was similar to the Cape Coral Bridge except that on Midpoint Memorial Bridge there was a high growth in both eligible and ineligible traffic over the years. However, when relative changes in percentage of eligible traffic was considered the traffic pattern was similar on both the bridges. These changes in percentage of eligible traffic on Midpoint Memorial Bridge were discussed in Chapter IV along with changes on the Cape Coral Bridge while analyzing the traffic volume data.

Overall it was found that more trips were altered their time of travel in the early morning (6:30 a.m. to 7:00 a.m.) discount period than in the late afternoon (6:30 a.m. to 7:00 a.m.) discount period. This was similar to results found on SR91 in that flexibility in the morning peak period was higher than the evening peak period (*34*). In general, the initial response to variable pricing included shifts in time of travel of many eligible bridge patrons. However, this impact decreased over time in many toll discount periods. The remainder of this research focuses on quantifying and explaining these changes.

SUMMARY

This chapter examined the Lee County variable pricing project. Various payment options in the Lee County variable pricing project were discussed, and based on these options, drivers were classified into eligible and ineligible patrons. In analyzing the data, the eligible group was used as the experimental group and the ineligible group as a control group. Half-hourly traffic flow profiles were developed using data collected for the 5 years from 1998 to 2002 on bridges where the Lee County Variable pricing project was implemented.

Preliminary analysis clearly indicated that the total number average daily trips by eligible patrons increased over time. It was also found that initially the variable pricing program had maximum impact in changing time of travel during 6:30 a.m. to 7:00 a.m. time periods on both Cape Coral and Midpoint Memorial Bridges. However, this impact decreased for subsequent years. In general, variable pricing did not have an effect on travel during the 6:30 p.m. to 7:00 p.m. time periods on either Cape Coral or Midpoint Memorial Bridges. It is likely that flexibility in changing time of travel is higher during early morning discount periods than late evening discount periods. It can be surmised that although eligible patrons initially considered small toll savings such as $0.25 or $0.50 to be worth a change in travel behavior, their perception toward these savings has changed over time; hence, their participation in the variable pricing program has changed.

The initial response of eligible patrons to toll discounts during the 2:00 p.m. to 4:00 p.m. time period has not faded considerably over time on both Lee County toll bridges. The same can be said during the 9:00 a.m. to 11:00 a.m. discount period on Cape Coral Bridge. Conversely, in this time period on Midpoint Memorial Bridge eligible patron participation in the variable pricing program has decreased over time.

It would be possible to apply these observations to other potential variable pricing projects. However, direct application of these observations may not accurately predict the impact of variable pricing over time in shifting time of day in many other projects for the following reasons:

- In the Lee County variable pricing project the toll discount is fixed based on time of day. However, in other variable pricing projects in which tolls vary based on level of traffic, impacts of variable pricing in shifting time of travel is higher (*31, 33*).
- In Lee County, most eligible patrons get a toll discount of $0.25 by driving in discount shoulder periods. If the discount was more, then the impact of variable pricing might be higher (*26, 31, 33*).
- As the variable pricing program was based on reduced tolls, there were no

abandoned trips. However, if the variable pricing program was based on increased tolls, some drivers may abandon trips.

CHAPTER IV
ANALYSIS OF TRAFFIC VOLUME DATA

INTRODUCTION

As outlined in previous chapters, the goal of this research is to analyze changes in variable pricing participation over time to better understand long-run impacts of variable pricing. Previous research on variable pricing projects examined the relationship between driver characteristics and their participation or non-participation in a variable pricing program near its time of implementation. No research has examined how participation in a variable pricing program has changed over time. Therefore, the analysis in this chapter helps in understanding how variable tolls impact driver participation in a variable pricing program over time, which is necessary to fully understand the costs and benefits of any variable pricing project.

To obtain this relationship it was necessary to collect traffic volume data on Lee County toll bridges to calculate daily traffic flow profiles for each year. Traffic volume data were collected for 5 years from 1998 to 2002 on Lee County bridges where a variable pricing project was implemented. In this chapter the following analysis were described:

1. Description of estimated traffic flow profiles,
2. Description of percentage changes in eligible and ineligible traffic over time,
3. Estimation of toll price elasticities of travel demand using different approaches, and
4. Toll price elasticity of demand model (similar to a peak spreading model) was developed. Results from this model were used to validate elasticity results.

TRAFFIC VOLUME DATA

Data Collection Effort

As a part of this research, data on traffic by payment type from 1998 to 2002 were obtained from Cape Coral and Midpoint Memorial Bridges in Lee County, which are part of the variable pricing project. As each vehicle passed through the toll plaza, vehicle detection and classification equipment recorded the time of transaction and the method of toll payment. Therefore, every vehicle that crossed Cape Coral and Midpoint Memorial Bridges is accounted for and used in the analysis.

As discussed in previous chapters, patrons who had a LeeWay PrePay account and drove a two-axle vehicle were eligible to receive a toll discount during certain times of day. These were termed eligible drivers. Therefore, based on payment type, two user groups were created for preliminary analysis: eligible drivers and ineligible drivers. Although this research focused on analyzing changes in eligible driver participation in the variable pricing program, these changes were compared with those of ineligible traffic to control for traffic pattern changes due to factors other than the variable pricing program.

Data Reduction

Traffic data were obtained from January to July 1998 to establish baseline conditions prior to implementation and for more than 4 years after introducing the variable pricing program. Midpoint Memorial Bridge was completed in October 1997; therefore, data prior to January 1998 could not be included in this analysis.

Initial preparation of raw data files required extensive use of Excel spreadsheets. From collected data, weekends and public holidays (New Years Day, Memorial Day, Independence Day, Labor Day, Thanksgiving, and Christmas) were excluded, as toll discounts were not offered on these days. Additionally, few days were removed from the data set due to hurricanes approaching Lee County and dramatically altering traffic patterns. After removal of these data points, data were grouped into three categories based on payment type: eligible, ineligible, and total users. These data were used to obtain overall trends of traffic on both Cape Coral and Midpoint Memorial Bridges. Next is a summary of preliminary findings based on more than 4 years of data, and succeeding parts present related details.

Data Analysis

Traffic Flow Profile Estimation

Traffic flow profiles were estimated using average daily traffic (ADT). The early morning and evening discount periods were both one-half hour in length, and the morning and afternoon discount periods were both 2 hours in length. Based on the minimum duration of the discount period, average half-hour daily traffic volumes (AHHDV) were calculated to analyze changes in traffic patterns over time. As variable pricing was introduced in August 1998, traffic flow profiles were calculated separately for the January to July and August to December analysis periods. They represent average half-hourly traffic for each half-hour of the day (excluding weekends, holidays, and hurricane days) during the analysis period (January to July or August to December). These profiles were estimated for each of the eligible, ineligible, and total driver categories. Detailed calculations of daily traffic flow profiles for these three categories were shown in an Excel spreadsheet attached in Appendix A.

Developing traffic flow profiles separately for the January to July period helps in comparing traffic after introducing the variable pricing program to traffic prior to the variable pricing program. This information was further used to calculate price elasticities of demand for several years, whereas August to December comparisons are simply comparisons between traffic patterns after introducing the variable pricing program.

Data were analyzed separately for January to July and August to December periods based on the assumption that drivers adjusted their travel behavior immediately after introduction of variable tolls in August 1998. To confirm this assumption, data were examined by calculating and plotting monthly traffic flow profiles of eligible users in the discount periods. Figures 10 and 11 indicate monthly traffic flow profiles of eligible users on Cape Coral and Midpoint Memorial Bridges. If drivers took time to adjust their travel behavior it can be expected that the increase in traffic from August to September (1 month after introducing variable pricing program) will be higher in 1998 than in other years. From these graphs it can be seen that the increase in traffic from August to September is more or less similar for all years. Conversely, the increase in traffic from July to August is very high in 1998 as compared to other years in the analysis period. It can be surmised that there was no ramp-up period involved and drivers adjusted their time of travel immediately after introduction of the variable pricing program. This can probably be attributed to a successful awareness campaign by the Lee County government to educate drivers regarding toll discounts in the Lee county variable pricing project (*28*).

Figures 12–15 represent average traffic volumes within each half-hour of the day for each successive January to July analysis period. Though entire analysis in this section is based on average 24-hour day traffic only half-hour traffic volumes from 6:00 a.m. to 7:30 p.m. were presented, as these were the time periods likely to be influenced by variable pricing toll discounts. Traffic volumes were the average of every day traffic excluding weekends, holidays, and hurricane days (as is the case with all data presented here). Figures 12 and 13 clearly show the impact of variable pricing on distribution of daily traffic volumes between January to July 1998 and January to July 1999. This can be clearly observed during the 6:30 a.m. to 7:00 a.m. time period. The same overall trend was observed when comparing traffic levels in January to July 1998 to other assessment periods.

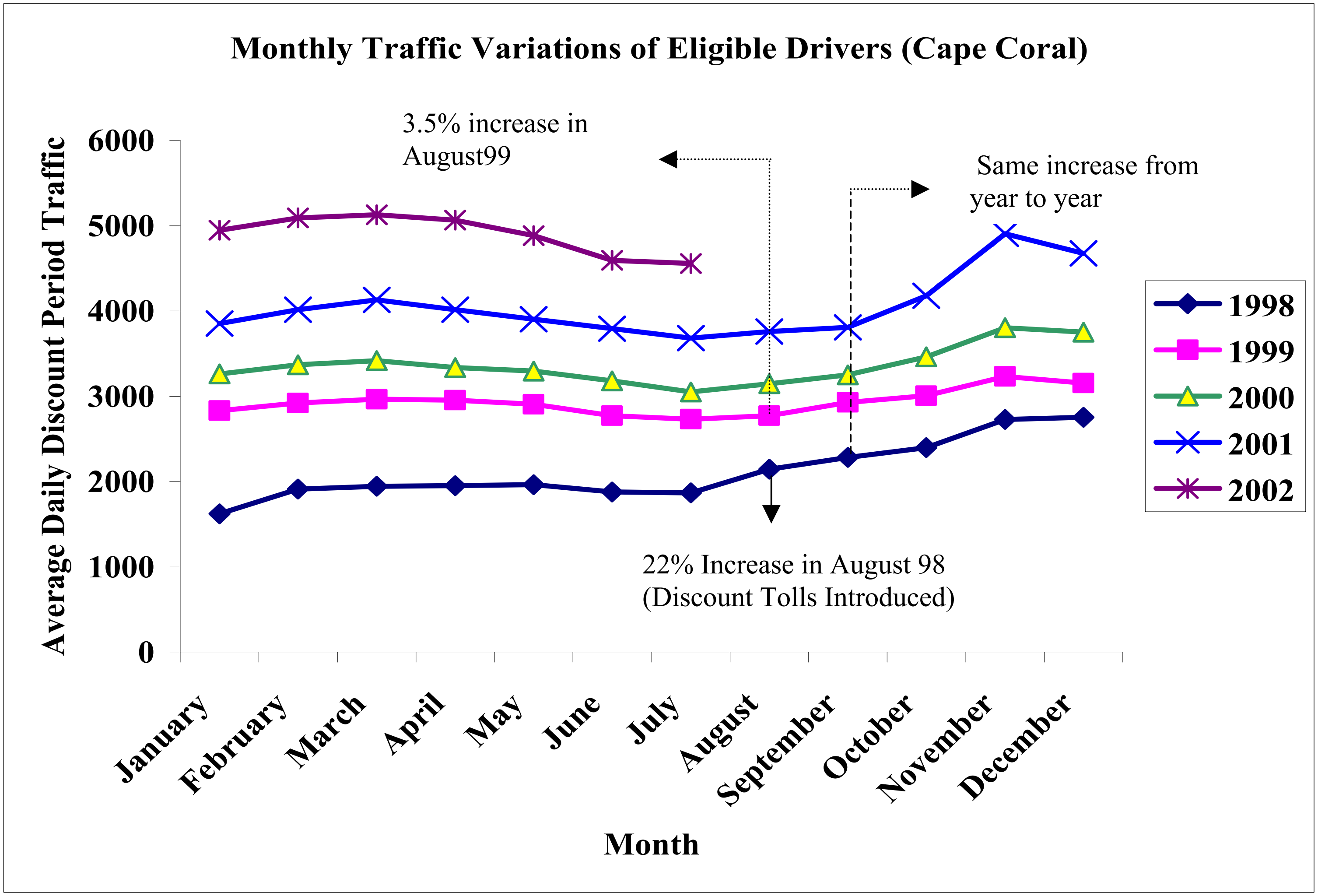

FIGURE 10 Monthly traffic flow profile of eligible trips on Cape Coral Bridge

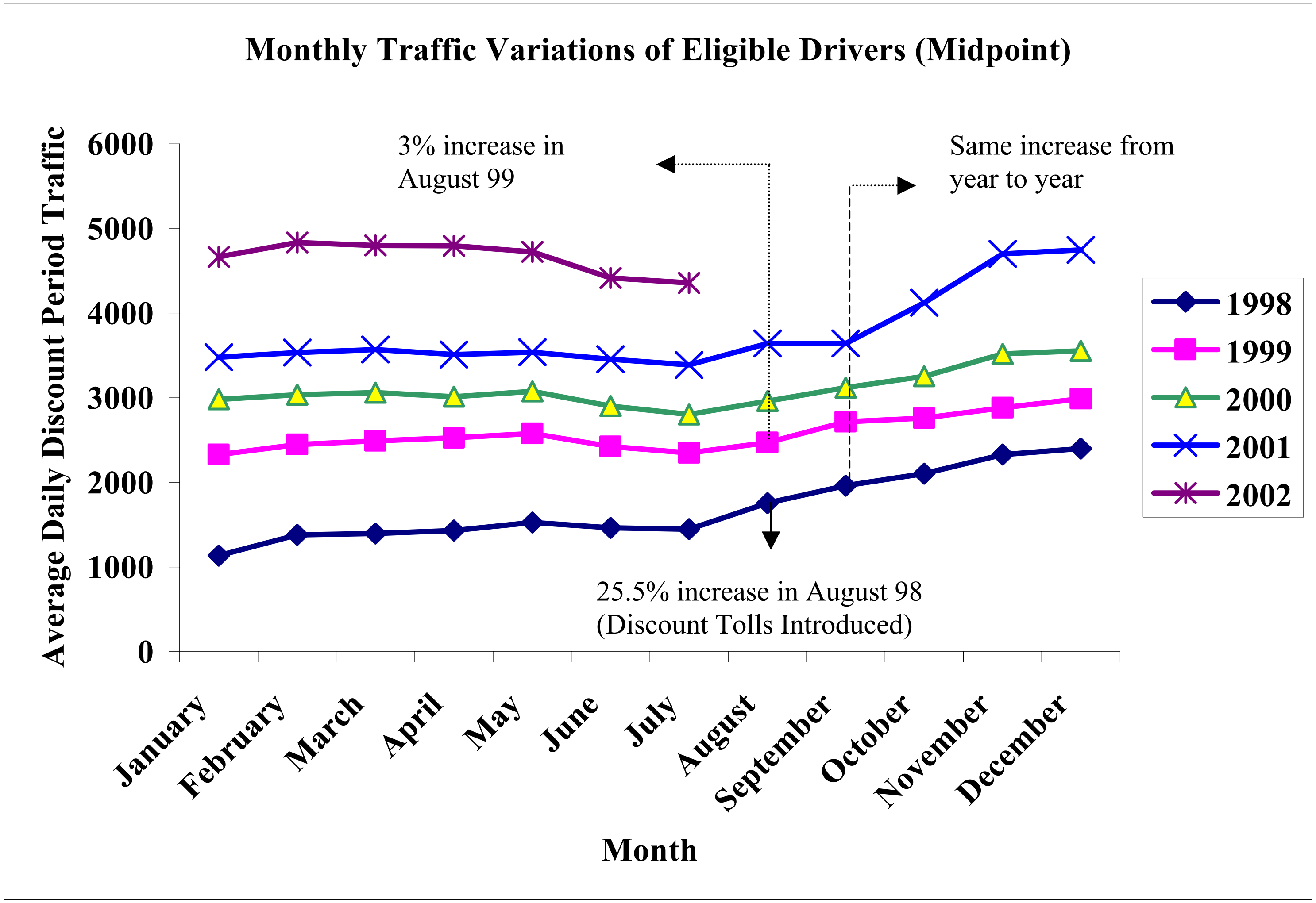

FIGURE 11 Monthly traffic flow profile of eligible trips on Midpoint Memorial Bridge

Figures 14 and 15 can be used as controls for Figures 12 and 13. While comparing traffic volumes within each half-hour of the day between ineligible and eligible users (compare Figures 12 and 14, Figures 13 and 15), it can be clearly seen that the increase in eligible user traffic is much higher than the ineligible traffic during all time periods for both Cape Coral and Midpoint Memorial Bridges.

However, based on these graphs, it was not possible to quantify impacts of the variable pricing program in changing time of travel of eligible drivers. For example, during the January to July 1998 analysis period in the 6:30 a.m. to 7:00 a.m. period there were 204 eligible trips out of total average 24-hour daily eligible trips of 5097. For the same analysis period during 2002, there were 672 eligible trips in the 6:30 a.m. to 7:00 a.m. period out of total average 24-hour daily trips of 15,830.

Although the above graphs represent an increase in eligible traffic from 204 to 672, it is difficult to elicit meaningful information on the increase relative to the proportion of average daily eligible traffic. Hence, half-hourly traffic volume as a percentage of daily traffic may better represent the impact of variable pricing on eligible traffic over time.

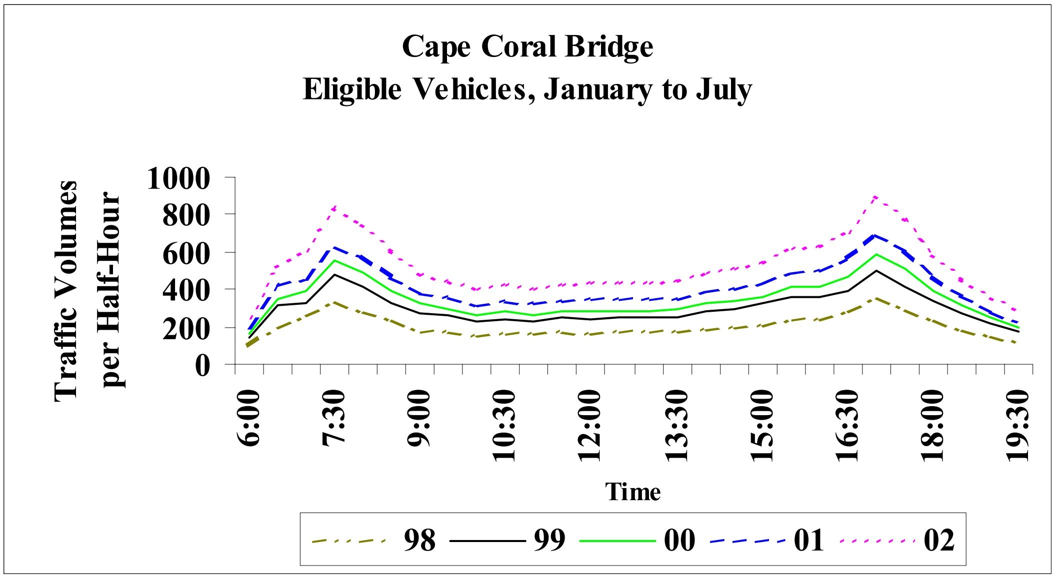

FIGURE 12 Comparison of eligible user traffic profiles on Cape Coral Bridge (January-July)

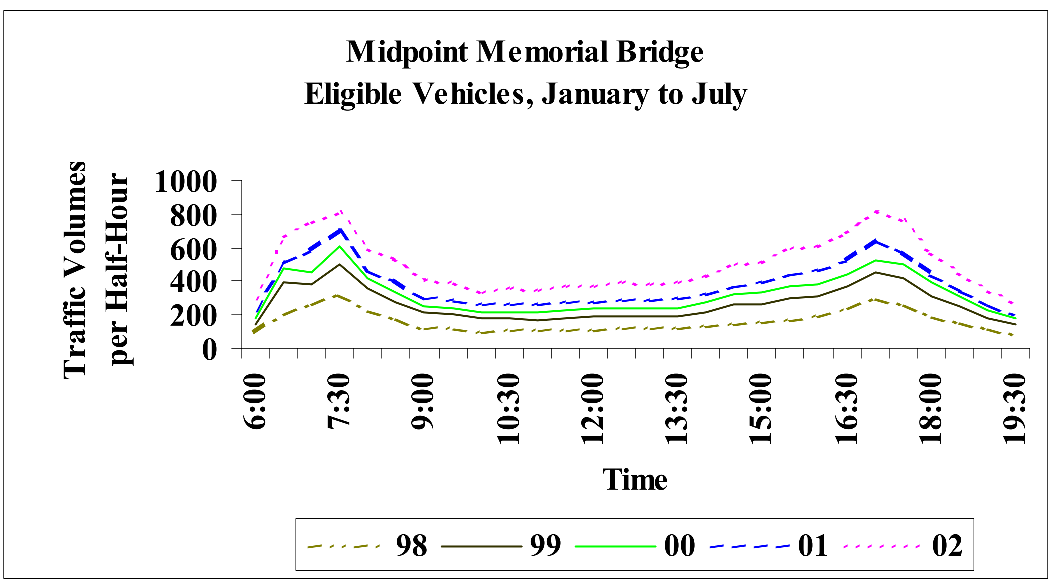

FIGURE 13 Comparison of eligible user traffic profiles on Midpoint Memorial Bridge (January-July)

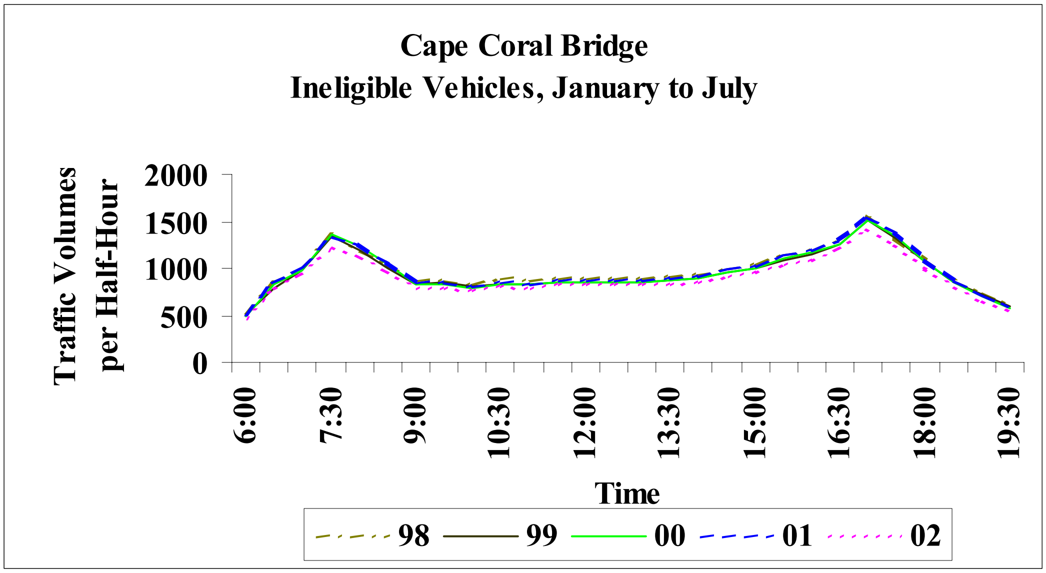

FIGURE 14 Comparison of ineligible user traffic profiles on Cape Coral Bridge (January-July)

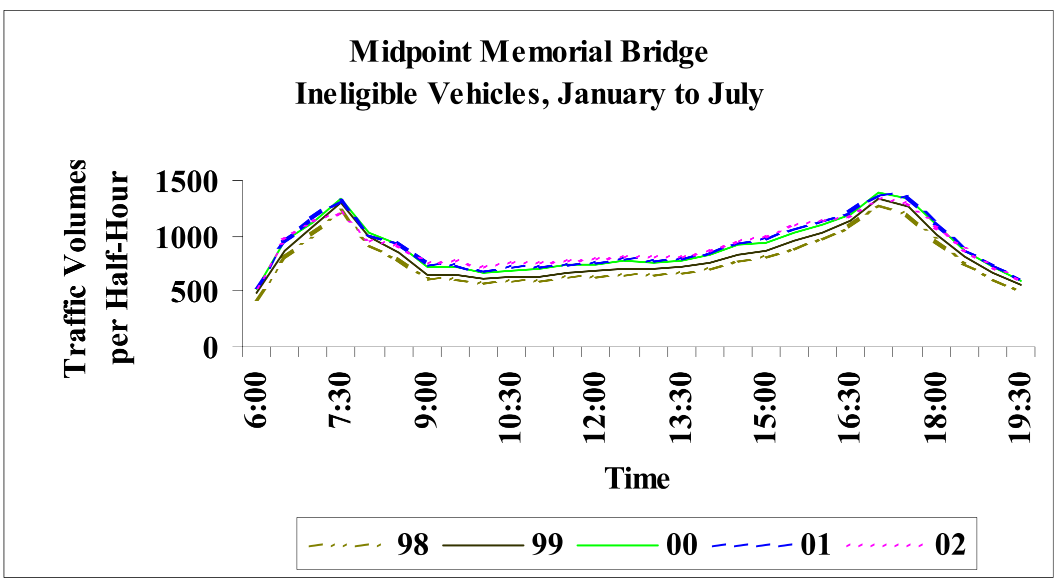

FIGURE 15 Comparison of ineligible user traffic profiles on Midpoint Memorial Bridge (January-July)

The percentage of traffic volumes in peak and discount periods were examined to assess the impact of variable pricing in changing traffic patterns over time. Tables 6 and 7 indicate the percentage of traffic during peak and discount periods for the January to July time frame.

From Table 6 it can be observed that the year after introducing the variable pricing program many eligible users have changed time of travel from peak periods to discount periods on Cape Coral Bridge. However, as indicated in Table 7, this impact decreased over time. For example, in 2002, in comparison with 2001, the percentage of eligible traffic in peak periods increased and during discount periods it decreased. Even more surprising was that for the same time period and assessment year, the percentage of ineligible traffic in peak periods decreased and during discount periods it increased.

TABLE 6 Eligible and ineligible traffic on Cape Coral Bridge (January-July)

Cape Coral January–July Traffic Comparisons						
Year	**Total Trips**		**Peak Period (%)**		**Discount Period (%)**	
	Eligible	**Ineligible**	**Eligible**	**Ineligible**	**Eligible**	**Ineligible**
1998	6,597	32,021	35.9	33.02	28.45	29.15
1999	9,563	30,841	34.80	33.34	30.00	28.86
2000	11,043	30,909	35.39	33.59	29.66	28.89
2001	13,161	31,614	35.13	33.58	29.73	28.97
2002	16,730	29,206	35.61	33.34	29.26	29.13

Total trips = average daily trips for the January-July period.

Peak period = percentage of trips in peak periods:

$(V_{7:00\text{-}9:00\text{ a.m.} + 12:00\text{-}2:00\text{ p.m.} + 4:00\text{-}6:30\text{ p.m.}})/V_{total}$

Discount period = percentage of trips in discount periods:

$(V_{6:30\text{-}7:00\text{ a.m.} + 9\text{-}11\text{ a.m.} + 2\text{-}4\text{ p.m.} + 6:30\text{-}7:00\text{ p.m.}})/V_{total}$

TABLE 7 Eligible and ineligible traffic on Midpoint Memorial Bridge (January-July)

Midpoint January-July Traffic Comparisons						
Year	**Total Trips**		**Peak Period (%)**		**Discount Period (%)**	
	Eligible	**Ineligible**	**Eligible**	**Ineligible**	**Eligible**	**Ineligible**
1998	5,097	25,494	39.14	34.48	27.41	27.97
1999	8,362	27,418	36.89	34.24	29.29	27.85
2000	10,223	29,508	36.61	33.64	29.18	28.29
2001	12,049	29,965	36.93	33.39	29.01	28.55
2002	15,830	29,923	35.97	32.65	29.41	29.31

Total trips = average daily trips for the August-December period.

Peak period = percentage of trips in peak periods:

$(V_{7\text{-}9 \text{ a.m.} + 12:00\text{-}2:00 \text{ p.m.} + 4\text{-}6:30 \text{ p.m.}})/V_{total}$

Discount period = percentage of trips in discount periods:

$(V_{6:30\text{-}7:00 \text{ a.m.} + 9\text{-}11 \text{ a.m.} + 2\text{-}4 \text{ p.m.} + 6:30\text{-}7:00 \text{ p.m.}})/V_{total}$

On Midpoint Memorial Bridge immediately after introducing the variable pricing program in 1999, the percentage of eligible vehicles decreased during peak periods and increased during discount periods (see Table 7), whereas in the same time periods the percentage of ineligible vehicles remained more or less constant. However, in 2002, percentages of both eligible and ineligible traffic reduced during peak periods and increased during discount periods.

Therefore, on Midpoint Memorial Bridge there was a general shift in time of travel from peak periods to discount periods, whereas on Cape Coral Bridge, there was only a small shift of eligible drivers from peak periods to discount periods. In later sections of this thesis this phenomenon was analyzed using equations developed for peak spreading analysis. Next, changes in the percentage of half-hour traffic volumes in peak, discount, and all other time periods were compared.

Figures 16–19 indicate average traffic volumes within each half-hour of the day for each successive assessment period for the August to December analysis period. As before, only half-hour traffic volumes from 6:00 a.m. to 7:30 p.m. were presented.

The shape of average daily traffic flow profiles for the August to December analysis period is similar to the January to July analysis period. Figures 16 and 17 indicate the change in impact of variable pricing on the distribution of daily traffic volumes between August and December for all assessment periods on Cape Coral and Midpoint Memorial Bridges. It should be noted that Figures 16 and 17 indicate variable pricing program usage over time. It can be seen that the increase in eligible traffic between January to July 1998 and January to July 1999 is higher than the increase in eligible traffic between August to December 1998 and August to December 1999 (see Figures 12 and 16 and Figures 13 and 17). This was not unexpected, as August to December traffic profiles compare traffic after introduction of the variable pricing program in contrast to January to July traffic flow profiles, which compare traffic before and after introduction of the variable pricing program. This also supports the previous finding (see Figures 10 and 11) that most eligible drivers who have adjusted their time of travel did so immediately after introduction of the variable pricing program.

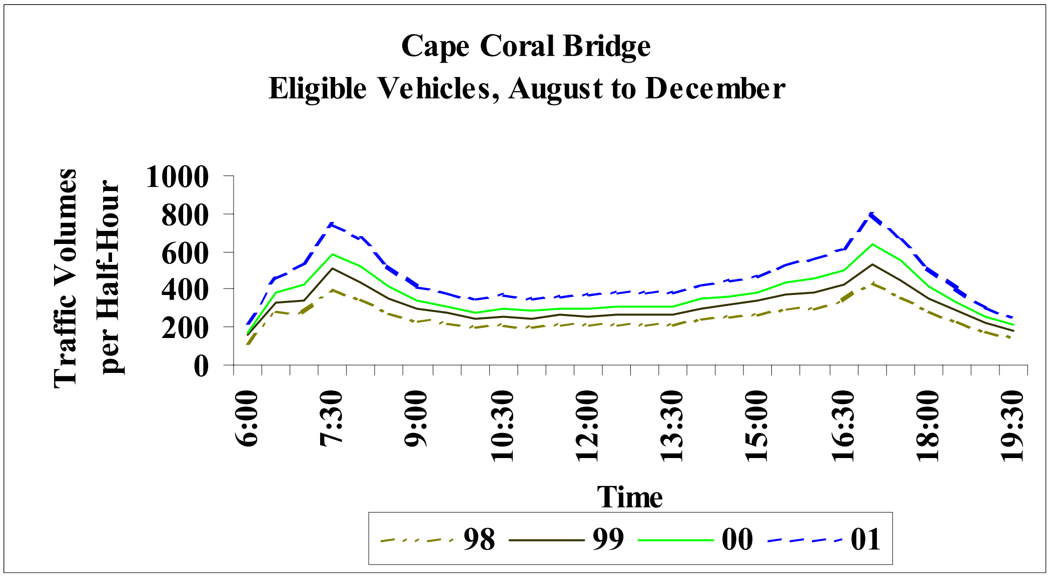

FIGURE 16 Comparison of eligible user traffic profiles on Cape Coral Bridge (August-December)

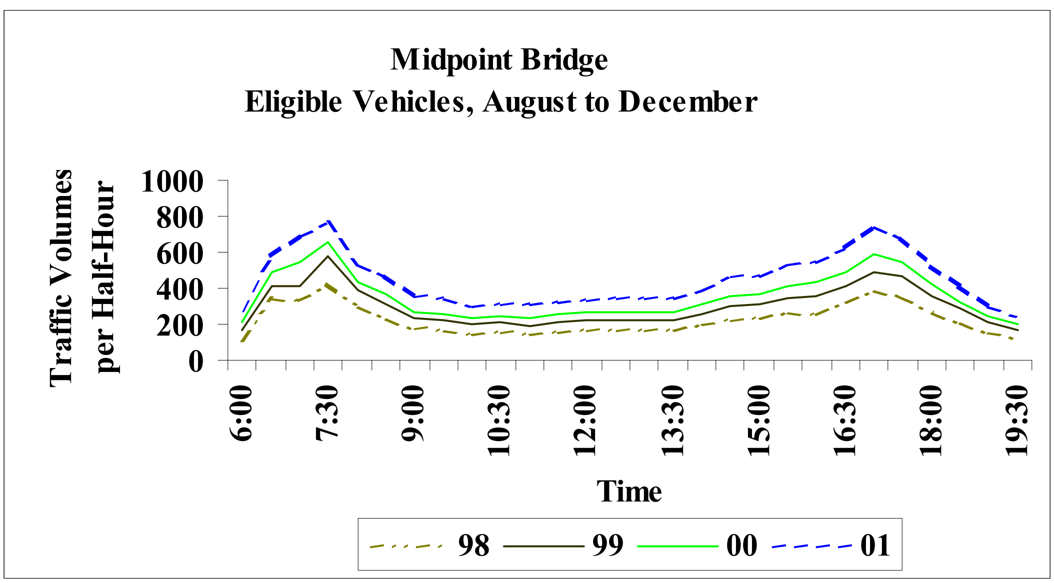

FIGURE 17 Comparison of eligible user traffic profiles on Midpoint Memorial Bridge (August-December)

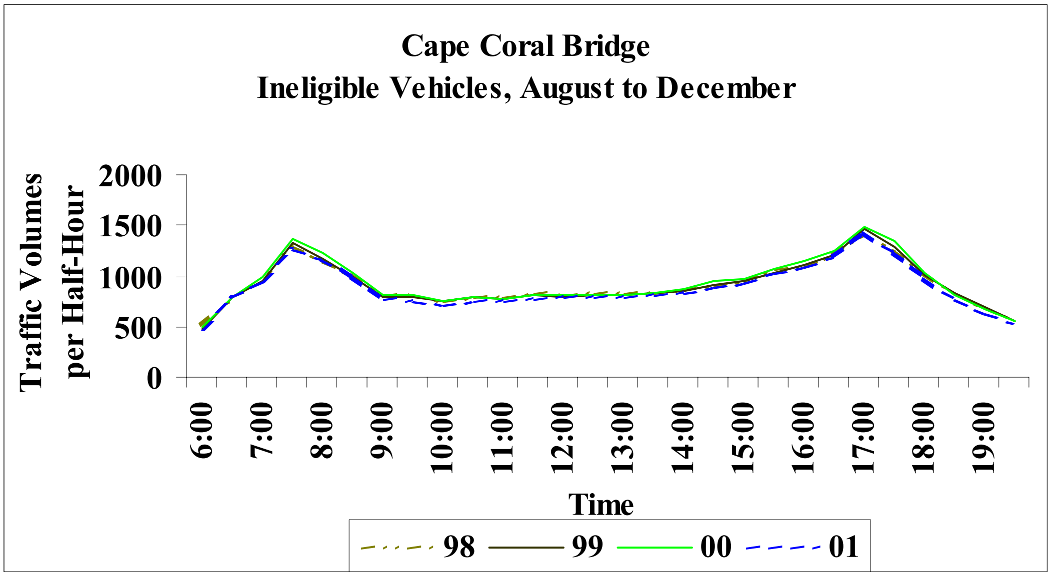

FIGURE 18 Comparison of ineligible user traffic profiles on Cape Coral Bridge (August-December)

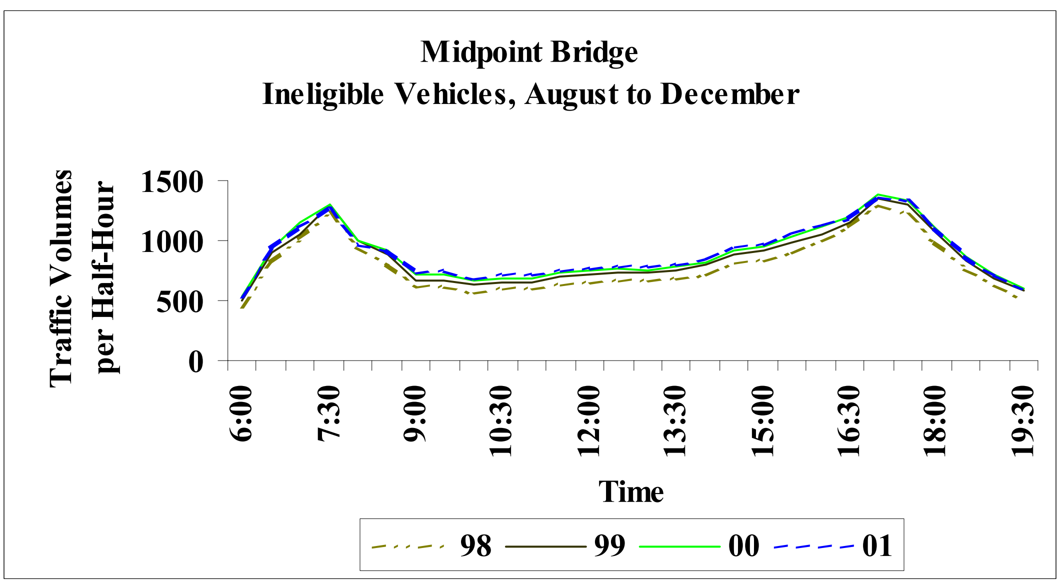

FIGURE 19 Comparison of ineligible user traffic profiles on Midpoint Memorial Bridge (August-December)

While comparing traffic volumes within each half-hour of the day between eligible and ineligible users (compare Figures 16 and 18 to Figures 17 and 19), it can be clearly seen that eligible traffic increased at a higher rate than ineligible traffic during all assessment periods for both Cape Coral and Midpoint Memorial Bridges. From Figures 16 and 17 it can be seen that eligible traffic not only increased in discount periods but also in time periods other than discount periods. Although these figures represent overall trends in traffic volume they were not very useful in interpreting whether drivers increased/decreased/did not change their variable pricing program participation over time.

However, instead of expressing traffic as vehicles per hour, expressing traffic as percentage of ADT will help in assessing whether drivers changed their variable pricing program participation over time. Tables 8 and 9 indicate the percentage of traffic during peak and discount periods for the respective years, for the August to December time frame.

TABLE 8 Eligible and ineligible traffic on Cape Coral Bridge (August-December)

Cape Coral August-December Traffic Comparisons						
Year	**Total Trips**		**Peak Period (%)**		**Discount Period (%)**	
	Eligible	**Ineligible**	**Eligible**	**Ineligible**	**Eligible**	**Ineligible**
1998	8,174	29,669	34.82	33.54	30.21	28.89
1999	10,077	29,452	35.07	33.88	30.00	28.84
2000	11,714	29,920	35.70	34.30	29.63	28.73
2001	14,513	28,569	36.08	34.03	29.30	28.86

Total trips = average daily trips for the August-December period.

Peak period = percentage of trips in peak periods:

$(V_{7\text{-}9\text{ a.m.} + 12:00\text{-}2:00\text{ p.m.} + 4\text{-}6:30\text{ p.m.}})/V_{total}$

Discount period = percentage of trips in discount periods:

$(V_{6:30\text{-}7:00\text{ a.m.} + 9\text{-}11\text{ a.m.} + 2\text{-}4\text{ p.m.} + 6:30\text{-}7:00\text{ p.m.}})/V_{total}$

TABLE 9 Eligible and ineligible traffic on Midpoint Memorial Bridge (August-December)

Midpoint August-December Traffic Comparisons						
Year	Total Trips		Peak Period (%)		Discount Period (%)	
	Eligible	Ineligible	Eligible	Ineligible	Eligible	Ineligible
1998	7,135	26,065	36.79	34.39	29.67	27.84
1999	9,457	28,112	36.65	34.02	29.24	28.17
2000	11,204	29,268	36.77	33.71	29.19	28.37
2001	14,160	29,469	36.38	33.20	29.36	28.97

Total trips = average daily trips for the August-December period.

Peak period = percentage of trips in peak periods:

$(V_{7\text{-}9\text{ a.m.}+12:00\text{-}2:00\text{ p.m.}+4\text{-}6:30\text{ p.m.}})/V_{total}$

Discount period = percentage of trips in discount periods:

$(V_{6:30\text{-}7:00\text{ a.m.}+9\text{-}11\text{ a.m.}+2\text{-}4\text{ p.m.}+6:30\text{-}7:00\text{ p.m.}})/V_{total}$

From Table 8 it can be observed that on Cape Coral Bridge the percentage of eligible traffic decreased in discount periods and increased in peak periods over time. Ineligible traffic followed the same trend in peak periods except during the August to December 2001 period. However, in discount periods percentage of ineligible traffic remained more or less the same. This may indicate that on Cape Coral Bridge some of those drivers who had initially changed their time of travel to obtain the toll discount gradually switched back to their original time of travel. On Midpoint Memorial Bridge, percentage of ineligible traffic decreased in peak periods and increased in discount periods (see Table 9), whereas percentage of eligible traffic has remained relatively consistent.

To account for changes due to factors other than variable tolls, the relative percentage change of eligible traffic was calculated based on changes in both eligible and ineligible traffic. This relative change will help control for changes due to factors other than variable pricing. These relative changes were examined in the following section.

Percentage Changes of Traffic Volume

In the previous section, the impact of variable pricing on average daily traffic flow profiles was discussed. This impact was investigated further using a normalized technique to show relative changes in traffic volume within each half-hour period of the day. To normalize traffic growth in each assessment period the percentage traffic within each half-hour period as a percentage of average total 24-hour day traffic was considered. These traffic volumes were expressed as percentage of ADT to represent overall changes in traffic volume in respective years. For example, 3.044 percent of total daily eligible trips from January to July, 1998 on Cape Coral Bridge were made during 6:30 a.m. to 7:00 a.m. time period. For the same bridge 3.090 percent of daily trips were made from 6:30 a.m. to 7:00 a.m. during January to July 2002. Therefore, eligible trips in this 6:30 a.m. to 7:00 a.m. discount period increased by 1.511 percent. This method removed the impact of rapidly increasing overall traffic volumes on changes in time of travel.

The percentage change of eligible traffic volumes in each half-hour period of assessment are presented in Figures 20–27. Figures containing the percentage change of eligible and ineligible drivers are attached in Appendix B along with graphs showing the percentage change of ineligible traffic volumes in each half-hour period.

Figures 20 and 23 indicate percentage change of eligible traffic between 1998 and 1999 for the January to July assessment period on Cape Coral and Midpoint Memorial Bridges. From these graphs it can be seen that variable pricing toll discounts had a positive effect in changing time of travel of eligible trips on both the Cape Coral and Midpoint Memorial Bridges. In the previous section of this chapter it was shown that eligible traffic volume increased considerably the year after introducing the variable pricing program (see Figures 12 and 13). These bar charts (Figures 20 and 21) quantify percentage change in each half-hour period. Time of travel shift from peak periods to discount periods can be readily seen in these figures.

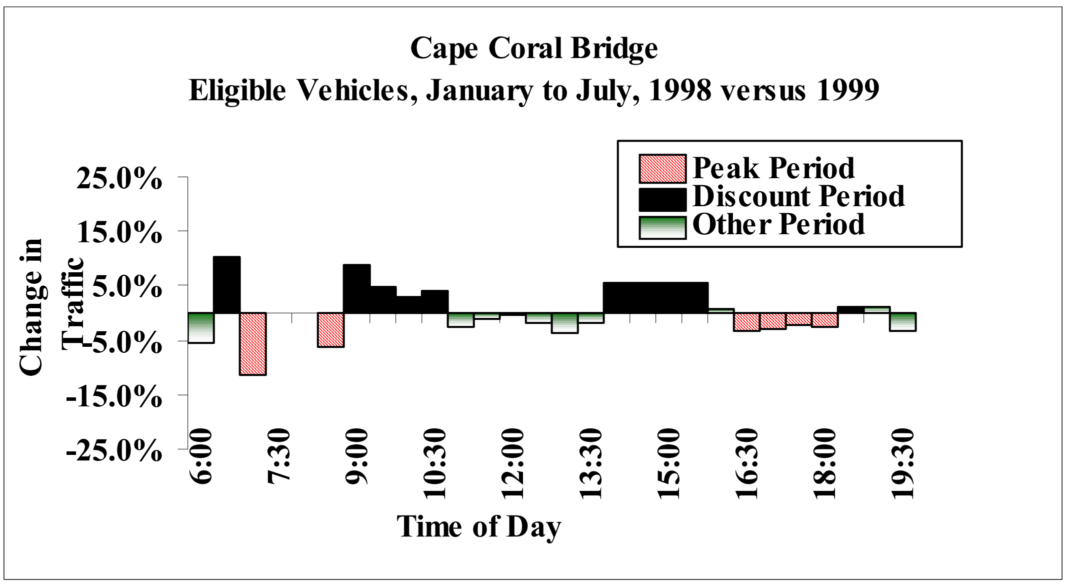

FIGURE 20 Eligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 1999)

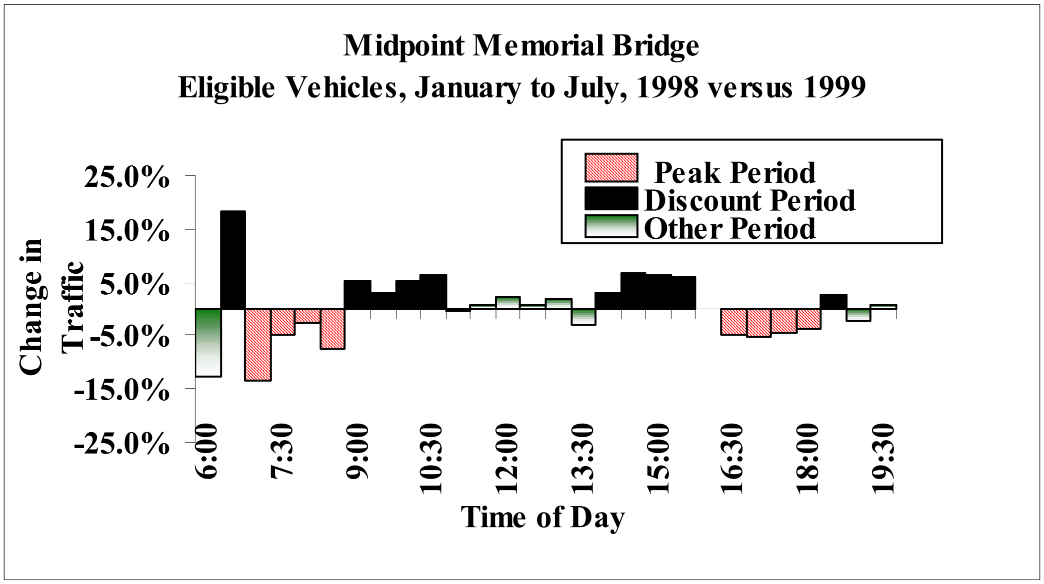

FIGURE 21 Eligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 1999)

From Figures 20 and 21 it can be readily observed that the maximum percentage change in eligible traffic from January to July 1998 to January to July 1999 occurred on Midpoint Memorial Bridge during the 6:30 a.m. to 7:00 a.m. period (18.11 percent increase). For the same time period on Cape Coral Bridge eligible traffic increased by 10 percent. The decrease in adjacent peak period traffic suggests that some of these peak period trips shifted time of travel to the 6:30 a.m. to 7:00 a.m. discount period. During the 9:00 a.m. to 11:00 a.m. discount period eligible traffic on Cape Coral Bridge increased by 3 to 9 percent. The highest increase occurred between 9:00 a.m. and 9:30 a.m. and the lowest increase occurred between 10:00 a.m. and 10:30 a.m. During the 9:00 a.m. to 11:00 a.m. discount period eligible traffic on Midpoint Memorial Bridge increased by 3 to 6 percent. The highest increase occurred between 10:30 a.m. and 11:00 a.m. and the lowest increase occurred between 9:30 a.m. and 10:00 a.m. However, there was little change in time of travel of ineligible traffic from January to July 1998 to January to July 1999.

Figures 22 and 23 indicate how the variable pricing program impacted time of travel of eligible drivers 3 years after the first year of its implementation (January to July 2002) with respect to base conditions (January to July 1998). When comparing these graphs to Figures 20 and 21 it is clear that time of travel of eligible drivers has changed over the years since variable pricing was implemented. This may indicate drivers' use of variable pricing, and therefore the perceived value of toll discounts, has changed over time.

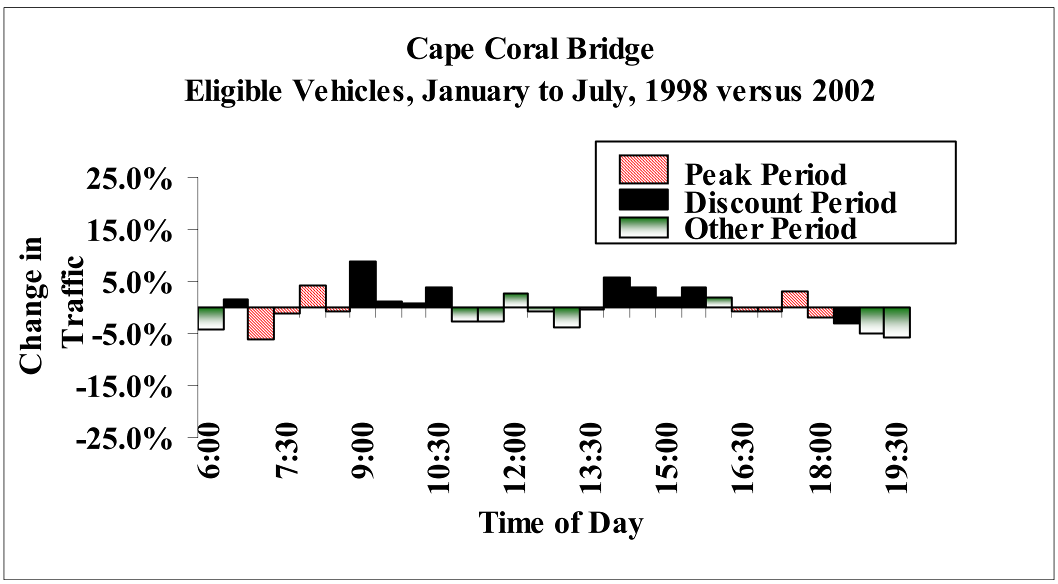

FIGURE 22 Eligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2002)

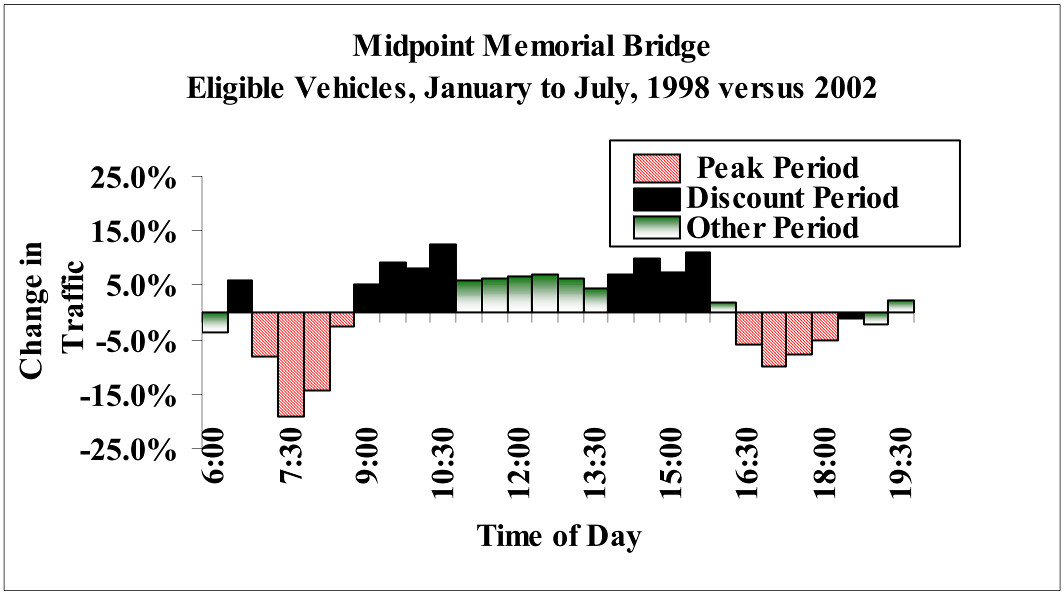

FIGURE 23 Eligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2002)

In many discount periods the impact of variable pricing decreased over time on Cape Coral Bridge, whereas it has increased in some discount periods on Midpoint Memorial Bridge.

Figures 24–27 indicate percentage changes in time of travel of eligible traffic during the analysis period after the introduction of the variable pricing program (August to December). As these comparisons are for the August to December period, they represent changes in variable pricing usage over time. The percentage changes of eligible traffic during many of the half-hour discount periods decreased substantially on the Cape Coral Bridge (compare Figures 24 and 26). Conversely, on the Midpoint Memorial Bridge the percentage changes of eligible traffic during many of the half-hour discount periods decreased substantially (compare Figures 25 and 27).

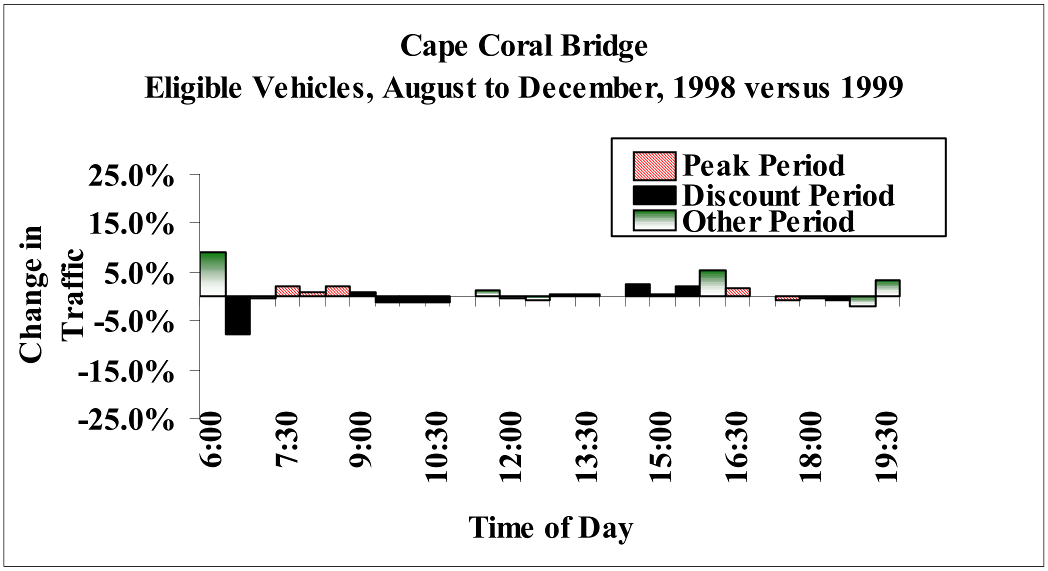

FIGURE 24 Eligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 1999)

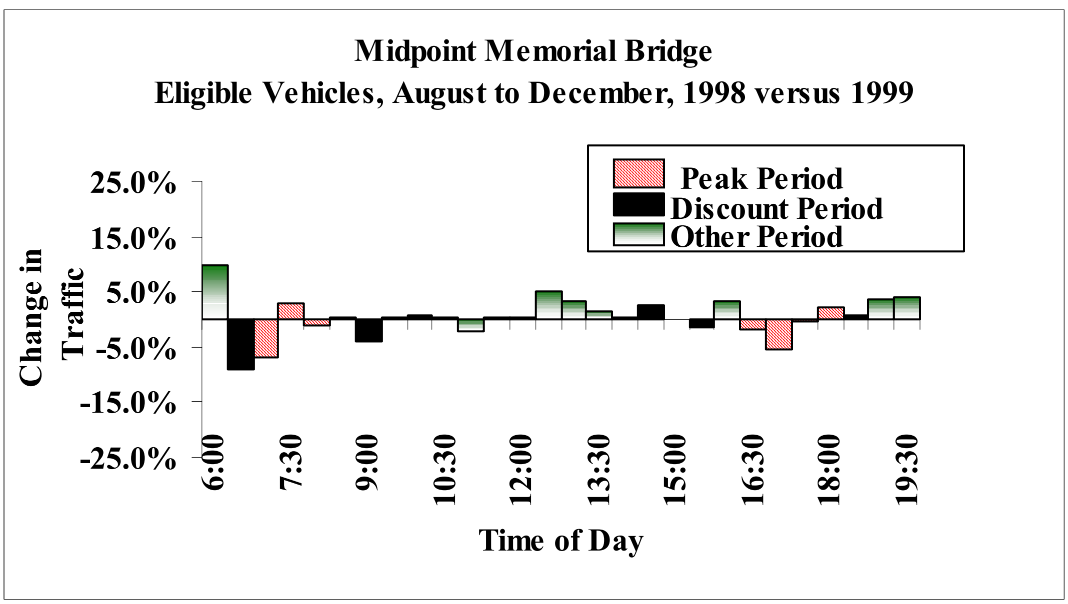

FIGURE 25 Eligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 1999)

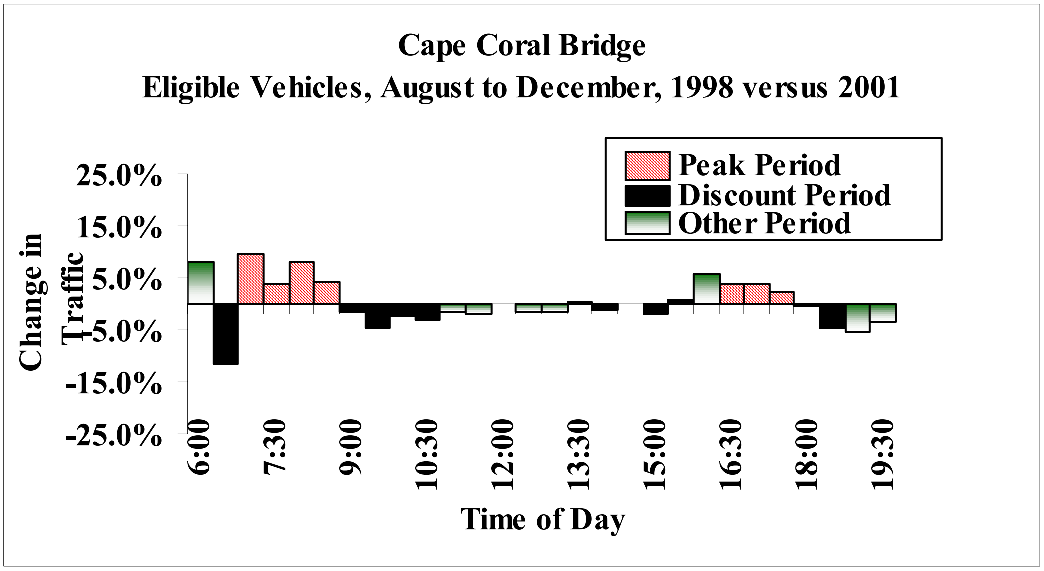

FIGURE 26 Eligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 2001)

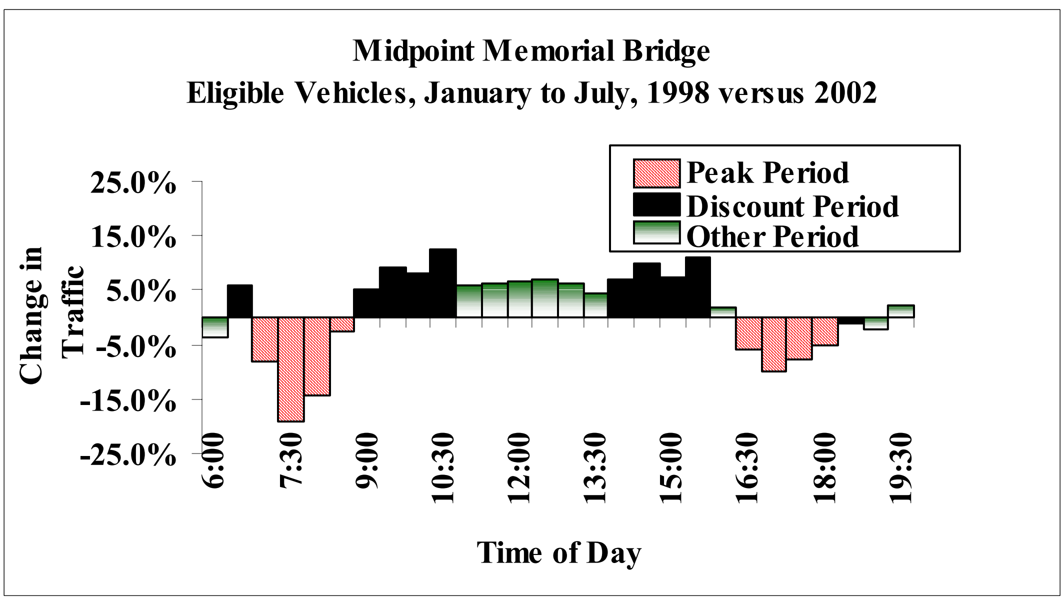

FIGURE 27 Eligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 2001)

From Figures 24 and 26 it can be observed that on Cape Coral Bridge there was a general decrease in percentage of eligible traffic during the August to December time frame. The only exception to this is during certain half-hours in the 2:00 p.m. to 4:00 p.m. period. There were no apparent trends found in this 2:00 p.m. to 4:00 p.m. time period.

From the above discussion it appears that when the variable pricing program was introduced, eligible drivers responded to the variable pricing program as predicted by shifting their time of travel from peak periods to discount periods on both Cape Coral and Midpoint Memorial Bridges. The impact of variable pricing in shifting time of travel from peak to discount periods gradually decreased over time on Cape Coral Bridge, and this was particularly pronounced in the 6:30 a.m. to 7:00 a.m. time period. Conversely, on the Midpoint Memorial Bridge, the impact of variable pricing substantially decreased during the 6:30 a.m. to 7:00 a.m. time period but it increased in many other discount periods.

In the above discussion, changes in the percentage of eligible traffic during the respective periods cannot be directly attributed to the variable pricing program with great confidence. To more confidently attribute these changes to the variable pricing program, any changes in traffic patterns due to factors other than the variable pricing program must be removed. This was accomplished by considering changes in time of travel of ineligible traffic (the control group) in corresponding half-hour periods, as shown in the next section.

In this section, the percentage of eligible traffic in each half-hour period was calculated based on total eligible traffic during the entire 24-hour day. 86–87 percent of total average daily trips on both Cape Coral and Midpoint Memorial Bridges occurred from 6:00 a.m. and 8:00 p.m. and variable pricing is intended to change time of travel of trips during this period. Therefore, for subsequent calculations only these time periods were used in the analysis.

Toll Price Elasticities of Demand

Consumer responsiveness to price changes is commonly measured by price elasticity of demand. In transportation projects, price elasticity of demand describes the relationship between travel cost and travel demand. It is measured as percentage change in travel demand divided by percentage change in travel cost. As mentioned in Chapter II, for transportation pricing projects, fixed-toll price elasticity of travel demand generally varies between –0.03 to –0.35 and variable-toll price elasticity of travel demand generally varies between –0.3 to –1.0 (*9*). This means a 10 percent reduction in fixed toll would result in a 0.3 to 3.5 percent increase in travel demand, whereas the same reduction in a variable toll results in a 3 to 10 percent increase in demand. Similarly, an increase in toll will lead to reduction in demand.

As mentioned in Chapters II and III, changes in traffic demand in the Lee County variable pricing project were primarily associated with changes in time of travel from peak periods to discount periods. On Lee County toll bridges the congestion is not excessive and there were no abandoned trips. Hence, price elasticities in this project are likely to be smaller than variable toll price elasticity values mentioned in the reviewed literature.

In the Lee County variable pricing project, there was a 50 percent change in toll. By driving in discount periods, drivers who were initially paying $1.00 could pay only $0.50 and drivers who were initially paying $0.50 could pay only $0.25. The majority (94 percent) of drivers eligible for the toll discount were in the latter category, saving $0.25 per trip. In this thesis the percentage change in traffic demand was calculated using three different normalization techniques. Also, for each technique price elasticities of travel demand were calculated using both absolute percentage changes in eligible traffic and relative percentage changes in eligible traffic with respect to ineligible traffic. This relative percentage change in eligible traffic was calculated by subtracting absolute percentage change in ineligible traffic from that of eligible traffic. Therefore, a total of six different elasticity estimates for each assessment period were calculated.

It should be noted that price elasticities of demand were estimated only for the January to July analysis period. For the August to December period only, percentage changes in eligible traffic were estimated, as there was no difference between toll amounts during the assessment period. The three methods used to calculate elasticities in this thesis are described below.

Price Elasticities of Demand Method 1

In this method, percentage changes in eligible traffic were calculated using the same normalized technique discussed previously. Each half hour traffic volume (both eligible and ineligible) was calculated as a percentage of the 24-hour traffic volume. Using change in percentage of traffic volume, absolute changes in percentage of eligible and ineligible traffic for several years with respect to 1998 were calculated. Then by subtracting absolute changes in ineligible traffic from those of eligible traffic, relative changes in eligible traffic were determined. In this method, we calculate the proportionate price elasticities of demand by dividing the percentage change in eligible traffic by percentage change in toll amount. Equations 7–9 illustrate how price elasticities of demand were estimated using this method.

$$\left(PED_{absolute}\right)_i = \frac{\left(\frac{P_{E_{i,j}} - P_{E_{i,R}}}{P_{E_{i,R}}}\right)\times 100}{\left(\frac{T_{vp} - T_{pre-vp}}{T_{pre-vp}}\right)\times 100} \tag{7}$$

$$Where\ P_{E_{i,j}} = \left(\frac{E_{i,j}}{E_j}\right)\times 100 \quad and \tag{8}$$

$$P_{E_{i,R}} = \left(\frac{E_{i,R}}{E_R}\right) \tag{9}$$

where;

$P_{E_{i,j}}$ = percentage of daily eligible trips during discount period *i*, in year *j*, for the January to July analysis period, where:

i = an index in the range of 1–4, which identifies each discount period,

1 = 6:30–7:00 a.m.,

2 = 9:00–11:00 a.m.,

3 = 2:00–4:00 p.m., and

4 = 6:30–7:00 p.m.

j = an index in the range of 1999–2002, representing years examined,

$P_{E_{i,R}}$ = percentage of daily eligible trips during discount period *i*, in year *R*, for the January to July analysis period,

R = the reference year 1998,

$E_{i,j}$ = average daily eligible trips during discount period *i* for year *j*,

E_j = average daily eligible trips in year *j,*

$E_{i,R}$ = average eligible daily trips in discount period *i* during year *R* (1998),

E_R = average daily eligible trips during reference year *R* (1998),

T_{vp} = toll with variable pricing discount (either \$0.50 or \$0.25), and

T_{pre-vp} = toll prior to variable pricing program (\$1.00 or \$0.50).

To determine relative changes in price elasticity of demand, Equation 7 was modified as follows:

$$\left(PED_{relative}\right)_i = \frac{\left(\frac{P_{E_{i,j}} - P_{E_{i,R}}}{P_{E_{i,R}}}\right)\times 100 - \left(\frac{P_{IE_{i,j}} - P_{IE_{i,R}}}{P_{IE_{i,R}}}\right)\times 100}{\left(\frac{T_{vp} - T_{pre-vp}}{T_{pre-vp}}\right)\times 100} \qquad (10)$$

where $P_{E_{i,j}}$ and $P_{E_{i,R}}$ are as described in Equations 8 and 9 and:

$$P_{IE_{i,j}} = \left(\frac{IE_{i,j}}{IE_j}\right)\times 100 \qquad (11)$$

$$P_{IE_{i,R}} = \left(\frac{IE_{i,R}}{IE_R}\right)\times 100 \qquad (12)$$

where:

$P_{IE_{i,j}}$ = percentage of daily ineligible trips during discount period *i*, in year *j*, for the January to July analysis period,

$P_{IE_{i,R}}$ = percentage of daily ineligible trips during discount period *i*, in year *R*, for the January to July analysis period,

$IE_{i,j}$ = average 24-hour daily ineligible trips in discount period *i* for year *j*,

IE_j = average ineligible daily trips in discount period *i* during reference year *R* (1998),

$IE_{i,R}$ = percentage of daily ineligible trips during discount period *i*, in year *R*, for January to July analysis period, and

IE_R = total average daily eligible trips during reference year *R* (1998).

Using Equations 7–12 and data collected on the toll bridges, toll price elasticities of demand were estimated (see Tables 10 and 11 for percentage change in eligible traffic for the August to December time frame and Tables 10 and 12 for toll price elasticities of demand for the January to July time frame). These tables contain percentage change in eligible traffic and elasticity estimates using the three different methods. Traffic data were available only to July 2002; therefore, no estimates were developed for the August to December 2002 period.

Estimates using relative changes of eligible traffic take into consideration changes occurring in traffic due to factors other than the variable pricing program, thereby greatly reducing these outside influences. For example, on Midpoint Memorial Bridge using method 1 and absolute changes in percentage of eligible traffic, in 2002 during 6:30 a.m. to 7:00 a.m. time period the elasticity was –0.12. However, using relative changes in percentage of eligible traffic elasticity estimated during the same time period decreased to –0.03.

For August-December time frame during analysis period there was no change in the toll amount. Hence, price elasticities of demand could not be calculated (see Tables 10 and 11). For January-July time frame only price elasticities were displayed (see Tables 12 and 13). The percentage changes in eligible traffic for January-July time frame are simply half of the price elasticities of demand as there was 50% reduction in toll amount. Hence, these values were not displayed separately in Tables 12 and 13.

It can be expected that initially after introducing variable tolls drivers may have reacted positively by changing their time of travel to discount periods. If drivers stopped using variable pricing program or used it less frequently than number of drivers who joined or increased frequency, then drops in toll price elasticities of demand would be experienced in January to July 2000. In subsequent years either this value will be consolidated or else it will gradually increase or decrease. Also, if there was no trend found in how elasticities changed over time, random changes in these estimates are of little help in interpreting how drivers reacted to variable toll over time.

From Table 12 it can be observed that elasticity estimates decreased during many discount periods between January to July 2000 and January to July 1999 on Cape Coral Bridge. On Midpoint Memorial Bridge it can be observed that using absolute elasticity estimates may overstate true elasticities (see Table 13). This is more so on Midpoint Memorial Bridge, as there was a high growth in both eligible and ineligible traffic on this bridge. For example, in 2002 the absolute toll price elasticity was -0.12, whereas the relative toll price elasticity was 0.03. Using relative estimates results in a very high variation in elasticity estimates in the 6:30 a.m. to 7:00 a.m. time period on both the bridges. This method also indicates an unusually high reduction in elasticities during the 6:30 a.m. to 7:00 a.m. time period from 1999 to 2000 during January to July. Also, these estimates fail to show a particular trend in 9:00 a.m. to 11:00 a.m. discount periods on Cape Coral Bridge. These issues necessitated looking into different methods of estimating price elasticities.

Price Elasticities of Demand Method 2

As stated before, 85–86 percent of traffic on both Cape Coral and Midpoint Memorial Bridges occurred between 6:00 a.m. and 7:30 p.m. Also, as variable pricing is intended to shift time of travel of trips in these time periods, this method only examines traffic between 6:00 a.m. to 7:30 p.m. Hence, instead of calculating each half-hour traffic volume as a percentage of a 24-hour day, half-hour traffic during discount periods was calculated as a percentage of traffic during the 6:00 a.m. to 7:30 p.m.

For example, in 1998 (January to July), average eligible daily traffic was 6597 vehicles per day (vpd), out of which peak, discount, and other time period (6:00 a.m. to 7:30 p.m.) traffic was 4249 vpd. Therefore, in this method the time periods consisting of only 4249 daily trips was used. The total number of eligible trips in the 6:30 a.m. to 7:00 a.m. discount period was 201 vpd. Therefore, the percentage of eligible trips in the 6:30 a.m. to 7:00 a.m. discount period using this method was (201/4249)*100 = 4.73 percent. In the same manner, percentages of trips in each half-hour period were calculated for all years, and from these percentages, the changes in percentages of eligible and ineligible trips in each half-hour period with respect to 1998 were calculated. These percentages were used in estimating price elasticities of demand over time. Therefore, the equations used for this method are identical to those in method 1 except E_j, E_R, IE_j, and IE_R consist of only traffic from 6:00 a.m. to 7:30 p.m.

Tables 12 and 13 contain the price elasticities of demand (January to July) developed using this method. Tables 10 and 11 indicate the percentage change in eligible traffic over time (August to December). Results obtained by this method were not following any particular pattern and as in method 1 there is a variation in elasticity estimates using this method. As in the previous method, considering relative changes in eligible traffic considerably decreased elasticity estimates during the 6:30 a.m. to 7:00 a.m. time period from 2001 to 2002 during January to July on Midpoint Memorial Bridge. Conversely, elasticity estimates remained the same using absolute change in eligible traffic. This confirms that on Midpoint Memorial Bridge there was a high growth of both eligible and ineligible drivers during the analysis period. Hence, not considering the changes in traffic patterns of ineligible trips will lead to artificially inflated elasticity estimates. Also, elasticity estimates do not appear to follow a particular trend in many discount periods on both Cape Coral and Midpoint Memorial Bridges. Seemingly random changes in price elasticities of demand are not useful in establishing any systematic pattern of elasticities over time; hence, results from this method were not used in further analysis. An approach was needed that defined any general decreasing/increasing trend in magnitudes of traffic in discount time periods (if they existed). This necessitated looking for another approach that extends upon the two previously described methods.

Price Elasticities of Demand Method 3

In predicting changes in long-run driver behavior due to variable tolls, a third method was considered. In this method, a more targeted approach was used, where the time periods that were most likely to be influenced by variable pricing were divided into four time blocks, based on the discount periods. These time blocks included:

1. Early morning trips (6:30 a.m. to 7:00 a.m.), were mostly commuter trips (confirmed using results from a 1999 survey of bridge drivers) and it is unlikely that commuters changed their time of travel by more than 1 hour to obtain the toll discount (in 2001 telephone survey many respondents indicated that they do not have flextime option). Also, from traffic volume data it was observed that there were only few trips during the 5:30 a.m. to 6:00 a.m. time period; therefore, this time period was not included in the analysis. Hence, 6:00 a.m. to 8:00 a.m. was divided into one block.
2. The next block (8:00 a.m. to 12:00 noon) includes the whole 9:00 a.m. to 11:00 a.m. discount period and one hour to either side of the discount period. Dividing the whole 9:00 to 11:00 a.m. into one block allows more flexibility in scheduling a trip (for example, a doctor appointment) during entire morning period.
3. Similarly, the third block (12:00 noon to 5:30 p.m.) includes the whole 2:00 p.m. to 4:00 p.m. discount period. Trips during these time periods are less likely to be commute trips; hence, it was assumed that drivers traveling in these time periods could adjust their time of travel by more than one hour. Dividing the entire afternoon into one block considers the flexibility of

drivers to change their time of travel from any of these periods to the discount period.

4. Similar to the early morning discount period the evening discount period (6:30 p.m. to 7:00 p.m.) is separated in a block ranging from 5:30 p.m. to 7:30 p.m.

Therefore, the equations used for this method were identical to those used in the previous method except E_j, E_R, IE_j, and IE_R consist only of traffic in specific blocks of time. Specifically:

$(E/IE)_{(j/R)}$ = average daily eligible/ineligible trips in year *j/R*, during either:

1. 6:00–8:00a.m,
2. 8:00 a.m. –12:00 noon,
3. 12:00 noon–5:30 p.m., or
4. 5:30–7:30 p.m.

Results of these analyses are shown in Tables 10,11,12, and 13. Resulting relative percentage changes and relative elasticities were more consistent using this method than from the previous two methods and clearly show a decreasing trend in price elasticities of demand over time on both the Cape Coral and Midpoint Memorial Bridges.

TABLE 10 Percentage change in eligible traffic on Cape Coral Bridge

Analysis	Year (*j*)	6:30–7:00 a.m.		9:00–11:00 a.m.		2:00–4:00 p.m.		6:30–7:00 p.m.	
		% C	% RC	% C	% RC	% C	% RC	% C	% RC
Method 1	1999	-7.85	-8.09	-0.62	-0.81	1.22	2.01	-1.01	-1.84
	2000	-9.16	-9.55	-1.93	-0.71	0.55	0.36	-4.23	-1.80
	2001	-11.40	-16.03	-2.87	-1.75	-0.46	-0.98	-4.63	-1.14
Method 2	1999	-7.91	-7.69	-0.68	-0.41	1.15	2.41	-1.08	-1.44
	2000	-9.59	-9.03	-2.40	-0.25	0.07	0.83	-4.68	-1.33
	2001	-11.90	-15.76	-3.41	-1.57	-1.02	-0.80	-5.17	-0.96
Method 3	1999	-7.42	-7.31	-0.95	-0.75	0.11	0.80	-0.02	0.44
	2000	-9.54	-7.93	-2.24	-0.84	-0.78	-0.48	-3.79	-0.61
	2001	-12.89	-15.82	-3.26	-1.88	-1.43	-0.69	-3.37	-1.38

% C = absolute percentage change in eligible traffic
% RC = relative percentage change in eligible traffic
Change was calculated with respect to August–December 1998 to August–December in year *j*

TABLE 11 Percentage change in eligible traffic on Midpoint Memorial Bridge

Analysis	Year (*j*)	6:30–7:30 a.m.		9:00–11:00 a.m.		2:00–4:00 p.m.		6:30–7:00 p.m.	
		% C	% RC	% C	% RC	% C	% RC	% C	% RC
Method 1	1999	-9.20	-11.68	-0.72	-0.95	0.35	-1.16	0.87	-0.50
	2000	-9.21	-11.00	-1.19	-3.42	0.93	-1.12	-1.80	-2.09
	2001	-14.36	-16.25	1.78	-3.80	2.60	-1.77	-3.65	-3.66
Method 2	1999	-8.41	-10.98	0.14	-0.17	1.22	-0.37	1.75	0.29
	2000	-8.52	-10.57	-0.44	-2.93	1.70	-0.61	-1.05	-1.60
	2001	-13.44	-15.45	2.88	-2.84	3.70	-0.79	-2.61	-2.74
Method 3	1999	-6.87	-10.34	-0.12	-0.29	0.28	-1.63	-0.30	-1.36
	2000	-9.03	-11.82	0.19	-1.69	-0.07	-2.22	-1.11	-1.97
	2001	-10.95	-16.12	1.90	-1.78	0.52	-2.90	-1.94	-3.39

% C = absolute percentage change in eligible traffic
% RC = relative percentage change in eligible traffic
Change was calculated with respect to August–December 1998 to August–December in year *j*

TABLE 12 Price elasticities of demand on Cape Coral Bridge

Analysis	Year (*j*)	6:30–7:00 a.m.		9:00–11:00 a.m.		2:00–4:00 p.m.		6:30–7:00 p.m.	
		PED(a)	PED(r)	PED(a)	PED(r)	PED(a)	PED(r)	PED(a)	PED(r)
Method 1	1999	-0.20	-0.27	-0.10	-0.12	-0.11	-0.14	-0.02	0.01
	2000	-0.10	-0.09	-0.10	-0.14	-0.09	-0.10	-0.02	0.01
	2001	-0.13	-0.13	-0.09	-0.13	-0.10	-0.10	0.01	0.03
	2002	-0.03	-0.01	-0.07	-0.09	-0.08	-0.07	0.06	0.08
Method 2	1999	-0.19	-0.26	-0.09	-0.11	-0.10	-0.12	-0.01	0.02
	2000	-0.08	-0.08	-0.07	-0.12	-0.07	-0.09	0.00	0.02
	2001	-0.12	-0.13	-0.07	-0.13	-0.09	-0.10	0.02	0.03
	2002	-0.02	-0.01	-0.06	-0.09	-0.06	-0.07	0.07	0.08
Method 3	1999	-0.24	-0.31	-0.09	-0.10	-0.10	-0.10	-0.04	-0.05
	2000	-0.15	-0.17	-0.06	-0.10	-0.07	-0.07	-0.01	-0.02
	2001	-0.21	-0.22	-0.06	-0.10	-0.06	-0.06	0.02	-0.01
	2002	-0.08	-0.06	-0.04	-0.06	-0.05	-0.06	0.04	0.03

PED(a) = price elasticities of demand estimated using absolute changes in eligible traffic
PED(r) = price elasticities of demand estimated using relative changes in eligible traffic
Price elasticities of demand are negative

TABLE 13 Price elasticities of demand on Midpoint Memorial Bridge

Analysis	Year (*j*)	6:30–7:30 a.m.		9:00–11:00 a.m.		2:00–4:00 p.m.		6:30–7:00 p.m.	
		PED(a)	PED(r)	PED(a)	PED(r)	PED(a)	PED(r)	PED(a)	PED(r)
Method 1	1999	-0.36	-0.34	-0.10	-0.12	-0.11	-0.11	-0.06	-0.07
	2000	-0.30	-0.22	-0.06	-0.05	-0.14	-0.12	-0.05	-0.06
	2001	-0.14	-0.13	-0.11	-0.05	-0.15	-0.10	0.02	0.02
	2002	-0.12	-0.03	-0.17	-0.04	-0.18	-0.08	0.03	0.00
Method 2	1999	-0.38	-0.34	-0.11	-0.12	-0.12	-0.11	-0.07	-0.07
	2000	-0.33	-0.23	-0.09	-0.05	-0.17	-0.13	-0.08	-0.06
	2001	-0.16	-0.13	-0.12	-0.05	-0.17	-0.11	0.01	0.01
	2002	-0.16	-0.05	-0.21	-0.06	-0.22	-0.10	-0.01	-0.02
Method 3	1999	-0.43	-0.42	-0.09	-0.10	-0.10	-0.09	-0.11	-0.11
	2000	-0.39	-0.28	-0.07	-0.05	-0.14	-0.09	-0.07	-0.06
	2001	-0.21	-0.14	-0.10	-0.06	-0.13	-0.06	-0.07	-0.06
	2002	-0.31	-0.11	-0.14	-0.06	-0.14	-0.05	-0.08	-0.03

PED(a) = price elasticities of demand estimated using absolute changes in eligible traffic
PED(r) = price elasticities of demand estimated using relative changes in eligible traffic
Price elasticities of demand are negative

Results obtained by using relative changes in eligible traffic were in general slightly higher than the estimates using absolute changes in eligible traffic on the Cape Coral Bridge. Conversely, on the Midpoint Memorial Bridge elasticity estimates using absolute changes are much higher than estimates using relative changes during the 6:30 to 7:00 a.m. time period. As mentioned previously, this is partially due to the fact that traffic is growing at much faster rate on Midpoint Memorial Bridge and not considering the increase in ineligible traffic may overestimate price elasticities of demand. Therefore, method 3, using relative eligible traffic, is considered to be the best method to calculate price elasticities of demand. As this method also calculated elasticities based only on time periods influenced by respective discount periods, the results using this method are considered a better indicator of how price elasticities of demand changed over time. It should be noted that all six elasticity estimates using three different methods indicated that, in general, price elasticities of demand decrease over time. However, percentage of reduction varies by method and time period. Results were analyzed based on price elasticities of demand calculated using method 3 and relative eligible traffic change. It is also interesting to note that results using this method indicated approximately the same traffic pattern amongst eligible vehicles on both bridges.

Results indicated that initially there is a change in their time of travel of eligible trips (by offsetting overall growth in eligible traffic) to obtain toll discount during the early morning period. However, over the course of time, the impact of variable pricing decreased, possibly indicating that many of these trips were switched back to the regular (peak period) time of travel. For example, from 1998 to 1999, 15.5 percent (see Table 12) of eligible trips on Cape Coral Bridge indicated change in time of travel to the 6:30 a.m. to 7:00 a.m. time period to obtain the toll discount. However, this was reduced to 3 percent during 2002. As these were likely to be commute trips, it was possible that initially many drivers perceived the discount of $0.25 per trip to be enough to alter their time of travel. However, over time, many of these drivers might have felt that $0.25 saving was not sufficient for an effort to change their time of travel of commute trips. The variable toll had little to no impact on traffic patterns during the 6:30 p.m. to 7:00 p.m. time period. This was similar to the findings on SR91 in California, that workplace to home trips were more inelastic than home to workplace trips.

Initial low elasticities found during the 9:00 a.m. to 11:00 a.m. and 2:00 p.m. to 4:00 p.m. time periods was not surprising, as trips made during these time periods may not be by regular drivers on these bridges. Infrequent drivers may not find it economically viable to obtain a transponder and maintain a PrePay account in order to qualify for a toll discount. However, it was found that those drivers who were obtaining a PrePay account were less likely to decrease their variable pricing program participation over time. One reason could be due to the 2-hour duration of the discount period drivers had more opportunity to shift their time of travel to these periods. Another reason could be some of these drivers may not be regular commuters and are likely to be retired, unemployed, and part-time employees, and hence, more price sensitive.

Based on the above discussion, it can be concluded that the impact of variable pricing in changing time of travel from peak periods to off-peak periods gradually decreased. In the earlier part of this section while analyzing percentage changes in traffic volume, it was noted that percentage of eligible traffic on Cape Coral Bridge gradually decreased but on Midpoint Memorial Bridge it increased in many discount periods (see Figure 20). However, elasticity estimates on Midpoint Memorial Bridge indicated gradual decrease in percentage of eligible traffic. This is probably due to negating percentage change of ineligible traffic from eligible traffic. This phenomenon was further investigated in the following section by using peak spreading analysis.

As mentioned earlier, in the reviewed literature it was found that long-run elasticities were at least twice than those of short-run elasticities. However, results in this thesis indicated that long-run elasticities were smaller in magnitude than the short-run elasticities. This also supports our earlier assumption that the toll discount was not sufficient enough to cause any changes in mode of travel, employment location or housing location; hence, it was likely that price elasticities of demand in this project were smaller than the elasticity values mentioned in literature. Results in this research suggest that transportation planners and policy makers should consider how driver reaction to variable tolls might change over time and not considering this aspect may grossly over or under estimate the expected benefits of a variable pricing program.

Peak Spreading Analysis

The phenomenon of expansion of peak-period traffic to shoulders of the peak periods as the level of congestion increases on a highway is known as peak spreading. In the Lee County variable pricing project discount periods are set in such a manner that toll discounts may influence some drivers to change their time of travel from peak periods to discount periods. Hence, it may be possible to measure the effectiveness of the Lee County variable pricing program in diverting peak-period trips to shoulder periods using the equations developed for peak spreading analyses. In this analysis ineligible drivers serve as a control group and eligible drivers serve as an experimental group. If the hypothesis that the variable pricing program has an effect on eligible traffic is true, then peak spreading for eligible traffic should be more than that of ineligible traffic. The results from this analysis were used to validate elasticity results estimated in previous section.

Peak spreading models that were developed in the literature were based on a traditional four-step travel demand modeling process (trip generation, trip distribution, mode choice, and transportation network assignment). The four-step travel demand modeling process does not consider the temporal distribution of travel demand, hence predicted growth rate in traffic volumes may not be accurate, especially in conditions of severe traffic congestion. Most of the peak spreading models were developed to address this issue. As these models were based on route choice, mode choice, and origin and destination trip matrix, they were not useful in this research. However, there were a few peak spreading models that were developed independent of the four-step modeling process.

One such study performed in the United Kingdom proposed a ratio to represent degree of peak spreading occurring on a roadway. This ratio is labeled PSREP. PSREP is similar to a peak-hour factor, but it is applied on a peak-period basis (*39*). PSREP is calculated by dividing typical peak-period flow by a traffic volume that would occur if the maximum 15-minute volume during the peak period of a reference year occurred during every 15-minute interval of the peak period in the reference year. This ratio is then multiplied by 100 to form a percentage. Calculation of PSREP for consecutive years should indicate how the peak has spread over time, but only if there were no dramatic changes occurring during every 15-minute interval of peak period. Hence, PSREP represents percentage of peak period traffic that remains on a highway facility in a given year with respect to the base year. If this percentage decreased for consecutive years then it indicates that there is peak spread of traffic. Equation 13 represents the calculation of peak spreading road efficiency percentage using this method.

$$E_i = \frac{100 * \sum_{j=1}^{10} Q_{i_j}}{10 * \underset{j \in [1,10]}{Max} Q_{r_j}} \qquad (13)$$

where;

E_i = peak spreading road efficiency percentage for year *i*.

Q_{i_j} = flow in year *i* during quarter-hour period *j;*

i = number of years after initial year

j = an index in the range of 1–10, which identifies each quarter-hour period in the 2.5-hour peak period; and

r = value of *i* corresponding to the year being used for reference.

By applying similar methodology it was possible to calculate percentage of eligible traffic adjacent to discount periods remaining on toll roads with respect to the base year (in this case, 1998). If this percentage changed for consecutive years, then it may indicate that variable pricing impacts change over time.

On the Lee County toll bridges it is highly unlikely that there was any natural diversion of peak-period traffic to the shoulders of the peak, as there was little congestion on these bridges. The Lee County toll bridges operate at a level of service C (*29*). Hence, diversion of traffic from peak periods to discount periods in this project could be directly attributed to impact of variable pricing. However, for toll roads operating at maximum capacity this diversion should be considered as a result of both natural phenomenon and impact of tolls. Not considering natural phenomenon of peak spreading may over estimate the impact of variable pricing on these roads. On the Lee County toll bridges discount periods were set in such a manner that some eligible trips may be diverted from peak periods to discount periods. However, due to variable tolls, traffic, in even some non-peak periods, may also be affected by variable pricing. For example, although the morning 6:00 a.m. to 6:30 a.m. period may not be a peak period, eligible driver traffic in this time period was affected by the 6:30 a.m. to 7:00 a.m. discount period. Hence, the analysis in this research was not only based on peak periods but also on time periods adjacent to discount periods. Therefore, changes in traffic patterns of periods adjacent to discount periods can be used to help evaluate impacts of variable pricing program. This also can be used as supporting evidence for the previous findings in this chapter, which were mainly based on traffic pattern changes during discount periods.

There is high growth in eligible traffic volume on the Lee County toll bridges; hence, comparing peak spread using the reference year traffic volumes in the peak period model may overestimate variable pricing impacts. Also, in calculating PSREP, the highest 15-minute volume in the reference year is used to calculate the peak spread. As mentioned previously, in this analysis it was necessary to include periods adjacent to discount periods, which are both peak and off-peak periods. As there were large differences in peak and off-peak period volumes, using the highest 15-minute volume may overstate the impacts of the variable pricing program.

Considering the above factors and objectives of this study, a model (see Equation 14) was developed that represents how the traffic pattern may spread over time during the time periods adjacent to the discount periods. Four time periods were considered for the analysis, based on the discount periods. The following mathematical expression was used to evaluate impacts of variable pricing in changing time of travel from peak to discount periods.

$$D_{k_{iN}} = \frac{\sum_{j=1}^{n} Q_{k_{ij_N}}}{n \times Q_{k_{i\,N}}} \qquad (14)$$

where:

$D_{k_{iN}}$ = discount period volume spreading ratio in *k*th year for type of traffic *N* during the discount period *i*,

where;

k = number of years used for analysis, index from 1999 to 2002,

N = 1 if eligible traffic

2 if ineligible traffic, and

i = an index from 1 to 4 representing each discount period (see Table 14):

Table 14 Discount period volume spreading model parameters

Index (*i*)	Discount period	# Of time Periods (*n*)	Analysis Period
1	6:30-7:00 a.m.	4	6:00-8:00 a.m.
2	9:00-11:00 a.m.	8	8:00-12:00 a.m.
3	2:00-4:00 p.m.	8	1:00-5:00 p.m.
4	6:30-7:00 p.m.	4	5:30-7:30 p.m.

$Q_{k_{ij\,N}}$ = average half hourly daily traffic volume for type of traffic *N* in year *k*, during the *j*th half-hour period corresponding to the *i*th discount period,

where;

j = an index from 1 to n representing the n half-hour periods corresponding to the *i*th discount period. For example, for 6:30 a.m. to 7:00 a.m., n = 4 (6:00 a.m. to 6:30 a.m., 6:30 a.m. to 7:00 a.m., 7:00 a.m. to 7:30 a.m., and 7:30 a.m. to 8:00 a.m.), and

$Q_{K_{i_N}}$ = average half hourly daily traffic volume for type of traffic N in year k, during the *i*th discount period.

The discount period volume spreading ratio represents change in traffic over time during time periods adjacent to discount periods. Volume spreading ratios were estimated separately for the January to July and August to December assessment periods to compare trends in eligible and ineligible traffic volumes to those of previous results in this chapter. Thus, this volume spreading ratio relates the total flow during the most influencing time periods for a particular discount period in a year *i* to the flow during the discount period in the same year. By comparing the total flow during influencing periods to the flow during the discount period in the same year will help in offsetting differential growth rates in traffic volumes over the years. Estimates of discount period volume spreading ratios for January to July and August to December were presented in Tables 15 and 16 respectively.

As mentioned earlier, these ratios would represent change in traffic during time periods adjacent to the discount period in respective years. For example, volume spreading ratio for eligible trips during the 9:00 a.m. to 11:00 a.m. discount period during January to July 1998 was calculated as follows; for this analysis only time periods from 8:00 a.m. to 12:00 noon were considered, as these were the time periods on which this discount period had maximum impact. Therefore, this time period consists of 8 (n=8) half-hour time periods out of which four half-hour time periods were discount periods. There were total 1530 ($\sum_{j=1}^{n} Q_{k_{i_{j_N}}}$ = 1530) average daily trips during 8:00 a.m. to 12:00 noon. Out of these trips, a total of 666 ($\sum Q_{k_{i\,N}}$ = 666) average daily trips were made during the 2-hour 9:00 a.m. to 11:00 a.m. discount period. The volume spreading ratio for this time period is

$$\frac{1530}{8*\left(666/4\right)}=1.15$$

This indicates that eligible traffic during the time periods around the discount period is 15 percent greater than the 9:00 a.m. to 11:00 a.m. discount period. In similar manner this ratio for 1999 was 1.10.

Hence, it can be concluded that eligible traffic decreased by 5 percent from 1998 to 1999 during the adjacent time periods relative to the discount period eligible traffic. It could be observed that for the same time period volume spreading ratio for ineligible traffic remained at 1.08. Hence, this decrease in volume spreading ratio from 1.15 to 1.10 could be attributed to a shift in time of travel of eligible trips from shoulder periods to the corresponding discount period. An increase in this ration indicates a smaller proportion of vehicles in the discount period.

TABLE 15 Discount period volume spreading ratios for January–July discount periods

Driver	Time Period	1998		1999		2000		2001		2002	
		Cape Coral	Midpoint	Cape Coral	Midpoint	Cape Coral	Midpoint	Cape Coral	Midpoint	Cape Coral	Midpoint
Eligible	6:30–7:00 a.m.	1.11	1.09	0.99	0.89	1.03	0.91	1.00	0.98	1.07	0.94
	9:00–11:00 a.m.	1.15	1.19	1.10	1.14	1.11	1.15	1.11	1.14	1.13	1.12
	2:00–4:00 p.m.	1.03	1.05	0.99	1.01	1.00	1.00	1.01	1.01	1.01	1.00
	6:30–7:00 p.m.	1.15	1.20	1.13	1.14	1.15	1.16	1.16	1.17	1.18	1.16
Ineligible	6:30–7:00 a.m.	1.10	1.08	1.14	1.07	1.11	1.03	1.10	1.04	1.09	0.98
	9:00–11:00 a.m.	1.08	1.11	1.08	1.12	1.10	1.10	1.10	1.09	1.09	1.07
	2:00–4:00 p.m.	1.02	1.03	1.02	1.02	1.02	1.01	1.02	1.01	1.02	1.00
	6:30–7:00 p.m.	1.14	1.16	1.15	1.15	1.15	1.15	1.16	1.16	1.15	1.13

TABLE 16 Discount period volume spreading ratios for August–December discount periods

Driver	Time Period	1998		1999		2000		2001	
		Cape Coral	Midpoint	Cape Coral	Midpoint	Cape Coral	Midpoint	Cape Coral	Midpoint
Eligible	6:30–7:00 a.m.	0.93	0.88	1.00	0.95	1.03	0.97	1.07	0.99
	9:00–11:00 a.m.	1.09	1.14	1.10	1.14	1.12	1.14	1.13	1.12
	2:00–4:00 p.m.	1.00	1.00	1.01	1.00	1.01	1.00	1.02	1.00
	6:30–7:00 p.m.	1.14	1.15	1.14	1.16	1.18	1.17	1.18	1.18
Ineligible	6:30–7:00 a.m.	1.13	1.08	1.13	1.05	1.15	1.05	1.10	1.03
	9:00–11:00 a.m.	1.09	1.12	1.10	1.12	1.10	1.10	1.11	1.08
	2:00–4:00 p.m.	1.02	1.03	1.03	1.01	1.03	1.01	1.03	1.01
	6:30–7:00 p.m.	1.15	1.17	1.15	1.16	1.19	1.16	1.17	1.15

In the same manner for calculating discount period volume spreading ratio for each discount period, time periods adjacent to the discount periods were considered. More specifically;

- 6:00 a.m. to 8:00 a.m. were considered for 6:30 a.m. to 7:00 a.m. discount period.
- 8:00 a.m. to 12:00 noon were considered for 9:00 a.m. to 11:00 a.m. discount period.
- 1:00 p.m. to 5:00 p.m. were considered for 2:00 p.m. to 4:00 p.m. discount period.
- 5:30 p.m. to 7:30 p.m. were considered for 6:30 p.m. to 7:00 p.m. discount period.

From Table 15 it can be observed that for the January to July analysis period, initially in 1999 there was a maximum reduction (20 percent on Midpoint Memorial Bridge and 12 percent on Cape Coral Bridge) in discount period volume spreading ratios than during any other analysis period. This would indicate that variable pricing had maximum impact during 1999. This result is quite similar to earlier findings in this chapter. It can also be observed reduction in these ratios during the 6:30 a.m. to 7:00 a.m. discount period was higher on Midpoint Memorial Bridge than Cape Coral Bridge.

From Table 16 (August to December analysis period) it can be observed that volume spreading ratios for both the bridges during the analysis period were in general least for 1998. For subsequent years during the 6:30 a.m. to 7:00 a.m. discount period these ratios were gradually increased. Especially there was a highest increase in 1999 on both the bridges during this discount period. It indicates that initially when variable pricing introduced in August 1998 there was a positive response from drivers to change their time of travel from peak to discount periods. However, this positive response decreased over time, which was also an earlier finding in this chapter. It could be observed that least changes occurred in these ratios during the 6:30 p.m. to 7:00 p.m. discount period over the years. It was possible that during initial year itself the volume spreading ratio for this time period changed the least. It supports the earlier findings that variable pricing had least effect during this time period.

For the January to July analysis period the discount period volume spreading ratios decreased from 1998 to 1999 on both the bridges during 9:00 a.m. to 11:00 a.m., and 2:00 p.m. to 4:00 p.m. discount periods (see Table 15). After 1999, for subsequent years there were only small variations in these ratios during these time periods. This would indicate that drivers who were traveling during these time periods and changed their time of travel to obtain toll discounts were likely to continue their variable pricing participation at approximately the same rate. Overall, these results confirm analysis used in previous section to estimate elasticities over time.

SUMMARY

Daily traffic flow profiles indicated that eligible traffic increased during all time periods from 1998 through 2002 on both Cape Coral and Midpoint Memorial Bridges. By calculating changes in percentage of eligible traffic during each half-hour assessment period, it was found that immediately after introducing the variable pricing program there was a positive impact of variable pricing in changing time of travel from peak to discount periods.

To quantify driver responses to toll discounts, price elasticities of demand were estimated based on real-world data from the Lee County variable pricing project. Using three different methods, six different elasticity estimates were calculated and these estimates clearly showed that variable pricing program participation decreased over time.

A discount period volume spreading ratio was used to evaluate effectiveness of variable pricing program in changing time of travel of eligible drivers from peak periods to discount periods. It was found that immediately after introducing variable pricing program maximum number of eligible trips changed time of travel from peak periods to the discount periods. However, this response decreased over time during the early morning discount period. This supported earlier findings that the impact of variable pricing decreased over time. During the 9:00 a.m. to 11:00 a.m., and 2:00 p.m. to 4:00 p.m. discount periods variable pricing participation of eligible drivers remained at approximately the same rate.

However, to completely assess long-run changes in driver behavior due to variable tolls, the changes in variable pricing participation must be associated with socio-economic and commute characteristics. These socio-economic and commute characteristics of drivers who altered their time of travel over the years were collected in telephone survey data. The next chapter in this thesis describes the telephone survey data and characteristics of drivers who altered their variable pricing program participation over time. In Chapter V, several research hypotheses were developed that associate driver characteristics with changes in variable pricing program participation over time. These hypotheses and subsequent models developed based on these hypotheses may help in a complete assessment of long-run changes in driver behavior due to variable tolls.

CHAPTER V
ANALYSIS OF TELEPHONE SURVEY DATA

INTRODUCTION

This chapter examines the socio-economic and commute characteristics of Lee County bridge drivers in an attempt to find any significant relationships between these characteristics and a driver's propensity to change variable pricing program participation over time. Ascertaining socio-economic and commute characteristics that influenced changes in variable pricing program participation was the first step in developing mathematical models that related these characteristics to long-run changes in driver behavior due to variable tolls.

To find and examine any potential relationships it was necessary to collect socio-economic and commute characteristic data on Lee County toll bridge drivers who had and had not changed their variable pricing program participation over time. A telephone survey was used to capture socio-economic and commute characteristics of a representative sample of eligible drivers on the Lee County toll bridges. This chapter detailed this telephone data collection process, the analysis of this data, and conclusions based on results of this analysis.

TELEPHONE SURVEY DATA

Data Collection Effort

As a part of the Lee County variable pricing project a telephone survey was conducted in 2001 to obtain the characteristics of Lee County bridge drivers eligible for the toll discount. This research used this data to model changes in variable pricing program participation over time. A large sample size was required to capture characteristics of drivers who had changed their variable pricing participation for the following two reasons:

1. Eligible drivers constituted a small percentage (25 percent in 1999 to 32 percent in 2002) of total drivers.
2. Only a small percentage of eligible drivers purposefully altered their time of travel to obtain toll discounts.

Collecting a very large sample is not economical and it is also time consuming. To compensate for this, the survey targeted only those drivers who had a LeeWay transponder and a PrePay account. Therefore, all respondents had a LeeWay PrePay account, traveled across the toll bridges, and resided in preselected zip codes relevant to the study. A total of 4000 drivers were randomly selected from that group to be interviewed and were asked if they would participate in the survey; a total of 794 surveys were collected successfully.

Questionnaire Design

Guided by the objectives of the Lee County variable pricing project, a survey questionnaire was designed to gather information on socio-economic and commute characteristics of those drivers eligible for toll discounts. The following section details socio-economic and commute characteristics captured in this survey.

Description of Data

The survey instrument consisted of 35 questions with many of these questions containing multiple parts (a copy of the survey instrument is in Appendix C). The independent variables expected to have significant ability to explain changes in driver variable pricing program participation were examined below.

Description of Independent Variables in the Survey

As the objective of this research was to analyze the participation of eligible drivers in a variable pricing program, in the initial stage of survey respondents were asked whether they had a LeeWay transponder and PrePay account. If the respondent indicated no, then the survey was immediately terminated.

Respondents were asked the total number of trips they made across each Lee County toll bridge per week. Also, respondents were asked how long they have been traveling across either bridge and how long they have had a LeeWay PrePay account. Only responses which indicated more than 1 year were analyzed in this thesis to model long-run changes in driver participation in a variable pricing program.

Respondents were asked their reason for obtaining a LeeWay PrePay account. Further, respondents were asked whether they were aware of the variable pricing program. Only those respondents who were aware of the variable pricing program were considered in the analysis.

Respondents were asked whether they have changed their time of travel to obtain the variable pricing toll discount and their reason to consider the variable pricing toll discount. Respondents also indicated their trip and vehicle occupancy during these trips.

Respondents were asked about their employment status, if their employer offered flextime (flexibility in working hours) and, if so, whether they participated in a flextime program. Also, respondents indicated the main reason for participating in the flextime program.

Finally, socio-economic and demographic characteristics of respondents were collected. Respondents indicated the number of persons in each household, household type (single adult, unrelated adults, married without children, married with child/children, single parent family, or other), how many months per year they live in Lee County, education level (less than high school, high school graduate, some college or vocational, college graduate, or post-graduate degree), six discrete categories of age (16–24, 35–44, 45–54, 55–64, or 65 years and older), gender of the driver, and five categories of total annual household income (less than $16,000, $16,001–$30,000, $30,001–$50,000, $50,001–$75,000, and over $75,000).

Description of Dependent Variables in the Survey

The dependent variables investigated in this research were obtained from the responses to two different questions in the telephone survey. In the first question (number 11) respondents were asked whether they were taking advantage of variable pricing toll discounts more often than last year. Three different responses were elicited to this question. Those respondents who said yes were asked how many more trips per week they drove during discount periods compared to last year. Those respondents who answered no or do not know were asked the second question (number 13), whether they were taking advantage of variable pricing toll discount less often than last year (see Appendix C for the survey instrument). Those respondents who said yes were asked how many fewer trips per week they drive during discount periods compared to last year. Those respondents who said "don't know" to both the questions 11 and 13 were not included in the analysis. Conversely, respondents who answered "no" to both questions were considered to not have changed their variable pricing program participation compared to last year and were included in the analysis.

The data set was substantially reduced in order to use the results from questions 11 and 13 for statistical analysis and development of a model. Consequently, for using the variable pricing usage over time as the dependent variable, the data set included only those respondents who had increased/decreased/not changed their variable pricing usage.

Data Reduction

The original data set of 794 usable survey responses was placed in a database and checked for data entry errors. Then the following individual responses that have incompatible and incomplete answers to key questions regarding driver participation in the variable pricing program over time were deleted from the data set:

- 18 respondents who did not know whether they had increased or decreased their participation in the variable pricing program (questions 11 and 13);
- 3 respondents who did not drive during discount periods and who did not answer whether they used to drive during variable pricing discount periods (question 22);
- 1 respondent who indicated that he/she used the variable pricing more often and also less often; and
- 11 respondents who started traveling across either bridge with in the past year and indicated that they had a LeeWay transponder and PrePay account for more than 1 year (questions 2 and 4).

A total of 33 responses were eliminated, resulting in total of 761 responses in the data set. Once this was done, characteristics of respondents were compared with general demographic characteristics of Lee County residents, which were captured in census surveys. Table 17 indicates the comparison between some characteristics of Lee County toll bridge drivers and the general population.

From Table 17 it can be clearly seen that when compared to the average resident of Lee County, survey respondents were older (likely to be 35–64 age group), more affluent, and were likely to be female. This was not unexpected, since bridge drivers do not represent the county as a whole but are a representative sample of Lee County bridge drivers who are traveling frequently across these bridges. The number of people in the household does not differ much between the general population and the sample collected.

TABLE 17 Comparison between Lee County toll bridge drivers and population

Characteristic	**Percentage in each Category**	
	Population (Census Data)	**Sample**
Q29: Number of People in Household	2.70	2.50
Q33: Age		
1. 16-24 years	11.52	3.10
2. 25-34 years	12.92	10.60
3. 35-44 years	15.35	16.00
4. 45-54 years	15.18	20.30
5. 55-64 years	15.38	22.30
6. 65 years and older	29.64	27.50
Q 34: Gender		
1. Male	48.90	39.40
2. Female	51.10	60.50
Q 35: Household Income		
1. Under $16,000	16.50	3.00
2. $16,001–$50,000	52.60	39.14
4. $50,001–$75,001	16.50	30.61
5. Over $75,000	14.40	27.25

Once the data were "cleansed", survey responses were examined to identify respondents who have been using the variable pricing toll discount for more than 1 year. Based on the responses to different questions, the data set was divided into several categories:

- 41 respondents did not know about the variable pricing program.
- 479 respondents know about the variable pricing program but did not use it.
- 11 respondents know about the program but have been using it for less than 1 year.
- 28 respondents know about the program but did not use it and started traveling across either bridge within the last year.
- 107 respondents use the variable pricing program more often compared to last year.
- 17 respondents use the variable pricing program less often compared to last year.
- 78 respondents use the variable pricing program the same amount as last year.

Implemented in August 1998, the Lee County variable pricing program is a mature pricing program and, based on previous discussion in Chapters II and IV, is beyond the time frame within which short-run changes in driver behavior are in effect and is well into the time frame for long-run changes in driver behavior to have manifested.

The objective of this research is to analyze the long-run changes in driver behavior due to variable tolls. Therefore, only those respondents who have used the variable pricing program for more than 1 year were considered in the further analysis.

This reduced the data set to 202 respondents that included 107 respondents who used the variable pricing program more often, 17 respondents who used the variable pricing program less often, and 78 respondents who did not change their variable pricing program participation. This data set consists of only 26.5 percent of the original successful responses collected. Since there were only 17 (8.4 percent of the revised data set) respondents who indicated they decreased their variable pricing program participation, it was difficult to obtain any meaningful explanatory variables using this category. Hence, these 17 respondents were combined with the 78 respondents who did not change their variable pricing program participation to create a new category of drivers who did not increase their participation in the program. This new category consisted of 95 respondents. Combining the data into two categories helped to compare the characteristics of eligible drivers who increased their variable pricing program participation to those who did not.

RESEARCH METHODOLOGY

In developing a valid statistical model, meaningful explanatory variables with statistical significance need to be identified from the data set. A descriptive analysis is essential for determining which variables warrant inclusion in the modeling process. Several statistical tests were used to determine whether there were significant differences ($p < 0.05$) between the respondents who increased their variable pricing program participation and those who did not increase their variable pricing program participation. The methodological aspects of these statistical tests and binary logit modeling are discussed further in the ensuing sections of this chapter.

Methodology for Explanatory Analysis

The descriptive analysis was conducted to identify those demographic, socio-economic, and travel behavior attributes that were significantly different between the two groups (drivers who increased and who did not increase their variable pricing program participation).

The first step in the descriptive analysis process involved an examination of the bivariate relationship that might exist between certain demographic, socio-economic, and travel behavior attributes between the two groups of respondents. For categorical responses (for example trip purpose or occupation), the chi-square contingency test was used. The t-test was used for comparison of means of continuous data (for example number of trips per week and years traveling across either bridge). For ordinal data (for example age and income), the Mann-Whitney test was used to compare the means based on the ranks.

Discrete Choice Modeling Method

An individual selecting an option from a finite set of alternatives is often described as a discrete choice process. Certain aspects of driver behavior, such as participation in a variable pricing program, may be captured through this method. Discrete choice models typically postulate the probability of individuals choosing a given option as a function of their socio-economic and commute characteristics and the relative attractiveness of the option (*51, 52*).

Binary Logit Modeling

The binary logit model is one of the most commonly used discrete choice models in practice. The general hypothesis of this model is that:

1. The user perceives the various alternatives as independent, and therefore the error covariances are zero and
2. The random term of each alternative has the same probability distribution.

The logit model uses the method of maximum likelihood estimation to derive estimators for the model (*51, 52*). The maximum likelihood method will choose those values for the unknown parameters that would, under the distribution assumption, maximize the likelihood (probability) that we will obtain the sample we actually observed. Maximum likelihood estimators have a number of asymptotic properties; the estimators are asymptotically consistent, asymptotically efficient, and distributed asymptotically normal. Probabilities in binary choice logit model were calculated as follows:

The utility that decision maker *n* obtains from alternative *j* is

$$U_{in} = V_{in} + \varepsilon_{in} \tag{15}$$

where;

U_{in} is the utility associated with alternative *i* for an individual *n*,

V_{in} is the systematic component of the utility of alternative *i* for an individual *n*,

ε_{in} is the random component of alternative *i* for an individual *n*.

The probability that an individual *n* chose an alternative *i* from the set of alternatives C_n $P(i / C_n)$ is

$$P(i / C_n) = \frac{e^{V_{in}}}{e^{V_{in}} + e^{V_{jn}}} \tag{16}$$

Log likelihood ratio tests can be used to determine the validity of a binary logit model. However, when comparing the effect of the omission of variable and conducting tests of significance, it was assumed that something is known about the correct specification of the model. It is statistically invalid to evaluate logit models using the log likelihood ratio when the correct specification of the model was unknown.

Furthermore, the sample was assumed to be logistically distributed, which has not been determined.

The logit model reports the percentages of outcomes the model correctly predicts by category given the observed sample. This approach was used to evaluate binary logit estimates for this study. However, it must be noted that we know little about the underlying data generation process for this proposed model and we have mixture of nominal, ordinal, and continuous variables.

Alternative Methodology

Non-parametric methods of estimation allow us to model underlying conditional probability functions (CPDF) with fewer restrictions than parametric models. However, the less rigid the modeling structure, the greater the need for large data samples to obtain a given degree of accuracy. One more problem is that results using the non-parametric tests are difficult to display and interpret when there are multiple explanatory variables. In this research there were many explanatory variables and the data set consists of only 202 responses; therefore, it was difficult to use any non-parametric methods of estimation.

The semiparametric approach is halfway between parametric and non-parametric methods. This approach imposes fewer restrictions than parametric models but more restrictions than non-parametric models (*51, 53*). It is a compromise between parametric and non-parametric models. Hence, a semiparametric model was also used to develop a model that could predict driver participation in a variable pricing program over time.

There were two approaches that were commonly used for binary choice semiparametric estimation. One is based on single index modeling and another approach is based on binary version of the median regression model. In this thesis, for semiparametric model estimation, median regression model using maximum score estimator was used.

The maximum score estimator was introduced by Charles Manski in 1975 as an alternative estimation technique to discrete choice model. Maximum score estimator was robust to unusual distributions of the disturbance term. Unlike the maximum likelihood estimator, the maximum score estimator required only one assumption inorder to be consistent; the median of error term, conditional on the set of regressors, must be zero. That is, if we examine a large number of respondents with similar characteristics half of the respondents would be expected to have higher values of the index and another half were expected to have lower values of index. Hence, maximum score estimator reflect the behavior of the typical respondent, while maximum likelihood estimates reflect the average behavior of all drivers (*54*).

The median approach in maximum score estimator was less sensitive to the overall shape of the distribution of a variable and hence these estimators are less sensitive to the outlier observations. This approach does not need any adhoc adjustments for the boundary values of the dependent variables and directly specifies model for expectancy of the dependent variable, y_i, given explanatory variable, x_i, ($E(y_i/x_i)$). The focus is on the estimation of asymptotically efficient estimator of coefficient, β, in the semiparametric approach which is the maximum score estimator (*55*). Consider the following econometric specification:

$$y^* = x_i{}^1 \beta + u_i \tag{17}$$

and

$$y_i = sgn\left(x_i^1 \beta + u_i\right); \quad i = 1,........,n \tag{18}$$

where; $y^* = Z = x_i{}^1 \beta + u_i$

and $y_i = \text{sgn}(Z) = \begin{cases} 1 & \text{if } Z = y^* \geq 0 \\ -1 & \text{otherwise} \end{cases}$

In this, $x_i \in R^k$ is a random vector of explanatory variables, where 'k' denotes the number of dependent variables. x^1 denotes the transpose of matrix, and 'x^1' is a $1 \times k$ random vector. u_i is a scalar error term. This error term is assumed to have a zero median. β is a unknown $k \times 1$ constant vector. For almost every x_i, $med\left({u_i}/{x_i} \right) = 0$.

Then for any p>0, $med\left(x_i^1 \beta\, p + p\, {u_i}/{x_i} \right) = x_i^1 \beta\, p$. Maximum score estimator solves the following problem;

$$\max_b \frac{1}{N} \sum y_i \cdot sgn\left(x_i^1 b\right), \quad \text{subject to normalization } b^1 b = 1 \qquad (19)$$

where; $\frac{1}{N} \sum y_i \cdot sgn\left(x_i^1 b\right)$ is called score function.

Analysis of Responses

The relationship between independent and dependent variables was initially examined by determining which socio-economic, demographic, and travel attributes were significantly different between the two groups of respondents. The dependent variable (had the respondent increased his/her variable pricing program participation) was used to stratify the two groups for comparison (see Table 18).

TABLE 18 Socio-economic and commute characteristics of Lee County toll bridge drivers

Characteristic	Variable Pricing Program	
	Increased (n=107)	Did not Increase (n=95)
Q1: Number of trips per week		
On the Cape Coral Bridge*	5.55	3.81
On the Midpoint Memorial Bridge*	4.84	3.41
Q2: Years traveling on either bridge	9.99	10.60
Q4: Years having LeeWay and PrePay	3.22	3.12
Q15: Reason to consider variable pricing discount		
1. Save money	64.50	57.90
2. Less traffic/Congestion	8.40	8.40
3. Contribute to better flow of traffic	7.50	4.20
4. Good for environment	0.90	1.10
5. Already drive during those hours	15.00	17.90
6. No opinion	1.90	3.20
7. Other	1.90	7.40
Q19: Primary trip purpose		
1. Commuting*	29.90	15.80
2. Delivering goods	0.00	1.10
3. Work-related	10.30	15.80
4. School	1.90	0.00
5. Shopping	28.00	35.80
6. Airport	1.90	1.10
7. Recreational	28.00	25.30
8. Drop Off/ Pick Up Person	0.00	1.10
9. Other	0.00	4.20
Q20: Mode		
1. Driving alone	59.80	53.70
2. 2-person Car or Vanpool	30.80	36.80
3. 3-person Car or Vanpool	8.40	7.40
4. Transit bus	0.00	0.00
5. Truck or Commercial vehicle	0.90	1.10
6. Don't know	0.00	1.10
Q25: Employment status		

TABLE 18 Continued

Characteristic	Variable Pricing Program	
	Increased (n=107)	Did not Increase (n=95)
1. Full time*	46.70	31.60
2. Part time	9.50	4.70
3. Retired*	41.10	51.60
4. Not employed	7.50	5.30
5. Refused	0.00	2.10
Q26: Flextime		
1. Availability: Yes	20.6	14.7
2. Availability: No	79.4	85.3
Q27: Flextime participation		
1. Yes	18.7	11.6
2. No	81.3	88.4
Q28: Reason for participating in Flextime		
1. Congestion, recreation, other	70.00	100.00
2.Variable Pricing toll discount	30.00	0.00
Q29: Number of people in household*	2.57	2.27
Q30: Household type		
1. Single adult	10.40	18.10
2. Unrelated adults	5.70	5.30
3. Married without children	43.40	40.40
4. Married with children	33.00	31.90
5. Single parent family	4.70	3.20
6. Other	2.80	1.10
Q 31: Months living in Lee County per year	12.00	11.87
Q32: Education level		
1. Less than high school	1.00	3.20
2. High school graduate	25.70	26.90
3. Some college/Vocational	33.30	31.20
4. College graduate	25.70	30.10
5. Post-graduate degree*	14.30	8.60
Q33: Age		
1. 16-24 years	1.90	4.20

TABLE 18 Continued

Characteristic	Variable Pricing Program	
	Increased (n=107)	Did not Increase (n=95)
2. 25-34 years*	11.20	3.20
3. 35-44 years	14.00	13.70
4. 45-54 Years	19.60	17.90
5. 55-64 years	24.30	24.20
6. 65 years and older	29.00	36.80
Q 34: Gender		
1. Male	45.80	37.90
2. Female	54.20	62.10
Q 35: Household income		
1. Under $16,000*	1.20	8.60
2. $16,001–$ 30,000	16.00	17.20
3. $30,001–$ 50,000	22.20	25.90
4. $50,001–$ 75,001	30.90	27.60
5: Over $75,000	29.60	20.70

* = Groups different at the 0.05 level
Chi-Square tests were used to compare nominal data,
Mann-Whitney tests were used to compare ordinal data, and
t-tests were used to compare continuous data by group

Statistically significant ($p = 0.05$) differences between the characteristics of the two groups, those who increased their variable pricing program participation and those who had not, were found in many categories. These categories include number of trips per week on the Cape Coral and Midpoint Memorial Bridges, primary trip purpose, employment status, number of people in household, education level, and income.

Demographic Characteristics

Employment status was found to be significantly different across the two groups. Drivers who used the variable pricing program more often were significantly more likely to be full-time employees and less likely to be retired. These full-time employees may use the toll bridges on a repetitive basis for commuting to work and could be reasonably expected to use the variable pricing program more often than those who have no such repetitive reason for bridge crossing. In the previous chapter it was found that although many commuters initially changed their time of travel to obtain toll discounts, over time some of these commuters switched back to their regular time of travel. Though many commuters either stopped using the variable pricing program or decreased the number of crossings during the discount periods over time, it could be expected that still some commuters were likely to use the variable pricing program more often.

Age was found to be significantly different across the two groups. Drivers who used the variable pricing program more often were significantly more likely to be between 25 and 34 years old and less likely to be 65 years and older. It could be expected that many drivers in the age group 25 to 34 years were likely to be full-time employees and have a repetitive reason for bridge crossing. Respondents 65 years and older were likely to be retired and it could be expected that these drivers were price sensitive. It could be possible that being more price sensitive these drivers initially changed their time of travel to discount periods when variable pricing was introduced. However, these drivers do not have any reason to cross toll bridges more frequently and hence, are unlikely to increase their participation in the variable pricing program over time. As found in the previous chapter, it was also unlikely that these drivers decreased their variable pricing program participation; hence participation of these drivers would not change over time.

Those eligible drivers who have a post-graduate degree were significantly more likely to increase their participation in a variable pricing program. Females represented 57.6 percent of all respondents, and there were no significant differences between the two groups based on gender.

Household Characteristics

Respondents who used the variable pricing more often reported an average of 2.57 persons per household, and those who do not use variable pricing more often reported an average of 2.27 persons per household. Based on the number of persons in a household, the two groups were significantly different from each other.

There were no differences between the two groups based on the household type. About 41.7 percent of all respondents were married without children. There were 18.10 percent of single adults who did not increase their variable pricing program participation and 10.40 percent of single adults who increased their variable pricing program participation over time.

There was a significant difference between the two groups based on household income. Drivers with household income less than $16,000 were significantly less likely to increase their variable pricing program participation over time than the drivers with other income groups. It was surprising to find that drivers with incomes less than $16,000 have not used the variable pricing more often. One possible explanation could be these low-income drivers had less flexibility in arriving at their workplace and, hence, it was difficult for them to change their time of travel to discount periods. Another possible explanation could be these drivers may have adjusted their time of travel immediately after introducing the variable pricing program and as already they were driving during these periods it was not likely that they will increase their participation.

Commute Characteristics

The two groups were significantly different based on the purpose of the trip during the toll discount periods. Those respondents who used toll bridges for commuting were significantly more likely to use the variable pricing program more often. Earlier, it was mentioned that full-time employees were significantly more likely to use the variable pricing program more often. It could be possible that these full-time employees would use these bridges for commuting purposes. To offset this, in the next section while developing statistical models variables were tested for correlation. If any variables were highly correlated then only one of these variables that improved the performance of model was used. There were no significant differences found between the two groups based on any other trip purpose. There were 35.80 percent of shopping trips in the group of drivers who did not increase their variable pricing program participation and 28.00 percent of shopping trips in the group of drivers who increased their variable pricing program participation over time.

Based on the number of crossings per week on either toll bridge, the two groups were significantly different from each other. Those who make more trips on these toll bridges were significantly more likely to increase their variable pricing program participation over time. It could be possible that those drivers who use the toll bridges more often were using these bridges for commute trips. If these two variables were highly correlated then only one of these will be used in subsequent model development.

MODEL ESTIMATION

This section presents the specifications of the binary logit model for predicting driver participation in a variable pricing program over time. The logit model was specified to estimate the likelihood of a driver increasing his or her participation in a variable pricing program. The data set was modeled initially with variables that were found to be significantly different across the two groups and other potential variables that might explain the differences between the two groups. Subsequently the data were analyzed by excluding variables that were identified in standard statistical tests as not being significantly different between the two groups of respondents. Various combinations of independent variables were tested in the binary logit model. However, only those variables that have negligible correlation with other variables were used in the final model. Limdep 7.0 software was used for model estimation in this thesis.

Numerous models were tried to address the hypotheses outlined in the previous section and in each model socio-economic, demographic, and commute characteristics were examined as potential independent variables. Several model specifications were tried and the one with the highest explanatory power using the fewest independent variables is presented in Table 19. The magnitude and sign of coefficient and significance of the variable in each model were examined to answer each hypothesis.

TABLE 19 Variable pricing participation using binary logit model

Variable*	Coeff.	Std. Err.	t-ratio	P-value
Constant	-0.13	0.24	-0.53	0.60
# Crossings across Cape Coral	0.08	0.04	2.27	0.02*
Age between 25 to 34 years	1.27	0.69	1.85	0.05*
Number of Observations				202
Log Likelihood				-133.7
Restricted Log Likelihood				-139.66
ρ^2				0.042

* = Significant at 0.05 level (p = 0.05)

The respondent's number of weekly trips across the Midpoint Memorial Bridge, trip purpose, number of persons in a household, household type, education level, employment status, and annual income level did not contribute significantly to any of the models developed or to the final model of variable pricing program participation over time (see Table 19). Conversely, number of weekly trips across Cape Coral Bridge, and age between 25 and 34 years contributed significantly to the model.

The constant term in the model was not significant (p = 0.05) and suggests that in the base case, where all coefficients were set to zero, the probability of a driver falling into either of the categories is equal. Though the constant term was not significant it improved the efficiency of the model; hence, included in the final model presented. The positive coefficients for both the variables were not reinforcing the findings in earlier chapters that the variable pricing program participation decreased over time.

The coefficients corresponding to number of trips per week on Cape Coral Bridge and age between 25 and 34 years were both positive and were statistically significant. As hypothesized, those respondents who make more trips on Cape Coral Bridge and respondents between 24 and 35 years of age were likely to increase variable pricing program participation. However, the coefficient corresponding to number of crossings across Cape Coral Bridge is small and it indicates that this variable had minimum impact in the model. It should be noted that contrary to our earlier assumption, there was no significant correlation between these two explanatory variables. In summary, utility equation for increasing the participation in a variable pricing program using binary logit model was as follows:

$$U_{1_n} = 0.08 * (number\ of\ trips\ on\ the\ Cape\ Coral\ Bridge)_n + 1.27 * (age\ between\ 24\ to\ 35\ years)_n \quad (20)$$

where;

U_{1_n} = utility of increasing participation in variable pricing program

n = respondent number

The logit model may be evaluated by percentages of outcomes the model correctly predicts by category given the observed sample. Table 20 indicates the percentage of outcomes the above binary logit model could predict by category. In the Table 20 the numbers in gray area represent the number of outcomes that were correctly predicted by the model in each group. The proposed logit model correctly predicts 61.38 percent of the data that include 51.57 percent of type 1 choice (those who did not increase their variable pricing program participation) and 70.09 percent of type 2 choice (those who increased their variable pricing program participation).

TABLE 20 Predicted values using binary logit model

Actual*	**Predicted***			
	1	**2**	**Total**	**Correct (%)**
1	49	46	95	51.57
2	32	75	107	70.09
Total	81	121	202	61.38

Actual* and predicted* = observed and predicted values for:
Group 1 (did not increase variable pricing program participation)
Group 2 (did increase their variable pricing program participation)

Though this model could able to predict 61.38 percent of total out comes correctly it could not able to differentiate between the two groups in base case scenario where every thing else is equal.

As mentioned in an earlier section, a semiparametric model using a maximum score estimator was also used to ascertain whether semiparametric models can improve the performance in predicting driver participation in a variable pricing program. The maximum score estimator attempts to maximize the number of correct predictions. This method yields consistent estimates under weak distributional assumptions. The estimated model using the semiparametric method is presented in Table 21. However, in this model only one variable, number of trips per week on Cape Coral Bridge, significantly contributes to the development of the model. Although full time employment increased the efficiency of the model, its coefficient was not statistically significant.

TABLE 21 Variable pricing participation using semiparametric model

Variable	Coeff.	Std. Err.	t-ratio	P-value
Constant	-0.74	0.18	-4.12	0.00*
# Crossings across Cape Coral	0.65	0.23	2.82	0.00*
Full time employment status	0.17	0.17	1.02	0.31

* = significant at 0.05 level (p = 0.05)

One noticeable aspect of this model was that unlike the binary logit model, the constant term in this model is negative and significantly contributes to the model. The constant term is negative, and it indicates that in the base case scenario when all things being equal, drivers were not likely to increase participation in a variable pricing program. As very few variables have explanatory power to differentiate between these two groups of drivers, it could be reasonable to expect that over time drivers' participation in a variable pricing program would not increase. The coefficient for the constant term was negative and greater than the positive coefficient for number of trips per week on the Cape Coral Bridge. This would indicate that the impact of the negative coefficient is greater than the positive effect of number of trips per week on the Cape Coral Bridge. These findings would support results based on traffic volume data in Chapter IV that price elasticities of demand decreased over time. Table 22 indicates the results obtained using the semiparametric approach. In the Table 22 the numbers in gray area represent the number of correct outcomes predicted by the model in each group.

TABLE 22 Predicted values using semiparametric model

Actual*	Predicted*			
	1	2	Total	Correct (%)
1	59	36	95	62.11
2	40	67	107	62.61
Total	99	103	202	62.37

Actual* and predicted* = observed and predicted values for:
Group 1 (did not increase variable pricing program participation)
Group 2 (did increase their variable pricing program participation)

The proposed semiparametric model correctly predicts 62.37 percent of the data that include 62.11 percent of type 1 choice (those who did not increase their variable pricing program participation) and 62.61 percent of type 2 choice (those who increased their variable pricing program participation). Although the overall predictive capability of this model is similar to the logit model, this model was able to predict both choices with the same efficiency.

SUMMARY

This chapter detailed the telephone data collection process and analysis based on these data. Descriptive analysis was performed to identify which variables significantly differ between those who increased their participation in the variable pricing program and those who did not. Based on the standard statistical tests, it was found that drivers who made more trips on Cape Coral Bridge, were commuting, were employed full-time, had more number of persons in the household, had a post-graduate degree, and were between 25 and 34 years old were more likely to have increased their variable pricing program participation over time. Characteristics such as being retired or with a household income less than $16,000 decreased the probability that a driver would use variable pricing more often.

However, when a standard binary logit model was developed based on these variables, only the number of trips on Cape Coral Bridge, and age between 25 and 34 years, contributed significantly to model development. Also, in this model the coefficient of the constant term was not significant.

When a semiparametric model was developed, despite using numerous independent variables, only one variable, number of trips per week on the Cape Coral Bridge, was significant in the model. One possible reason for this was similarity in socio-economic and commute characteristics between those who increased and those who did not increase their participation in a variable pricing program. In this model the constant term was also significant. The negative coefficient of constant term and only one significant variable indicates that the variable pricing program participation did not increase over time.

CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

SUMMARY

One potential solution to the serious problem of traffic congestion is the use of variable tolls to regulate the demand for travel. One of the important objectives of any variable pricing project is to transfer some of peak-period traffic to the off-peak period. The impact of this variable toll depends on driver willingness to pay the toll and driver response to price changes. These reactions can be measured in terms of the price elasticity of demand. However, due to lack of experience with variable pricing projects in the U.S., there has been limited research on long-run changes in price elasticities of variable tolls. Therefore, little is known regarding the long-term impacts of a variable pricing program.

To address these issues, information is needed at both the aggregate and disaggregate level. Using aggregate data, overall changes in price elasticities of demand over time can be estimated. At the disaggregate level, the influence of drivers' socio-economic and commute characteristics in changing their variable pricing program participation over time can be examined. This understanding will improve the accuracy of variable pricing project evaluation and can reduce overestimation/under estimation of long-term benefits of a variable pricing program.

This thesis thoroughly examined data from the Lee County variable pricing project, one of the few operational projects under Federal Highway Administration's value pricing pilot program. Implemented in August 1998, it is a mature pricing program and well into the time frame for long run changes to have occurred.

Using traffic volume data from the Lee County variable pricing project, daily traffic flow profiles were estimated for the two bridges with variable tolls. To quantify impacts of a variable pricing program over time, the percentage changes in traffic during each half-hour assessment period were calculated. The results indicated that the impact of variable pricing in changing drivers' time of travel has gradually decreased.

To quantify driver response to the toll discount, price elasticities of demand were estimated. Three different methods were used to determine both the absolute and relative changes in eligible traffic, resulting in six different elasticity estimates. These estimates indicated that variable pricing program participation decreased over time. A discount period volume spreading ratio was developed to validate the elasticity results. These discount period volume spreading ratios also indicated that the impact of variable pricing has decreased over time.

A telephone survey was conducted to identify socio-economic and commute characteristics of eligible users who have increased/decreased/not changed their participation in a variable pricing program. A descriptive analysis was performed using standard statistical tests to identify independent variables that were significantly different between those respondents who had increased their variable pricing participation and those who had not.

A disaggregate choice model was developed using telephone survey data to better understand the relationship between drivers' socio-economic and commute characteristics and changes in their variable pricing program participation over time. A semiparametric model was also developed to evaluate whether this model improved the efficiency over the disaggregate choice model in predicting driver participation in a variable pricing program over time.

CONCLUSIONS

This thesis examined variable pricing program participation over time on Lee County toll bridges, based on traffic volume data and a revealed preference (conducted approximately 3 years after introduction of the variable pricing program) telephone survey. It was found that driver response to the variable toll program has generally decreased over time.

Daily traffic flow profiles indicated that eligible traffic increased in comparison to the ineligible traffic on the Lee County toll bridges. To better illustrate the changes in both eligible and ineligible traffic, the percentage of traffic in each half-hour period was calculated. From these percentages, the annual percentage change in traffic during each half-hour was estimated. It was found that from 1998 to 1999 during 6:30 a.m. to 7:00 a.m. discount period, absolute percentage of eligible traffic increased by 18.11 percent on the Midpoint Memorial Bridge and by 10 percent on the Cape Coral Bridge. During the 9:00 a.m. to 11:00 a.m. discount period there was an increase of approximately 4 percent on both these bridges. Though initial driver response to variable tolls was very positive, eligible driver participation in the variable pricing program subsequently decreased over time.

When variable pricing was initially introduced in 1998, drivers responded positively by changing their time of travel to discount periods (*28, 29, 54, 56*). This change in time of travel was higher during the early morning discount period with estimated relative elasticity of up to –0.42 on the Midpoint Memorial Bridge. However, driver participation dropped by 2002 and relative elasticity estimates were only –0.11. It was also found that during the evening discount period fewer drivers were willing to change their time of travel to obtain a toll discount.

After first year of implementation price elasticities of demand decreased during the 2:00 p.m. to 4:00 p.m. time period ranged from –0.10 to –0.07. Demand elasticity during this time of day stabilized at this point. During the 9:00 a.m. to 11:00 a.m. discount period similar results were found. This indicates that eligible drivers who shifted their time of travel in 1999 to the discount periods were likely to continue their variable pricing usage at just a bit lower rate.

A discount period volume spreading ratio was developed to validate the elasticity results. These ratios decreased in 1999 (January to July) in comparison to 1998 (January to July), which indicates that immediately after introducing the variable pricing there was a change in the time of travel of eligible trips to the discount periods. This change in time of travel in response to variable tolls was greatest during the 6:30 a.m. to 7:00 a.m. discount period and smallest during the 6:30 p.m. to 7:00 p.m. discount period. In 2000 (January to July), in the second year of variable pricing implementation the discount period volume spreading ratios increased during the 6:30 a.m. to 7:00 a.m. discount period on both the bridges and for subsequent years also it has shown an increasing trend. This would indicate that during the first year many eligible trips were altered to the discount period and over time some of these trips were reverted back to the peak period. This would support earlier findings that the price elasticities of demand gradually decreased over time during the 6:30 a.m. to 7:00 a.m. discount period.

However, these ratios for 9:00 a.m. to 11:00 a.m. and 2:00 p.m. to 4:00 p.m. decreased in 1999 and thereafter they remained relatively stable. This would indicate that many eligible drivers who shifted their time of travel in 1999 to discount periods were likely to continue their variable pricing usage at approximately the same rate. This was comparable to the earlier finding that the reduction in price elasticities of demand in these time periods was minimum compared to the 6:30 a.m. to 7:00 a.m. discount period.

Using standard statistical tests, it was found that certain driver characteristics, such as drivers who have made more frequent trips on Cape Coral and Midpoint Memorial Bridges, were on commute trips, were full-time employees, had more persons in their household, had a post-graduate degree, and were between 25 to 34 years old all were significantly more likely to have increased their variable pricing participation over time. Other characteristics like being retired or having a household income less than $16,000 indicated that drivers were less likely to increase their variable pricing participation. This analysis was used when developing mathematical models of variable pricing participation over time.

A binary logit model was developed to predict the probability of a driver participating in a variable pricing program more often. Various combinations of independent variables were tested in the binary logit model and only those variables that had negligible correlation with other variables and had a statistically significant impact on the model were used in the final model. Results of the binary logit model were as follows:

- The binary logit model correctly predicted 61.38 percent of respondents choices, including 51.57 percent of those who did not increase their variable pricing participation and 70.09 percent of those who have increased their participation in the variable pricing program.
- Survey respondents who made more trips per week across the Cape Coral Bridge or, were between 25 to 34 years old were significantly more likely to increase their variable pricing program participation over time.

A semiparametric model using maximum score estimator was used to test whether this model could improve on the accuracy of the logit model. Results of the semiparametric model were as follows:

- Semiparametric model correctly predicted 62.37 percent of respondents choices, including 62.11 percent of those who did not increase their variable pricing participation and 62.61 percent of those who have increased their participation in the variable pricing program.
- In this model, unlike the binary logit model, the constant term contributes significantly to the model. The constant term in the model is negative and it indicates that in the base case scenario, when all other factors are equal, drivers were significantly less likely to increase their participation in variable pricing program.
- Survey respondents who made more trips across the Cape Coral Bridge were significantly more likely to increase their variable pricing program participation.

When comparing the binary logit and semiparametric models it can be observed that though overall predictive capability of both models is approximately the same, the semiparametric model was able to predict both the choices with nearly same efficiency. In the semiparametric model the constant term was negative and greater than the positive coefficient for number of weekly trips across the Cape Coral Bridge. This would indicate that the impact of the constant term is greater than effect of number of weekly trips across the Cape Coral Bridge. As there was only one explanatory variable which could differentiate between those who were increasing their variable pricing participation and those who were not, and because of the high magnitude of negative coefficient for the constant term, it could be expected that in spite of toll discounts many drivers were significantly more likely not to increase their variable pricing participation over time.

As opposed to the perception in the reviewed literature that the long-run elasticities were at least twice that of short-run elasticities, the results in this research showed that the long-run elasticity of variable pricing tolls is smaller in magnitude in comparison with the short-run elasticity. Results in this research suggest that transportation planners and policy makers should consider how drivers' reaction to variable tolls might change over time without any change in his/her travel attributes. Not considering this aspect may result in an over/under estimation of the expected benefits of a variable pricing program. One reason that could explain this change in driver perception towards toll discounts is, approximately 94 percent of drivers were getting a toll discount of 25 cents and due to inflation the purchasing power of 25 cents would decrease over time.

FUTURE RESEARCH

Analyses in this research did not consider the influence of inflation rates in driver decision making. Value of a dollar in 2002 may not be same as value of dollar in 1998. As inflation generally goes up, the value of dollar will decrease over time. Hence, it could be argued that the monetary value of toll discounts in 2002 might be less than the value of toll discounts in 1998. This factor could explain to some extent the general decrease in price elasticities of demand over time.

This research indicated that driver reaction to variable pricing toll discounts may not remain same over time; hence, his or her participation in a variable pricing program will change over time. The other existing/potential variable pricing projects may exhibit higher price elasticities of demand based on alternate route choice, mode choice, and the absolute amount of toll discounts. Elasticity estimates in this project may not be directly applicable to other projects; this research indicates that the potential exists for the long-run elasticity of a variable pricing project to be smaller in magnitude than the short-run elasticity. This is unusual for price elasticities of demand in transportation. Not considering this aspect may overstate or understate impacts of a variable pricing program. Standardizing findings in this thesis to reflect changes in driver participation in a variable pricing program based on characteristics of a variable pricing project and socio-economic characteristics of the populace would be a valuable asset to transportation planners and researchers. However, due to the relatively small survey data set available this could not be accomplished here.

Analysis of this survey indicated that as of 2002 there were 47,151 PrePay accounts with transponders. However, there were only 9550 average daily eligible trips during discount periods on both bridges during 2002. This was not surprising since the monetary incentive was only 25 cents for a majority of variable pricing participants. However, it was also observed that although the existing level of service during peak periods is C, traffic at both variably priced bridges is growing at a considerable percentage. At this rate, it is only a matter of time before these bridges become congested during peak periods. It can be reasonably expected that the future impact of variable pricing in changing the time of travel increase due to additional eligible drivers changing their travel behavior to both avoid congestion and obtain toll discounts. Hence, it can be envisaged that if a congestion factor were included in the analysis impact of variable pricing program may increase.

Another important concern was that many of the variables in the telephone survey data were not used in analysis due to inconsistencies in responses and small sample size. At the time of the survey it had been 3 years since the variable pricing program was introduced and hence drivers may have to drive during discount periods but forgot about the variable pricing program or they may forgot that they had switched time of travel due to the program. When asked about extent of participation in a variable pricing program it is possible that their responses misrepresent the actual scenario. To over come this, it might be better to select some number of transponders and track the extent of participation in the variable pricing program using transponder data. Socio-economic and demographic characteristics of these drivers can be collected to associate driver characteristics to changes in variable pricing program participation over time. Also, this will lead to greatly simplifying the questionnaire.

Due to small sample size several hypotheses that were initially planned could not be verified and several models could not be constructed. Due to small sample sizes, three groups who increased/decreased/not changed their variable pricing participation had to be combined to form two groups those who increased their variable pricing program participation and those who had not. Hence, it was suggested that any future research to evaluate impacts of a potential/existing variable pricing program (or any research with similar objective) should collect a larger sample size.

REFERENCES

1. Anderson, A.L., R.D. McLellan, J.P. Overton, and G.L. Wolfram. *Demand Elasticities*. MACKINAC Center for Public Policy, Policy Research. http://www.mackinac.org/1247. Accessed Nov. 23, 2002.

2. Lee, D. B. Demand Elasticities for Highway Travel. *Highway Economic Requirements System Technical Report,* Appendix C, U.S. Department of Transportation, Washington, D.C., 2000.

3. Litman, T. *Why Manage Transportation Demand*. Victoria Transport Policy Institute. www.vtpi.org. Accessed April 7, 2003.

4. Burris, M. W. *Analysis of Driver Response to Variable Tolls.* Ph.D. Dissert., South Florida University, Tampa, Florida, 2001.

5. Schrank, D., and T. Lomax. *The 2002 Urban Mobility Report*, Texas Transportation Institute, College Station, Texas, 2002. http://mobility.tamu.edu. Accessed March 25, 2003.

6. Walters, A. A. The Allocation of Joint Costs with Demands as Probability Distributions. *American Economic Review*, Vol. 50, No. 3, June 1960, pp 419-432.

7. Small, K. A., and J. A. Gomez-Ibanez. Road Pricing for Congestion Management: The Transition from Theory to Policy. Presented at the Taxation, Resources, and Economic Development Conference, Lincoln Institute of Land Policy, Cambridge, Massachusetts, Sept. 30–Oct. 1, 1994.

8. Hau, T. D. *Economic Fundamentals of Road Pricing: A Diagrammatic Analysis*. Policy Research Working Papers, WPS 1070, The World Bank, Washington D.C., December 1992.

9. Burris, M. W. The Toll-Price Component of Travel Demand Elasticity. *The International Journal of Transport Economics*, Vol. 30, No. 1, February 2003, pp. 45–59.

10. Curbing Gridlock: *Peak Period Fees to Relieve Traffic Congestion,* Volume 1, Transportation Research Board, Special Report 242, National Academy Press, Washington, D.C., 1994.

11. Loukakos, D. *Congestion Pricing,* Travel Demand Management. An ITS Decision Report, University of California, June 6, 2000. http://www.path.berkeley.edu/~leap/TTM/Demand_Manage/pricing.html. Accessed August 22, 2003.

12. Sullivan, E. *Continuation Study to Evaluate the Impacts of the SR91Value-Priced Express Lanes*. Final Report, Submitted to State of California Department of Transportation, December, 2000. http://ceenve.calpoly.edu/sullivan/SR91/final_rpt/FinalRep2000.pdf. Accessed March 28, 2003.

13. Wilbur Smith Associates. *Potential for Variable Pricing of Toll Facilities.* Prepared for the Federal Highway Administration, New Haven, Connecticut, 1995.

14. Litman, T. *Transportation Elasticities: How Prices and Other Factors Affect Travel Behavior*. Victoria Transport Policy Institute. www.vtpi.org. Accessed April 7, 2003.

15. Nicholson, W. *Micro Economic Theory: Basic Principles and Extensions*, 3rd edition. The Dryden Press, New York, 1985.

16. Mansfield, E. *The Price Elasticity of Demand for Automobiles.* Report published by Senate Subcommittee on Antitrust and Monopoly W.W. Norton & Company, New York, 1998.

17. Margetts, S. *Price Demand Elasticities*. Revision Guru, the home of Economics and Business Studies Revision. http://www.revisionguru.co.uk/economics/ped.html. Accessed Nov. 23, 2002.

18. LeeWay Info. *Variable Pricing, Frequently Asked Questions,* Lee County Toll Authorities. Fort Myers, Florida. http://leewayinfo.com/index2.htm. Accessed April 6, 2003.

19. Borenstein, S. The Evolution of Airline Competition. *The Journal of Economic Perspectives*, Vol. 6, No. 2 (Spring 1992), pp. 45–73.

20. Gomez-Ibanez, J. A. Transportation Economics and Policy. In Gomez-Ibanez, J. A., W. B. Tye, and C. Winston (Eds.), *Essays in Transportation Economics and Policy*. Brookings Institution Press, Washington, D.C., 1999.

21. Lee, D. B., L. A. Klein, and G. Camus. Induced Traffic and Induced Demand. *Transportation Research Record 1659*, TRB, National Research Council, Washington, D.C., 1999, pp. 68–75.

22. Hirshchman, I. Bridge and Tunnel Toll Elasticities in New York: Some Recent Evidence. *Transportation*, Vol. 22, 1995, pp. 97–113.

23. Harvey, G. *Transportation Pricing and Travel Behavior, Curbing Gridlock: Peak-Period Fees to Relieve Congestion*, Volume 2. Transportation Research Board, Special Report 242. National Academy Press, Washington, D.C., 1994, pp. 89–114.

24. Mekky, A. Forecasting Toll Revenues for Fully Electronic Highways Operating under Transponder and Video-Imaging Systems. *Transportation Research Record 1659*, TRB, National Research Council, Washington, D.C., 1999, pp. 11–22.

25. Value Pricing Notes, No. 6, Spring 2000, Federal Highway Administration. http://www.fhwa.dot.gov/policy/vpnotes6v4.htm. Accessed April 18, 2003.

26. Congestion Pricing Notes, No. 1, Spring 1996, Federal Highway Administration. http://www.hhh.umn.edu/centers/slp/projects/conpric/news/spring96.pdf. Accessed April 18, 2003.

27. Value Pricing Homepage, Lee County, Florida, Federal Highway Administration. http://www.hhh.umn.edu/centers/slp/projects/conpric/leecounty/index.htm. Accessed April 18, 2003.

28. Burris, M. W. *Lee County Variable Pricing Project: Evaluation Report*. Center for Urban Transportation Research, CUTR Account No. 21-17-271-L.O. Tampa, Florida, January 2001.

29. Cain, A., M. W. Burris, and R. M. Pendyala. The Impact of Variable Pricing on the Temporal Distribution of Travel Demand. *Transportation Research Record 1747*, TRB, National Research Council, Washington, D.C., 2001, pp. 36–43.

30. Value Pricing Homepage, Port Authority of NY and NJ, Federal Highway Administration. http://www.hhh.umn.edu/centers/slp/projects/conpric/portauthority/index.htm. Accessed April 18, 2003.

31. Komanoff, C., Komanoff Energy Associates. A Value-Pricing Toll Plan for the MTA: Saving Drivers Time while Generating Revenues. Prepared for the Tri-State Transportation Campaign, February 2003. http://www.tstc.org/MTApricing.pdf. Accessed August 15, 2003.

32. Value Pricing Homepage, San Diego, California (I-15), Federal Highway Administration. http://www.hhh.umn.edu/centers/slp/projects/conpric/sandiego/index.htm. Accessed April 18, 2003.

33. FAS TRAK Users Response to Toll Changes: A Time Series Analysis of Time of Travel. San Diego Association of Governments, July 1999. http://argo.sandag.org/fastrak/pdfs/tollprice.pdf. Accessed August 15, 2003.

34. Value Pricing Homepage, Houston, Texas (Katy Freeway), Federal Highway Administration. http://www.hhh.umn.edu/centers/slp/projects/conpric/houston/index.htm. Accessed April 18, 2003.

35. Value Pricing Homepage, Orange County, California (SR91), Federal Highway Administration. http://www.hhh.umn.edu/centers/slp/projects/conpric/orangecounty/index.htm. Accessed April 18, 2003.

36. Crozet, Y., G. Marlot. Congestion and Road Pricing: Where Is the Bug. Presented at the 9th World Conference on Transport Research, University of Lumiere, Lyon, France, 2001.

37. Barnes, J. *Peak Spreading Analysis: Review of Relevant Issues and Synthesis of Current Practice,* Phase 1. Research report prepared for Washington State Transportation Commission, Washington D.C., July 1998.

38. Loudon, W. R., E. R. Ruiter, and M. L. Schlappi. *Predicting Peak Spreading under Congested Conditions*. Transportation Research Board, Washington, D.C., 1998.

39. Ramsey, B., and G. Hayden. An Investigation of Peak Spreading in Relation to the Cross Tyne Study. *Traffic Engineering and Control*, Vol. 36, No. 3, March 1995, pp. 139–141.

40. Goodwin, R. P., and R. D. Coombe. *Dealing with the National Road Traffic Forecasts in Urban Areas.* Transportation Planning Methods: Paper presented at the Highways and Planning Summer Annual Meeting, University of Sussex, England, 1996.

41. Bacquie, R., and J. Wang. Peak Spreading–Temporal Changes in Travel Demand in the GTA. Paper presented at the Transportation Planning Session of the 1997 X111th IRF World Meeting, Toronto, Ontario, Canada, 1997.

42. Small, K. A., and C. Winston. The Demand for Transportation: Models and Applications. In Gomez-Ibanez, J. A., W. B. Tye, and C. Winston (Eds.), *Essays in Transportation Economics and Policy.* Brookings Institution Press, Washington, D.C., 1999.

43. Tae H. O., W. G. Walters II, and J. –S. Yong. Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates*.* *Journal of Transport Economics and Policy,* Vol. 26, No. 2, May 1992, pp. 139–154.

44. Walters, A. A. *The Economics of Road User Charges.* International Bank for Reconstruction and Development. The Johns Hopkins Press, Maryland, 1968.

45. Yelds, A. Electronic Toll Collection Participation in the Context of Variable Pricing in Lee County, Florida. Research Paper and Analysis for Course: ECO 6936. University of South Florida, Tampa, Florida, October 1999.

46. Dargay, J. and P. Goodwin. Changing Prices: A Dynamic Analysis of the Role of Pricing in Travel Behavior and Transport Policy. In *From Realism to Reality in Transport Policy*. London Publishing LTD, London, UK, 2000, pp. 1–68.

47. Cairns, S., C. Hass-Klau, and P. Goodwin. *Traffic Impact of Highway Capacity Reductions*. Prepared for London Transport, London, UK, March 1998.

48. Goodwin, P. B. A Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes. *Journal of Transport Economics and Policy,* Vol. 26, No. 2, May 1992, pp. 155–169.

49. J. M. Dargay. Demand Elasticities: A Comment. *Journal of Transport Economics and Policy*, Vol. 27, No. 1, January 1993, pp. 87–90.

50. *Profile of General Demographic Characteristics: 2000*, Lee County, Florida. http://factfinder.census.gov/bf/_lang=en_vt_name=DEC_2000_SF1_U_DP1_geo_id=05000US12071.html. Accessed May 21, 2003.

51. Horowitz, L. J., and N. E. Savin. Binary Response Models: Logistics, Probits and Semiparametrics. *Journal of Economic Perspectives,* Vol. 15, No. 4, Fall 2001, pp. 43–56.

52. Train, K. E. *Discrete Choice Methods with Simulation.* Cambridge University Press, Cambridge, UK, 2003.

53. Hensher, A. D., and W. H. Greene. The Mixed Logit Model: The State of Practice and Warnings for the Unwary. Presented at 2003 Annual Meeting of the Transportation and Public Utilities Group, Denver, Colorado, July 11–15, 2003.

54. Kotlyarova, Y., and V. Zinde-Walsh. Improving the Efficiency of the Maximum Score Estimator. Presented at the CESG (Canadian Econometrics Study Group) Conference, Waterloo, Ontario, Canada, September 2001.

55. Greene, W.H. *Econometric Analysis*. Macmillan Publishing Company, New York, 1993.

56. Burris, M. W., and R. M. Pendyala. Discrete Choice Models of Traveler Participation in Differential Time of Day Pricing Programs. *Transport Policy,* Vol. 9, No. 3, 2002, pp. 241-251.

APPENDIX A

CALCULATED DAILY TRAFFIC FLOW PROFILES

TABLE A-1 Cape Coral Bridge January-July (1998)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	102	1.55	524	1.64	626
6:30	201	3.04	850	2.65	1051
7:00	256	3.88	1014	3.17	1270
7:30	333	5.05	1358	4.24	1691
8:00	285	4.32	1198	3.74	1482
8:30	242	3.66	1052	3.29	1294
9:00	174	2.64	873	2.73	1047
9:30	173	2.63	880	2.75	1054
10:00	156	2.37	834	2.60	990
10:30	162	2.46	886	2.77	1048
11:00	165	2.49	865	2.70	1030
11:30	173	2.62	902	2.82	1075
12:00	167	2.54	897	2.80	1064
12:30	174	2.63	901	2.81	1074
13:00	178	2.69	903	2.82	1081
13:30	176	2.66	915	2.86	1091
14:00	183	2.78	942	2.94	1125
14:30	194	2.94	998	3.12	1191
15:00	212	3.21	1050	3.28	1261
15:30	234	3.55	1143	3.57	1377
16:00	243	3.69	1184	3.70	1427
16:30	281	4.26	1305	4.07	1586
17:00	359	5.43	1551	4.84	1909
17:30	293	4.45	1320	4.12	1614
18:00	235	3.57	1082	3.38	1318
18:30	187	2.84	877	2.74	1065
19:00	149	2.26	737	2.30	886
19:30	123	1.87	612	1.91	735
Total Day	**6597**	**88.07**	**32021**	**86.36**	**38618**

TABLE A-2 Cape Coral Bridge August-December (1998)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	115	1.41	506	1.71	626
6:30	292	3.57	787	2.65	1051
7:00	279	3.41	944	3.18	1270
7:30	403	4.93	1314	4.43	1691
8:00	350	4.28	1139	3.84	1482
8:30	281	3.43	1007	3.40	1294
9:00	238	2.91	803	2.71	1047
9:30	225	2.75	803	2.71	1054
10:00	200	2.45	759	2.56	990
10:30	213	2.61	794	2.68	1048
11:00	199	2.43	786	2.65	1030
11:30	209	2.56	823	2.77	1075
12:00	210	2.57	819	2.76	1064
12:30	217	2.65	823	2.77	1074
13:00	217	2.65	831	2.80	1081
13:30	216	2.64	836	2.82	1091
14:00	243	2.98	864	2.91	1125
14:30	252	3.08	921	3.10	1191
15:00	271	3.31	955	3.22	1261
15:30	299	3.65	1060	3.57	1377
16:00	298	3.64	1098	3.70	1427
16:30	342	4.19	1201	4.05	1586
17:00	434	5.31	1436	4.84	1909
17:30	366	4.47	1254	4.23	1614
18:00	290	3.55	1026	3.46	1318
18:30	237	2.90	825	2.78	1065
19:00	185	2.26	685	2.31	886
19:30	146	1.79	566	1.91	735
Total Day	**8174**	**88.40**	**29669**	**86.50**	**37843**

TABLE A-3 Midpoint Memorial Bridge January-July (1998)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	100	1.97	439	1.72	539
6:30	204	4.00	799	3.13	1003
7:00	264	5.19	1005	3.94	1269
7:30	321	6.30	1224	4.80	1545
8:00	224	4.39	929	3.64	1153
8:30	177	3.47	791	3.10	968
9:00	122	2.40	619	2.43	741
9:30	117	2.29	613	2.40	729
10:00	101	1.97	570	2.24	671
10:30	103	2.03	592	2.32	695
11:00	104	2.05	594	2.33	699
11:30	110	2.16	626	2.45	736
12:00	113	2.21	638	2.50	751
12:30	117	2.30	650	2.55	767
13:00	117	2.29	647	2.54	764
13:30	121	2.37	670	2.63	790
14:00	130	2.56	710	2.78	840
14:30	146	2.87	779	3.06	925
15:00	153	3.00	808	3.17	961
15:30	171	3.36	884	3.47	1055
16:00	192	3.76	970	3.81	1162
16:30	236	4.63	1083	4.25	1319
17:00	294	5.77	1280	5.02	1574
17:30	264	5.18	1196	4.69	1461
18:00	193	3.78	949	3.72	1142
18:30	149	2.93	756	2.97	906
19:00	114	2.23	609	2.39	722
19:30	87	1.71	508	1.99	595
Total Day	**5097**	**89.15**	**25494**	**86.05**	**30591**

TABLE A-4 Midpoint Memorial Bridge August-December (1998)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	116	1.63	454	1.74	570
6:30	343	4.81	813	3.12	1156
7:00	332	4.65	1019	3.91	1351
7:30	420	5.89	1237	4.75	1657
8:00	295	4.14	952	3.65	1247
8:30	232	3.25	804	3.08	1036
9:00	181	2.54	618	2.37	799
9:30	166	2.33	616	2.36	782
10:00	147	2.07	574	2.20	722
10:30	155	2.17	605	2.32	760
11:00	149	2.09	601	2.31	750
11:30	158	2.22	639	2.45	797
12:00	164	2.30	653	2.51	817
12:30	163	2.29	662	2.54	826
13:00	164	2.30	665	2.55	829
13:30	168	2.35	681	2.61	849
14:00	195	2.73	724	2.78	919
14:30	219	3.07	809	3.10	1028
15:00	235	3.29	831	3.19	1066
15:30	263	3.69	896	3.44	1159
16:00	260	3.65	998	3.83	1258
16:30	317	4.44	1114	4.27	1431
17:00	391	5.48	1307	5.01	1698
17:30	354	4.96	1217	4.67	1571
18:00	261	3.66	984	3.77	1245
18:30	213	2.98	769	2.95	982
19:00	153	2.14	630	2.42	783
19:30	122	1.71	521	2.00	643
Total Day	**7135**	**88.82**	**26065**	**85.92**	**33200**

TABLE A-5 Cape Coral Bridge January-July (1999)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	140	1.46	513	1.66	653
6:30	321	3.35	789	2.56	1110
7:00	329	3.44	972	3.15	1300
7:30	484	5.06	1340	4.34	1823
8:00	412	4.31	1186	3.85	1598
8:30	328	3.43	1010	3.28	1338
9:00	275	2.88	836	2.71	1111
9:30	263	2.75	846	2.74	1109
10:00	233	2.44	804	2.61	1037
10:30	244	2.55	836	2.71	1080
11:00	232	2.43	826	2.68	1058
11:30	247	2.59	859	2.79	1107
12:00	242	2.53	846	2.74	1088
12:30	248	2.59	847	2.75	1095
13:00	248	2.60	851	2.76	1099
13:30	250	2.62	869	2.82	1119
14:00	280	2.93	886	2.87	1166
14:30	297	3.10	954	3.09	1251
15:00	323	3.38	999	3.24	1322
15:30	359	3.75	1092	3.54	1450
16:00	355	3.71	1146	3.71	1501
16:30	394	4.12	1247	4.04	1641
17:00	503	5.26	1504	4.88	2007
17:30	416	4.35	1309	4.25	1725
18:00	333	3.48	1055	3.42	1388
18:30	274	2.87	859	2.79	1134
19:00	218	2.28	728	2.36	946
19:30	173	1.81	593	1.92	765
Total Day	**9563**	**88.06**	**30841**	**86.25**	**40404**

TABLE A-6 Cape Coral Bridge August-December (1999)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	154	1.53	483	1.64	637
6:30	331	3.29	783	2.66	1114
7:00	343	3.40	948	3.22	1291
7:30	508	5.04	1323	4.49	1831
8:00	436	4.32	1165	3.96	1600
8:30	353	3.50	994	3.37	1347
9:00	296	2.94	801	2.72	1097
9:30	274	2.72	801	2.72	1075
10:00	244	2.42	744	2.53	988
10:30	260	2.58	796	2.70	1056
11:00	245	2.43	776	2.63	1020
11:30	262	2.60	814	2.76	1076
12:00	257	2.55	795	2.70	1053
12:30	265	2.63	806	2.74	1071
13:00	268	2.66	810	2.75	1079
13:30	267	2.65	828	2.81	1094
14:00	300	2.97	853	2.90	1153
14:30	318	3.16	908	3.08	1226
15:00	335	3.33	944	3.20	1279
15:30	376	3.73	1037	3.52	1413
16:00	386	3.83	1101	3.74	1487
16:30	429	4.26	1210	4.11	1640
17:00	536	5.31	1461	4.96	1996
17:30	446	4.43	1280	4.35	1726
18:00	356	3.53	1018	3.46	1374
18:30	289	2.87	826	2.80	1115
19:00	223	2.21	688	2.33	911
19:30	186	1.85	564	1.92	750
Total Day	**10077**	**88.75**	**29452**	**86.77**	**39529**

TABLE A-7 Midpoint Memorial Bridge January-July (1999)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	144	1.52	492	1.75	636
6:30	395	4.18	870	3.10	1265
7:00	375	3.97	1080	3.84	1455
7:30	501	5.30	1297	4.61	1799
8:00	358	3.78	994	3.54	1352
8:30	268	2.84	850	3.03	1119
9:00	211	2.23	649	2.31	860
9:30	197	2.08	647	2.30	843
10:00	174	1.84	610	2.17	784
10:30	180	1.90	635	2.26	815
11:00	171	1.81	638	2.27	809
11:30	182	1.93	676	2.40	858
12:00	189	2.00	686	2.44	875
12:30	194	2.05	709	2.52	903
13:00	195	2.06	697	2.48	892
13:30	192	2.03	714	2.54	906
14:00	220	2.33	756	2.69	976
14:30	256	2.71	839	2.99	1095
15:00	267	2.82	869	3.09	1135
15:30	297	3.15	951	3.38	1249
16:00	314	3.32	1035	3.68	1349
16:30	369	3.90	1143	4.07	1512
17:00	457	4.83	1340	4.77	1797
17:30	414	4.37	1258	4.48	1672
18:00	305	3.22	1015	3.61	1319
18:30	251	2.66	808	2.87	1059
19:00	182	1.92	667	2.37	849
19:30	144	1.53	557	1.98	701
Total Day	**9457**	**88.27**	**28112**	**86.45**	**37569**

TABLE A-8 Midpoint Memorial Bridge August-December (1999)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	170	1.93	507	1.83	677
6:30	413	4.69	899	3.24	1312
7:00	410	4.66	1052	3.80	1462
7:30	573	6.51	1305	4.71	1878
8:00	387	4.40	994	3.59	1382
8:30	309	3.51	881	3.18	1190
9:00	231	2.62	665	2.40	896
9:30	221	2.51	666	2.41	888
10:00	197	2.24	627	2.26	823
10:30	206	2.34	651	2.35	857
11:00	193	2.20	655	2.37	848
11:30	211	2.39	697	2.52	907
12:00	218	2.48	710	2.56	929
12:30	228	2.59	726	2.62	954
13:00	224	2.55	726	2.62	950
13:30	226	2.56	751	2.71	977
14:00	259	2.95	797	2.88	1056
14:30	298	3.38	881	3.18	1179
15:00	311	3.53	914	3.30	1225
15:30	344	3.91	978	3.53	1322
16:00	356	4.04	1047	3.78	1403
16:30	413	4.70	1149	4.15	1562
17:00	490	5.57	1355	4.89	1845
17:30	468	5.31	1305	4.71	1773
18:00	354	4.02	1063	3.84	1417
18:30	284	3.23	841	3.04	1125
19:00	210	2.39	686	2.48	896
19:30	168	1.91	579	2.09	747
Total Day	**8801**	**85.13**	**27696**	**84.05**	**36497**

TABLE A-9 Cape Coral Bridge January-July (2000)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	162	1.46	497	1.61	659
6:30	352	3.19	825	2.67	1177
7:00	388	3.51	977	3.16	1365
7:30	553	5.00	1368	4.43	1921
8:00	491	4.44	1227	3.97	1718
8:30	389	3.52	1035	3.35	1424
9:00	323	2.92	832	2.69	1154
9:30	298	2.70	837	2.71	1136
10:00	265	2.40	790	2.56	1056
10:30	282	2.55	826	2.67	1108
11:00	266	2.41	828	2.68	1094
11:30	286	2.59	850	2.75	1136
12:00	279	2.53	843	2.73	1122
12:30	284	2.57	842	2.73	1127
13:00	284	2.57	845	2.73	1128
13:30	295	2.67	865	2.80	1160
14:00	321	2.91	889	2.88	1210
14:30	337	3.05	965	3.12	1302
15:00	364	3.30	997	3.22	1361
15:30	416	3.76	1106	3.58	1522
16:00	417	3.77	1170	3.79	1587
16:30	465	4.21	1262	4.08	1728
17:00	590	5.35	1520	4.92	2110
17:30	509	4.61	1342	4.34	1851
18:00	387	3.51	1060	3.43	1447
18:30	317	2.87	861	2.79	1178
19:00	249	2.25	707	2.29	955
19:30	199	1.81	584	1.89	783
Total Day	**11043**	**88.45**	**30909**	**86.54**	**41952**

TABLE A-10 Cape Coral Bridge August-December (2000)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	174	1.49	501	1.67	675
6:30	380	3.24	797	2.66	1176
7:00	429	3.66	989	3.31	1418
7:30	584	4.99	1367	4.57	1952
8:00	524	4.47	1228	4.11	1752
8:30	414	3.54	1026	3.43	1441
9:00	345	2.94	816	2.73	1161
9:30	310	2.65	804	2.69	1114
10:00	278	2.38	744	2.49	1023
10:30	298	2.54	783	2.62	1081
11:00	285	2.43	777	2.60	1061
11:30	298	2.55	806	2.70	1105
12:00	301	2.57	805	2.69	1106
12:30	307	2.62	811	2.71	1118
13:00	309	2.64	821	2.74	1130
13:30	313	2.67	837	2.80	1150
14:00	346	2.95	865	2.89	1211
14:30	364	3.11	941	3.14	1305
15:00	386	3.30	963	3.22	1349
15:30	438	3.74	1070	3.58	1508
16:00	452	3.86	1141	3.81	1594
16:30	504	4.30	1248	4.17	1752
17:00	634	5.41	1487	4.97	2120
17:30	549	4.69	1338	4.47	1887
18:00	411	3.51	1035	3.46	1446
18:30	325	2.77	812	2.71	1137
19:00	252	2.15	667	2.23	919
19:30	208	1.78	555	1.86	764
Total Day	**11714**	**88.95**	**29920**	**87.02**	**41634**

TABLE A-11 Midpoint Memorial Bridge January-July (2000)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	184	1.80	523	1.77	707
6:30	471	4.61	960	3.25	1431
7:00	457	4.47	1128	3.82	1585
7:30	605	5.92	1345	4.56	1950
8:00	421	4.12	1030	3.49	1451
8:30	335	3.28	918	3.11	1254
9:00	251	2.46	715	2.42	966
9:30	236	2.31	717	2.43	953
10:00	208	2.04	665	2.25	874
10:30	220	2.15	694	2.35	914
11:00	214	2.09	700	2.37	913
11:30	229	2.24	735	2.49	965
12:00	236	2.30	747	2.53	983
12:30	243	2.37	769	2.60	1011
13:00	239	2.34	752	2.55	992
13:30	242	2.37	780	2.64	1022
14:00	273	2.67	823	2.79	1096
14:30	317	3.10	915	3.10	1232
15:00	328	3.21	948	3.21	1276
15:30	372	3.64	1036	3.51	1407
16:00	385	3.77	1097	3.72	1482
16:30	442	4.32	1194	4.05	1636
17:00	526	5.15	1389	4.71	1915
17:30	504	4.93	1339	4.54	1843
18:00	391	3.82	1098	3.72	1489
18:30	307	3.00	874	2.96	1181
19:00	229	2.24	723	2.45	952
19:30	182	1.78	603	2.04	785
Total Day	**10223**	**88.49**	**29508**	**85.46**	**39731**

TABLE A-12 Midpoint Memorial Bridge August-December (2000)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	209	1.86	530	1.81	739
6:30	489	4.37	929	3.17	1419
7:00	542	4.83	1149	3.93	1690
7:30	659	5.88	1308	4.47	1967
8:00	434	3.87	995	3.40	1429
8:30	365	3.26	914	3.12	1279
9:00	269	2.40	711	2.43	980
9:30	261	2.33	718	2.45	979
10:00	235	2.10	659	2.25	895
10:30	244	2.18	683	2.33	926
11:00	239	2.13	689	2.36	928
11:30	252	2.25	726	2.48	978
12:00	262	2.34	743	2.54	1005
12:30	270	2.41	765	2.61	1035
13:00	266	2.37	753	2.57	1018
13:30	270	2.41	780	2.66	1050
14:00	308	2.75	823	2.81	1131
14:30	350	3.12	922	3.15	1272
15:00	372	3.32	955	3.26	1327
15:30	414	3.70	1037	3.54	1451
16:00	433	3.87	1119	3.82	1552
16:30	490	4.38	1199	4.10	1689
17:00	590	5.27	1384	4.73	1975
17:30	543	4.84	1337	4.57	1880
18:00	417	3.72	1099	3.76	1516
18:30	328	2.93	866	2.96	1194
19:00	242	2.16	717	2.45	959
19:30	199	1.78	608	2.08	807
Total Day	**11204**	**88.83**	**29268**	**85.82**	**40471**

TABLE A-13 Cape Coral Bridge January-July (2001)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	197	1.49	516	1.63	712
6:30	427	3.25	841	2.66	1268
7:00	462	3.51	1020	3.23	1482
7:30	631	4.79	1337	4.23	1968
8:00	575	4.37	1254	3.97	1829
8:30	469	3.56	1072	3.39	1541
9:00	379	2.88	852	2.70	1231
9:30	361	2.74	855	2.70	1216
10:00	313	2.37	808	2.55	1120
10:30	336	2.55	846	2.68	1182
11:00	322	2.44	838	2.65	1160
11:30	340	2.58	870	2.75	1210
12:00	345	2.62	865	2.74	1210
12:30	346	2.63	870	2.75	1216
13:00	349	2.65	881	2.79	1230
13:30	350	2.66	895	2.83	1244
14:00	393	2.98	924	2.92	1317
14:30	405	3.08	990	3.13	1396
15:00	437	3.32	1027	3.25	1464
15:30	491	3.73	1141	3.61	1632
16:00	504	3.83	1191	3.77	1695
16:30	564	4.28	1306	4.13	1870
17:00	700	5.32	1544	4.88	2243
17:30	607	4.61	1385	4.38	1991
18:00	466	3.54	1082	3.42	1549
18:30	371	2.82	873	2.76	1244
19:00	285	2.17	713	2.26	998
19:30	230	1.75	592	1.87	823
Total Day	**13161**	**88.55**	**31614**	**86.63**	**44774**

TABLE A-14 Cape Coral Bridge August-December (2001)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	221	1.52	466	1.63	687
6:30	459	3.16	793	2.77	1252
7:00	543	3.74	945	3.31	1487
7:30	744	5.13	1272	4.45	2016
8:00	671	4.62	1158	4.05	1830
8:30	519	3.58	988	3.46	1507
9:00	417	2.87	774	2.71	1191
9:30	381	2.62	758	2.65	1139
10:00	347	2.39	721	2.53	1068
10:30	367	2.53	754	2.64	1121
11:00	347	2.39	745	2.61	1092
11:30	365	2.52	776	2.72	1141
12:00	373	2.57	786	2.75	1159
12:30	379	2.61	793	2.77	1171
13:00	379	2.61	794	2.78	1173
13:30	385	2.66	807	2.82	1192
14:00	426	2.94	838	2.93	1265
14:30	448	3.09	890	3.12	1338
15:00	472	3.25	925	3.24	1397
15:30	535	3.68	1025	3.59	1559
16:00	559	3.85	1092	3.82	1651
16:30	619	4.27	1195	4.18	1814
17:00	801	5.52	1428	5.00	2229
17:30	665	4.58	1237	4.33	1901
18:00	512	3.53	963	3.37	1475
18:30	401	2.76	767	2.68	1168
19:00	310	2.14	627	2.20	937
19:30	251	1.73	536	1.87	786
Total Day	**14513**	**88.84**	**28569**	**87.00**	**43082**

TABLE A-15 Midpoint Memorial Bridge January-July (2001)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	228	1.89	535	1.79	763
6:30	516	4.28	945	3.15	1460
7:00	584	4.85	1156	3.86	1740
7:30	703	5.83	1315	4.39	2018
8:00	467	3.88	1011	3.37	1478
8:30	409	3.39	942	3.14	1351
9:00	293	2.43	735	2.45	1028
9:30	287	2.39	749	2.50	1036
10:00	256	2.12	691	2.30	947
10:30	266	2.20	716	2.39	981
11:00	256	2.13	715	2.39	971
11:30	274	2.27	745	2.49	1019
12:00	277	2.30	767	2.56	1044
12:30	292	2.42	787	2.63	1078
13:00	286	2.37	776	2.59	1062
13:30	294	2.44	792	2.64	1086
14:00	324	2.69	841	2.81	1165
14:30	368	3.05	949	3.17	1317
15:00	393	3.26	973	3.25	1366
15:30	445	3.69	1072	3.58	1517
16:00	465	3.86	1140	3.81	1606
16:30	522	4.33	1212	4.04	1734
17:00	640	5.31	1382	4.61	2023
17:30	574	4.77	1361	4.54	1935
18:00	440	3.65	1114	3.72	1554
18:30	349	2.89	886	2.96	1234
19:00	265	2.20	734	2.45	999
19:30	208	1.73	612	2.04	820
Total Day	**12049**	**88.64**	**29965**	**85.60**	**42014**

TABLE A-16 Midpoint Memorial Bridge August-December (2001)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	275	1.94	527	1.79	802
6:30	583	4.12	937	3.18	1520
7:00	689	4.87	1122	3.81	1812
7:30	765	5.40	1272	4.32	2037
8:00	532	3.76	961	3.26	1493
8:30	467	3.30	918	3.12	1385
9:00	351	2.48	729	2.47	1080
9:30	344	2.43	748	2.54	1092
10:00	302	2.13	687	2.33	989
10:30	316	2.23	717	2.43	1033
11:00	307	2.17	718	2.44	1025
11:30	323	2.28	749	2.54	1072
12:00	329	2.33	763	2.59	1092
12:30	344	2.43	788	2.67	1132
13:00	341	2.41	781	2.65	1122
13:30	350	2.47	804	2.73	1154
14:00	390	2.75	849	2.88	1239
14:30	464	3.28	956	3.25	1421
15:00	472	3.33	973	3.30	1445
15:30	530	3.74	1069	3.63	1599
16:00	547	3.87	1125	3.82	1673
16:30	627	4.43	1191	4.04	1818
17:00	748	5.29	1358	4.61	2107
17:30	681	4.81	1330	4.51	2011
18:00	522	3.68	1104	3.75	1626
18:30	406	2.87	870	2.95	1276
19:00	304	2.14	708	2.40	1012
19:30	245	1.73	593	2.01	838
Total Day	**14160**	**88.67**	**29469**	**86.02**	**43629**

TABLE A-17 Cape Coral Bridge January-July (2002)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	248	1.48	462	1.58	710
6:30	517	3.09	782	2.68	1298
7:00	610	3.65	943	3.23	1553
7:30	836	5.00	1227	4.20	2063
8:00	752	4.50	1123	3.84	1875
8:30	608	3.64	973	3.33	1582
9:00	481	2.87	786	2.69	1266
9:30	445	2.66	795	2.72	1240
10:00	399	2.39	761	2.61	1160
10:30	426	2.55	798	2.73	1225
11:00	406	2.42	788	2.70	1193
11:30	426	2.55	822	2.82	1248
12:00	436	2.61	822	2.81	1258
12:30	437	2.61	825	2.82	1262
13:00	433	2.59	829	2.84	1262
13:30	444	2.66	835	2.86	1279
14:00	492	2.94	860	2.95	1352
14:30	510	3.05	906	3.10	1416
15:00	547	3.27	959	3.28	1506
15:30	617	3.69	1052	3.60	1670
16:00	629	3.76	1095	3.75	1723
16:30	707	4.22	1204	4.12	1910
17:00	901	5.38	1422	4.87	2323
17:30	768	4.59	1263	4.33	2031
18:00	585	3.49	990	3.39	1574
18:30	461	2.75	808	2.77	1269
19:00	359	2.14	660	2.26	1019
19:30	294	1.76	549	1.88	844
Total Day	**16730**	**88.30**	**29206**	**86.76**	**45935**

TABLE A-18 Midpoint Memorial Bridge January-July (2002)

Time	Eligible	Eligible %	Ineligible	Ineligible %	Total
6:00	300	1.90	541	1.81	841
6:30	672	4.24	982	3.28	1653
7:00	755	4.77	1136	3.80	1892
7:30	806	5.09	1209	4.04	2014
8:00	596	3.77	959	3.20	1555
8:30	536	3.38	927	3.10	1462
9:00	400	2.53	757	2.53	1157
9:30	395	2.50	770	2.57	1165
10:00	337	2.13	717	2.40	1054
10:30	361	2.28	755	2.52	1116
11:00	344	2.17	754	2.52	1098
11:30	363	2.30	781	2.61	1144
12:00	373	2.36	797	2.66	1170
12:30	390	2.47	812	2.71	1202
13:00	384	2.43	807	2.70	1192
13:30	391	2.47	819	2.74	1210
14:00	433	2.74	860	2.87	1293
14:30	498	3.15	957	3.20	1455
15:00	510	3.22	991	3.31	1501
15:30	591	3.73	1105	3.69	1695
16:00	607	3.83	1133	3.79	1740
16:30	689	4.35	1180	3.94	1869
17:00	823	5.20	1344	4.49	2167
17:30	757	4.78	1309	4.37	2066
18:00	567	3.58	1079	3.61	1646
18:30	457	2.89	878	2.93	1336
19:00	345	2.18	720	2.41	1065
19:30	277	1.75	608	2.03	885
Total Day	**15830**	**88.18**	**29923**	**85.84**	**45753**

APPENDIX B

IMPACT OF VARIABLE PRICING ON ELIGIBLE AND INELIGIBLE TRAFFIC PATTERNS

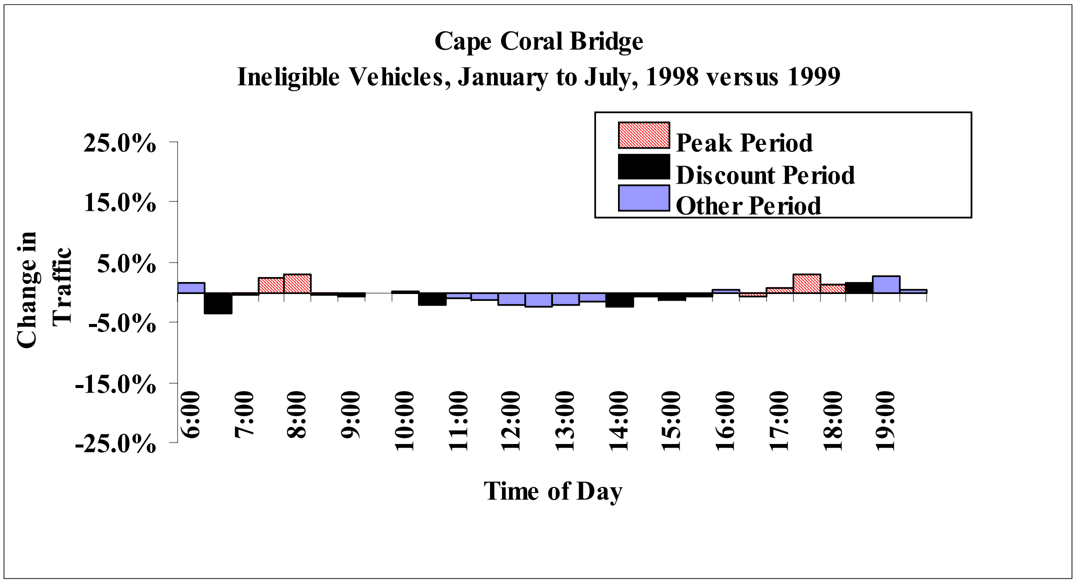

FIGURE B-1 Ineligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 1999)

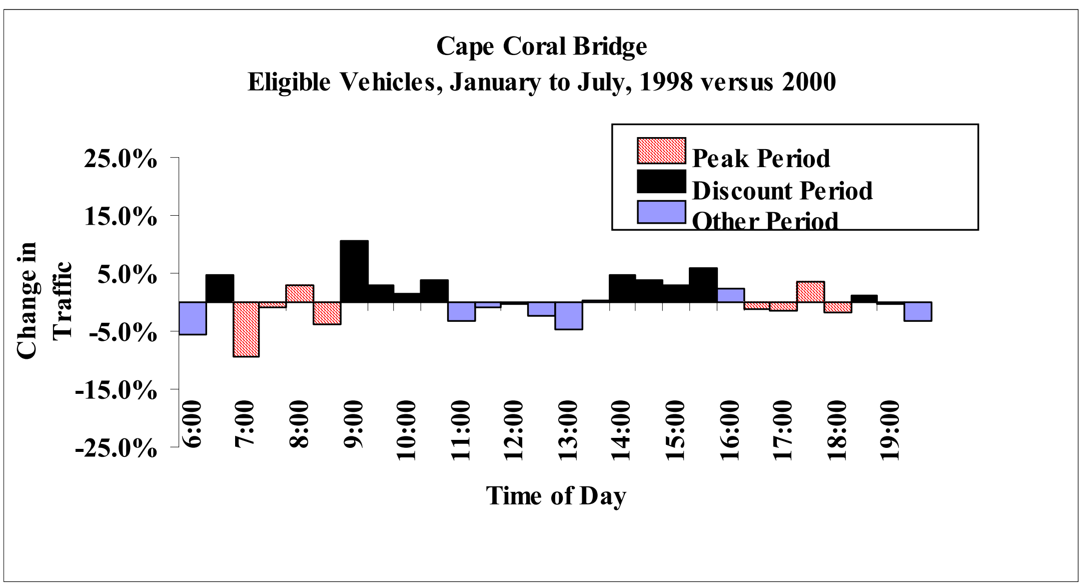

FIGURE B-2 Eligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2000)

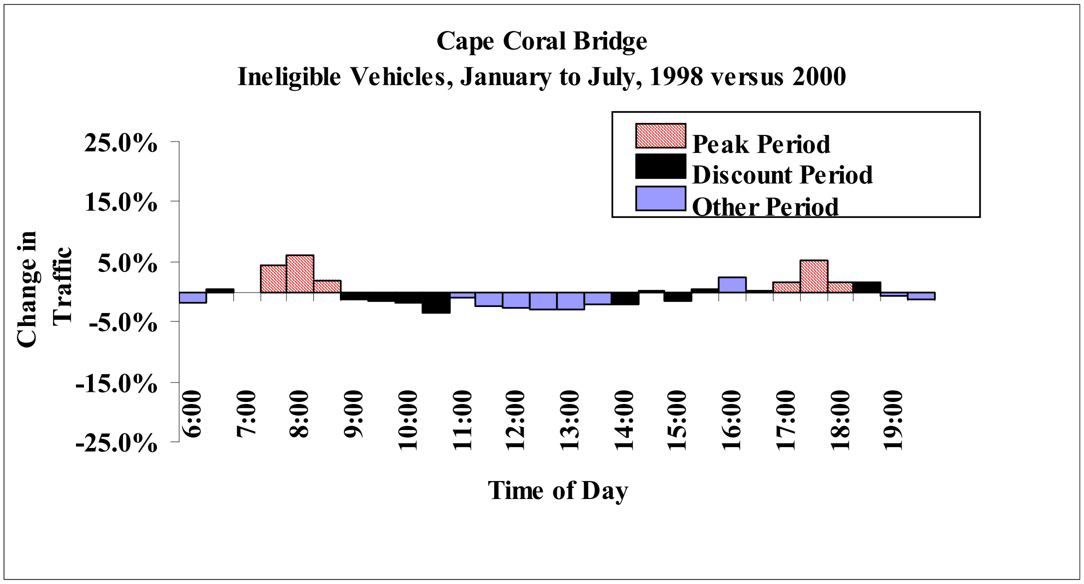

FIGURE B-3 Ineligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2000)

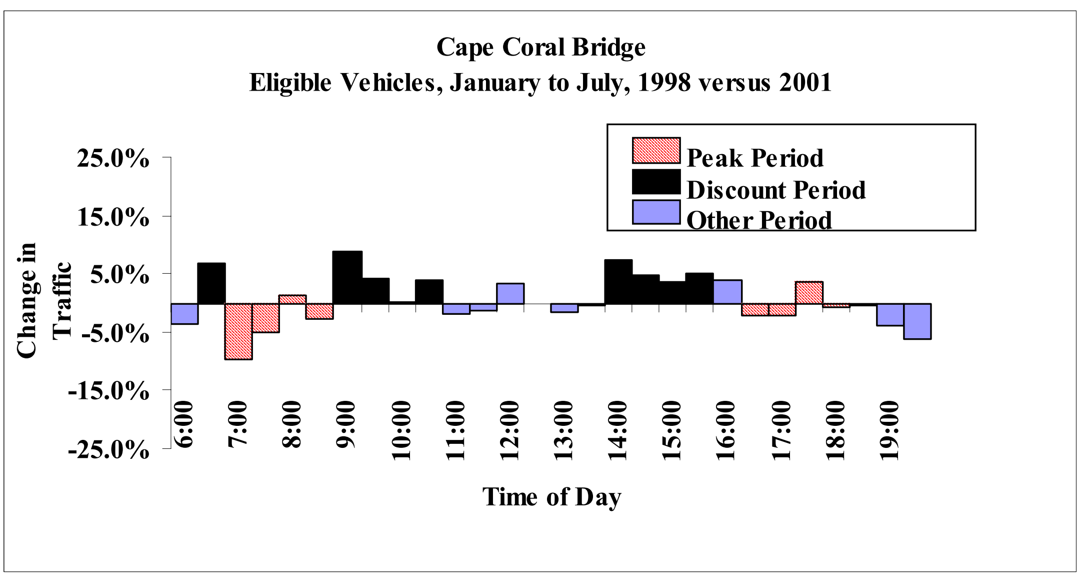

FIGURE B-4 Eligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2001)

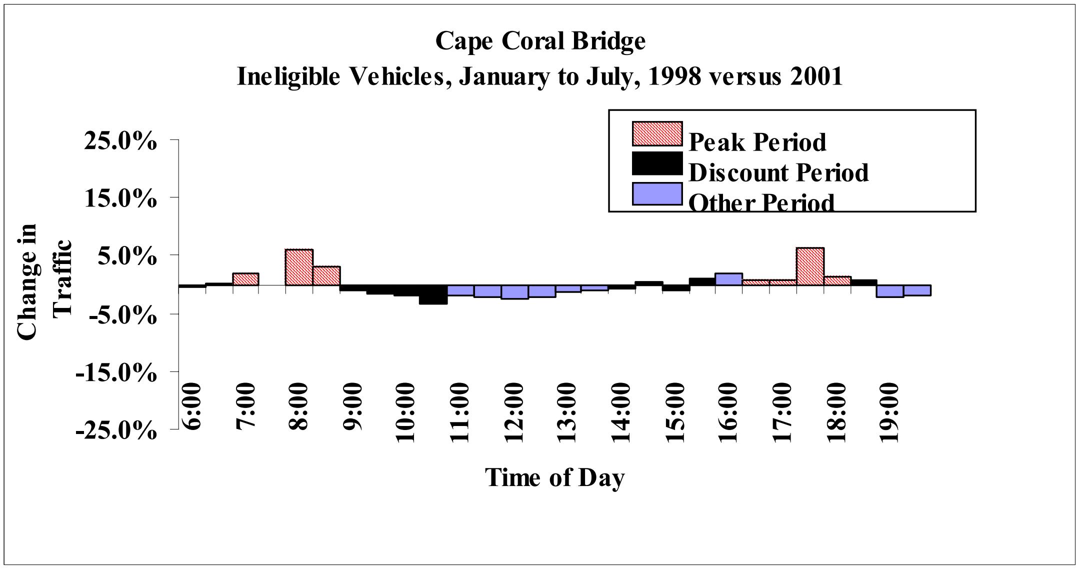

FIGURE B-5 Ineligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2001)

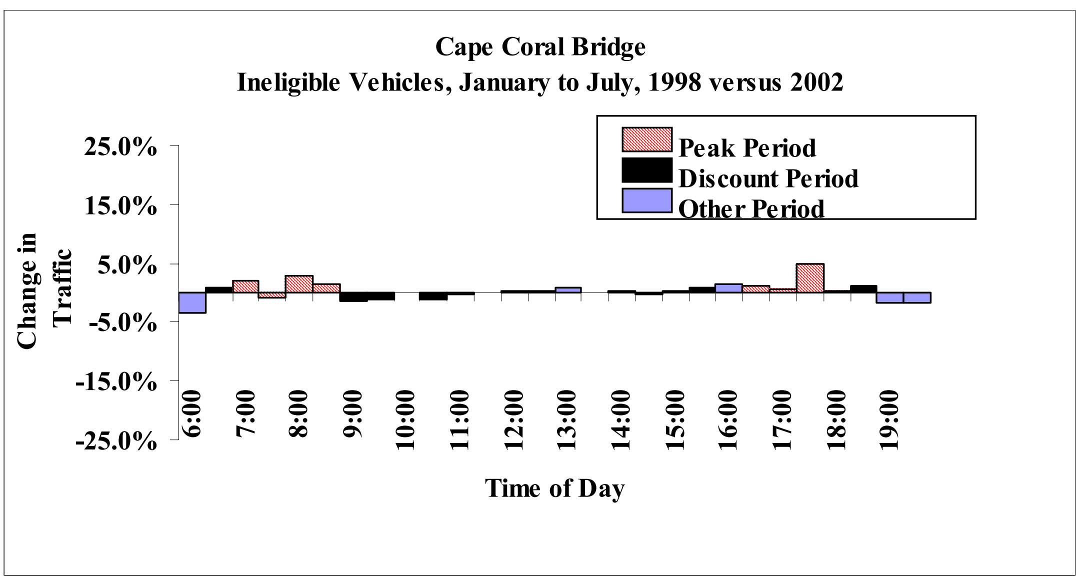

FIGURE B-6 Ineligible traffic pattern changes on Cape Coral Bridge (January-July, 1998 versus 2002)

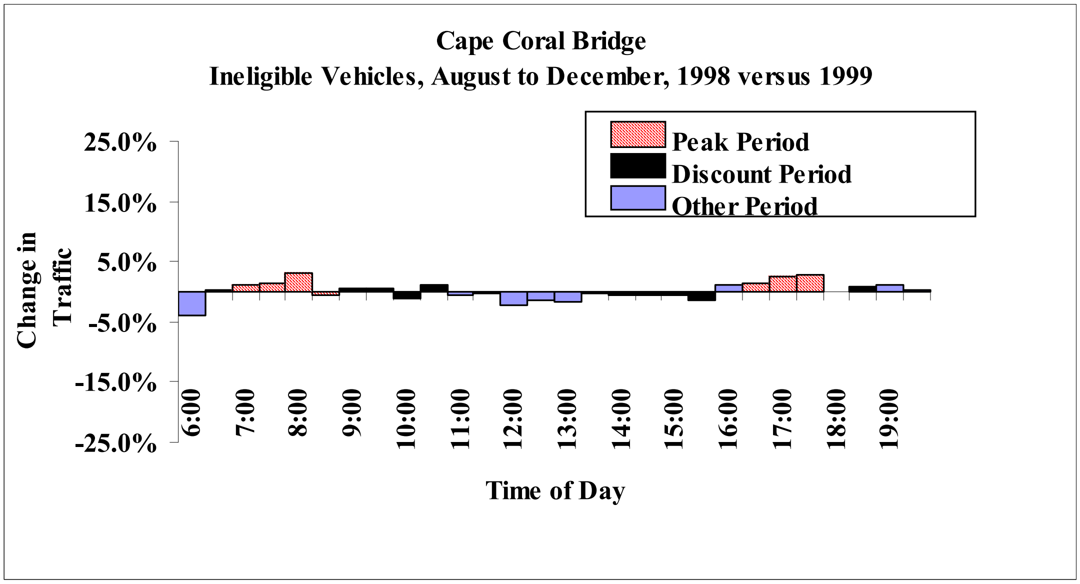

FIGURE B-7 Ineligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 1999)

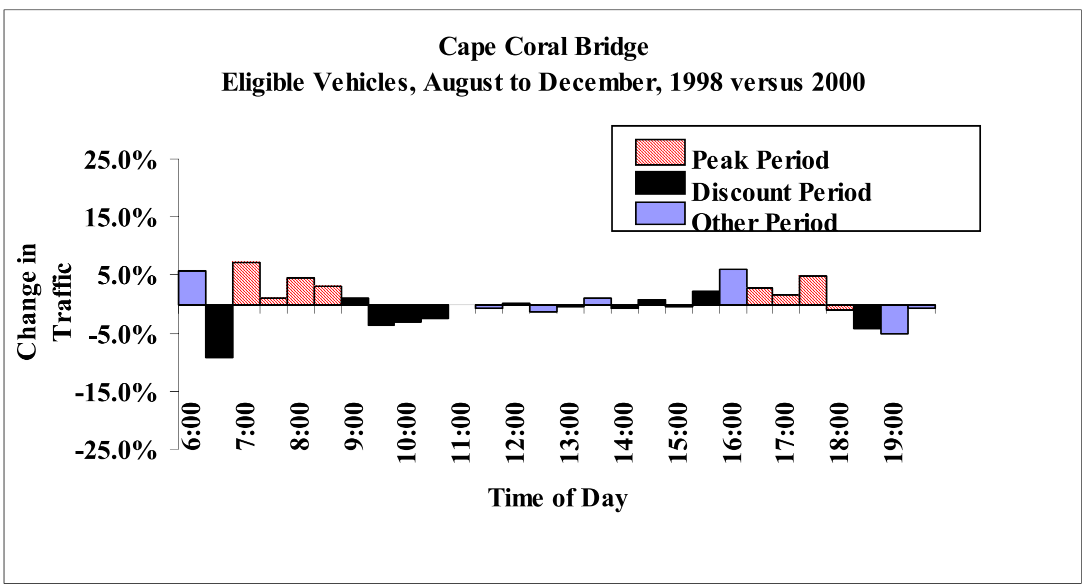

FIGURE B-8 Eligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 2000)

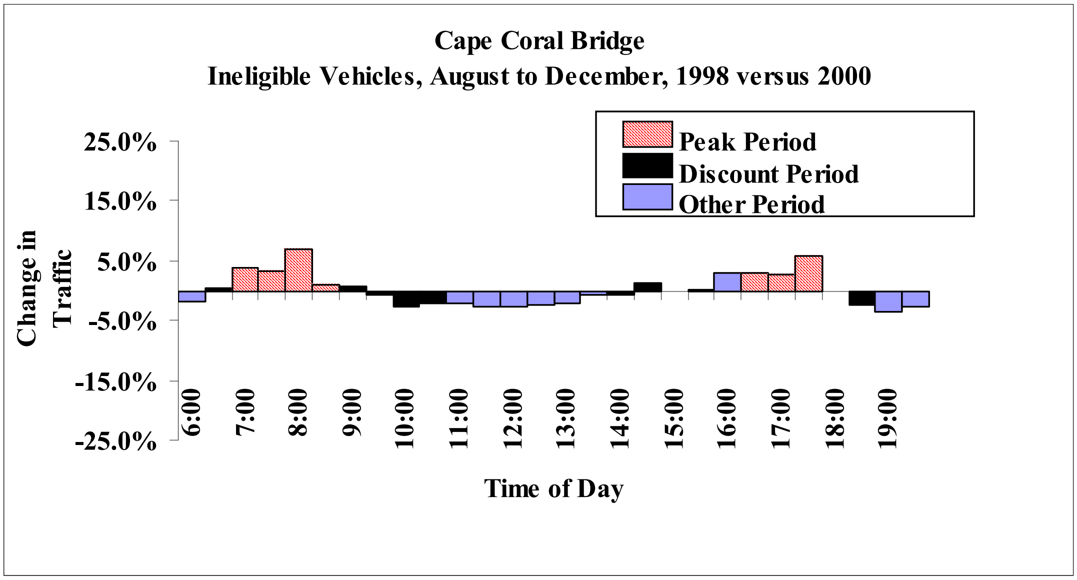

FIGURE B-9 Ineligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 2000)

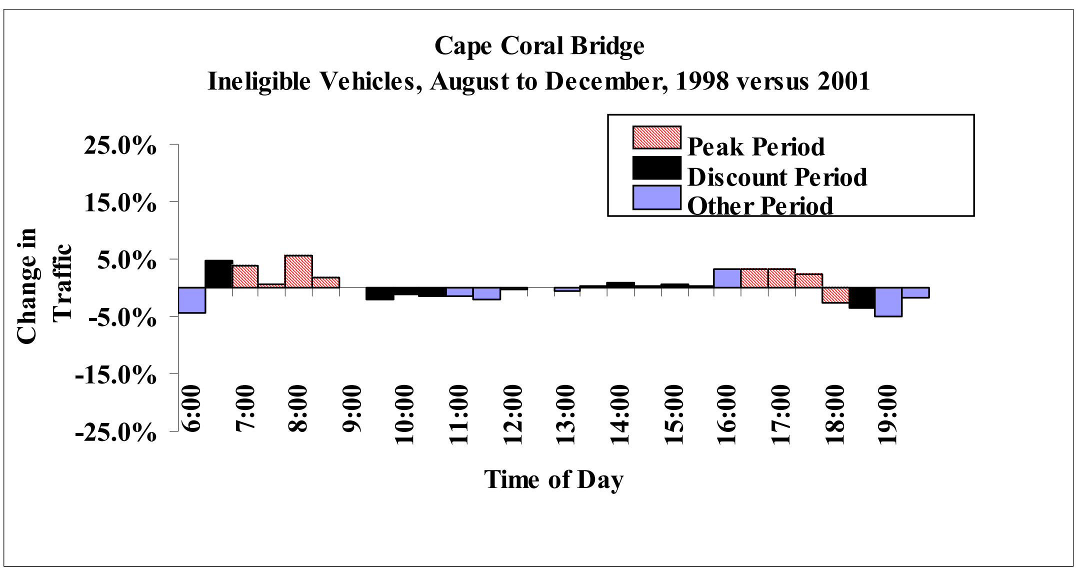

FIGURE B-10 Ineligible traffic pattern changes on Cape Coral Bridge (August-December, 1998 versus 2001)

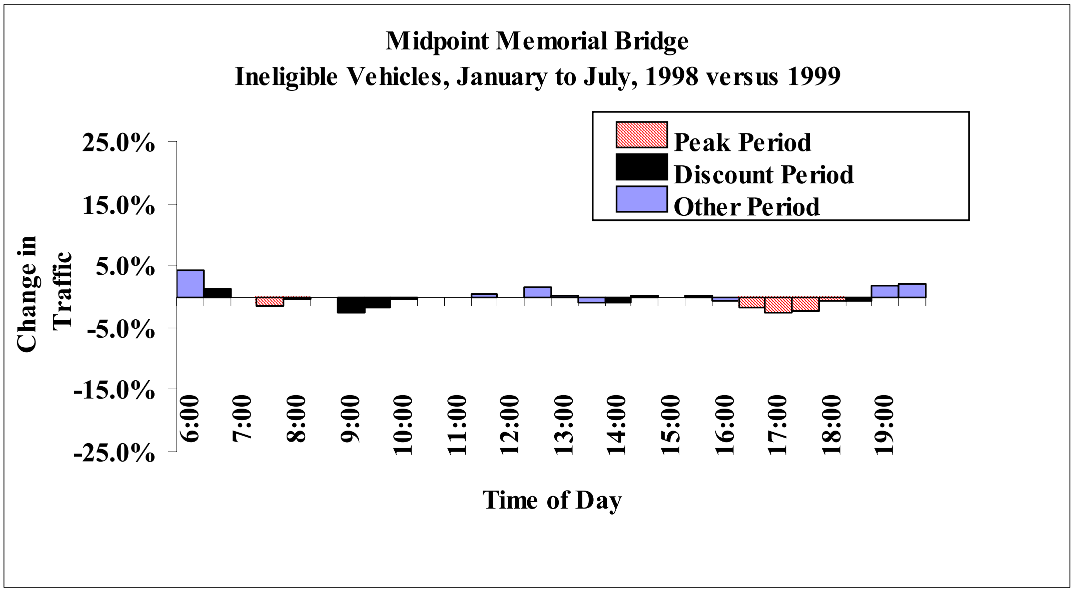

FIGURE B-11 Ineligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 1999)

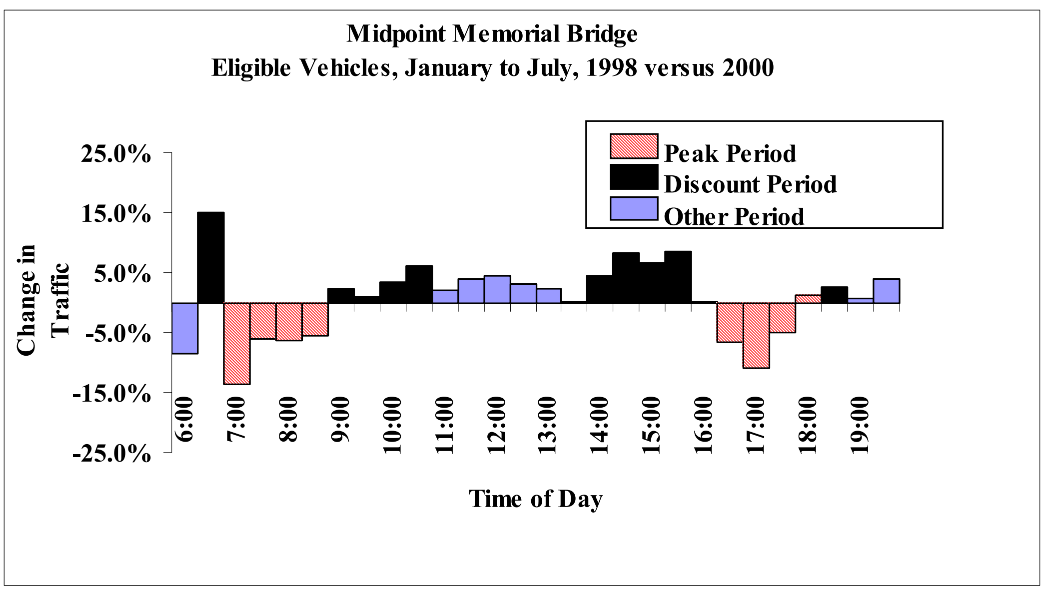

FIGURE B-12 Eligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2000)

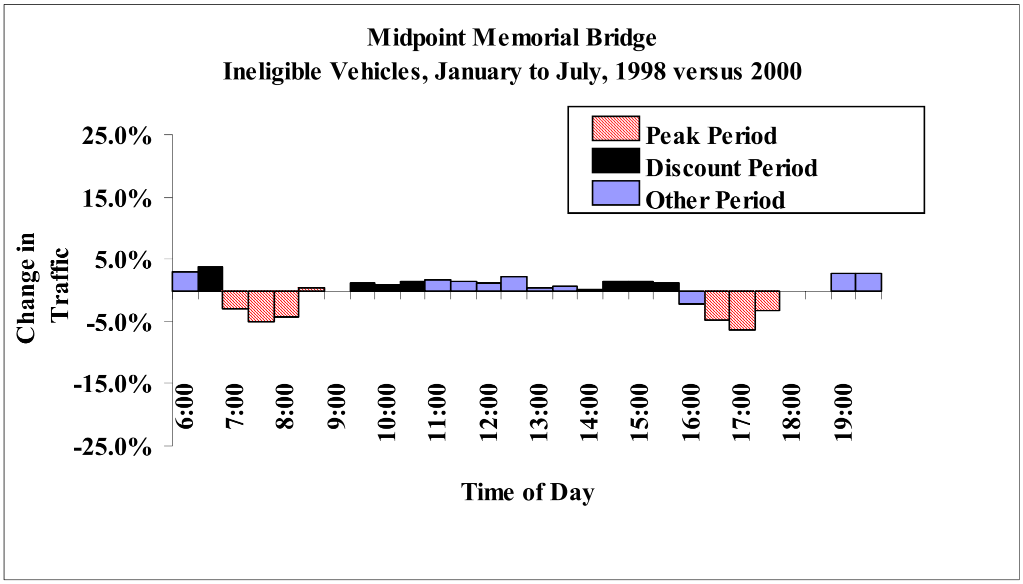

FIGURE B-13 Ineligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2000)

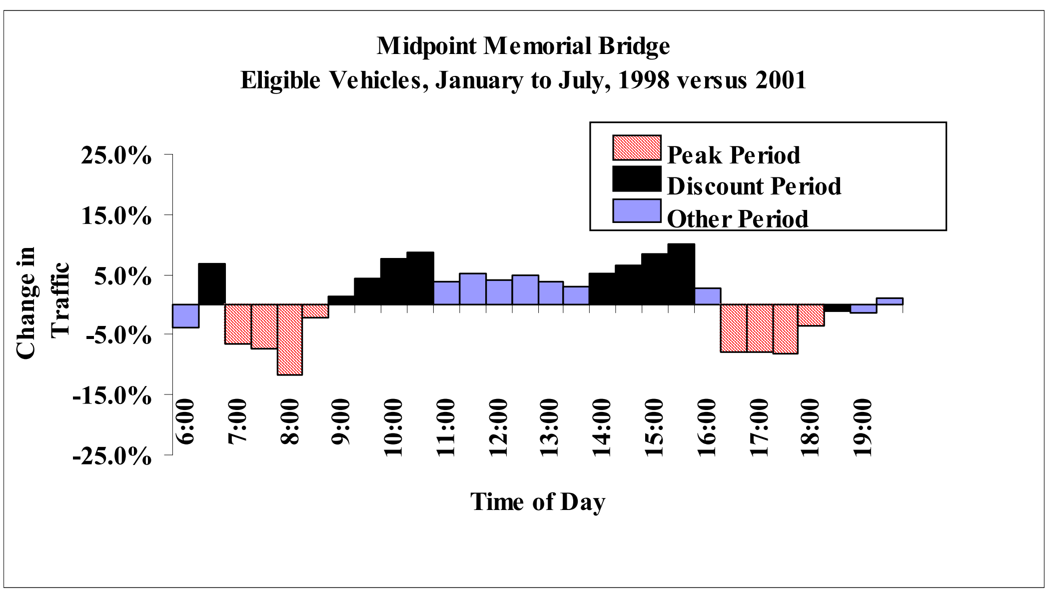

FIGURE B-14 Eligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2001)

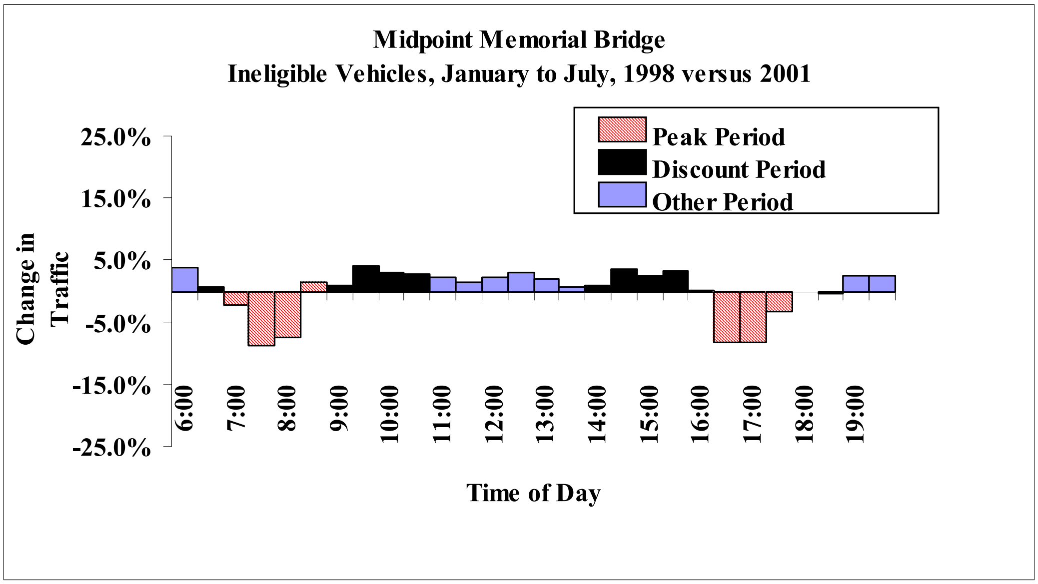

FIGURE B-15 Ineligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2001)

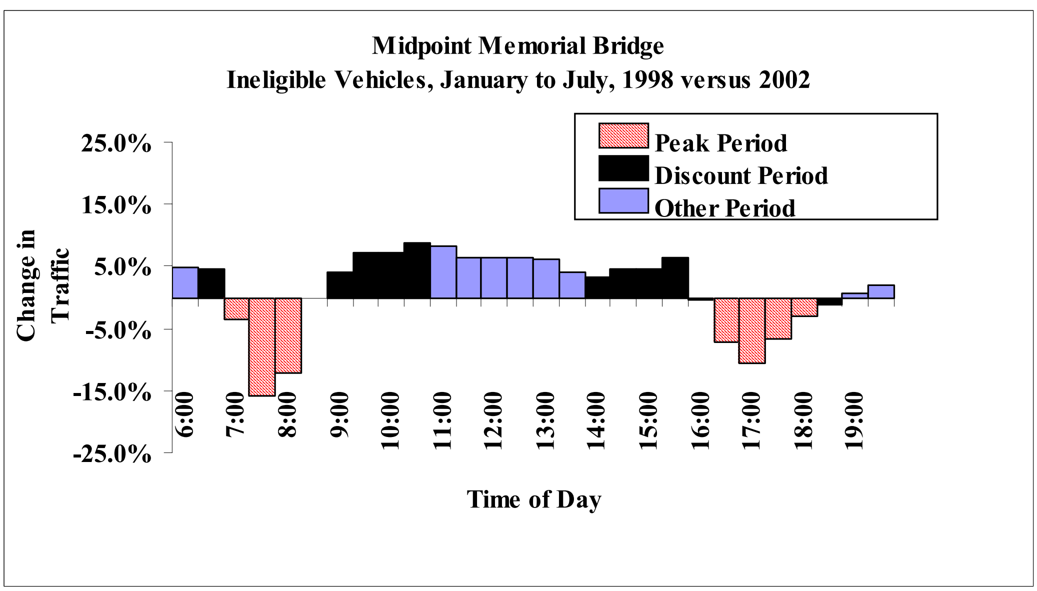

FIGURE B-16 Ineligible traffic pattern changes on Midpoint Memorial Bridge (January-July, 1998 versus 2002)

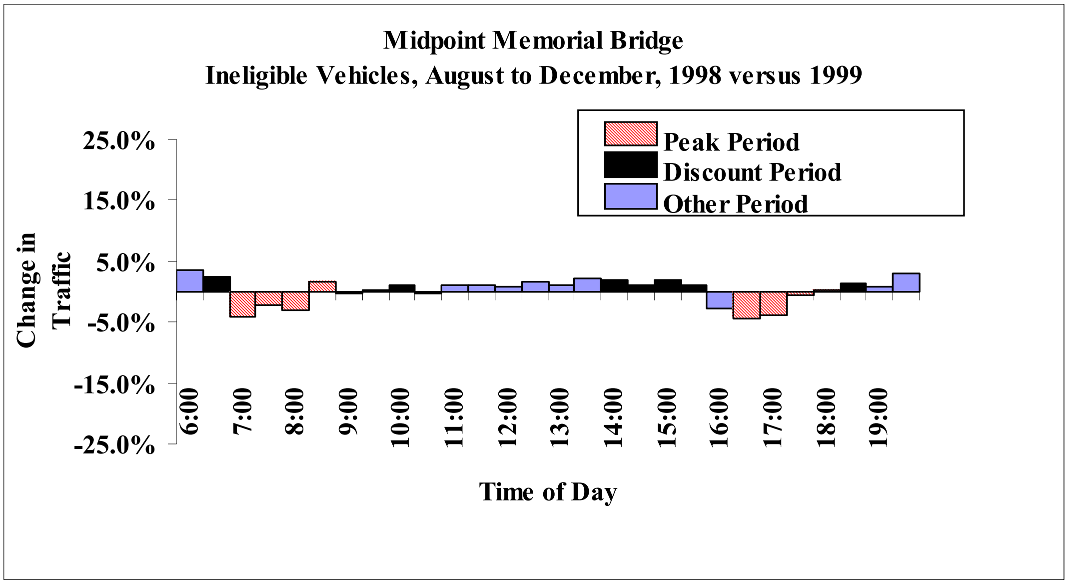

FIGURE B-17 Ineligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 1999)

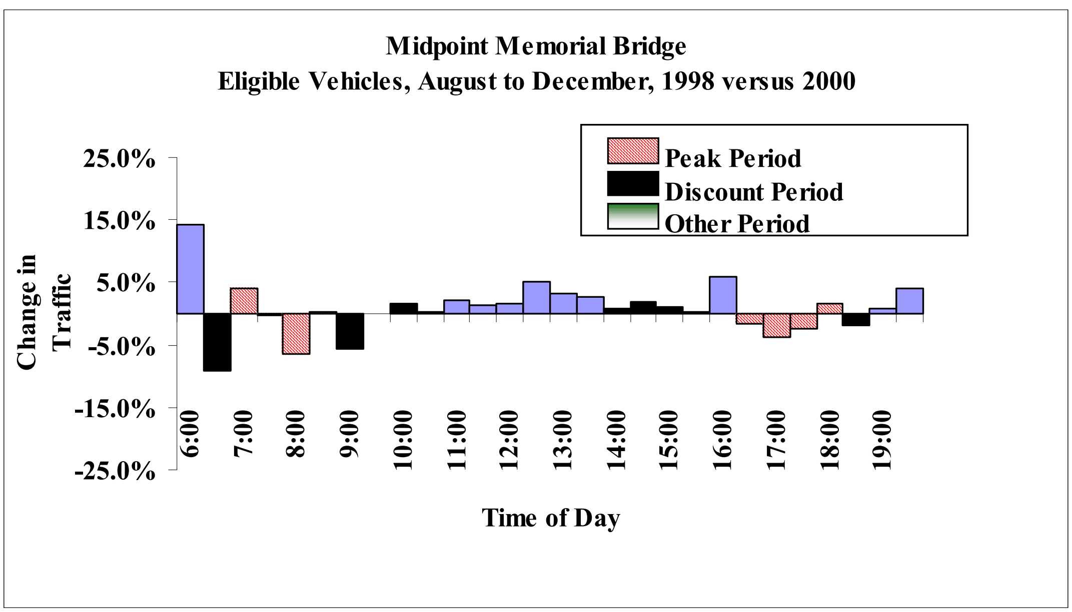

FIGURE B-18 Eligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 2000)

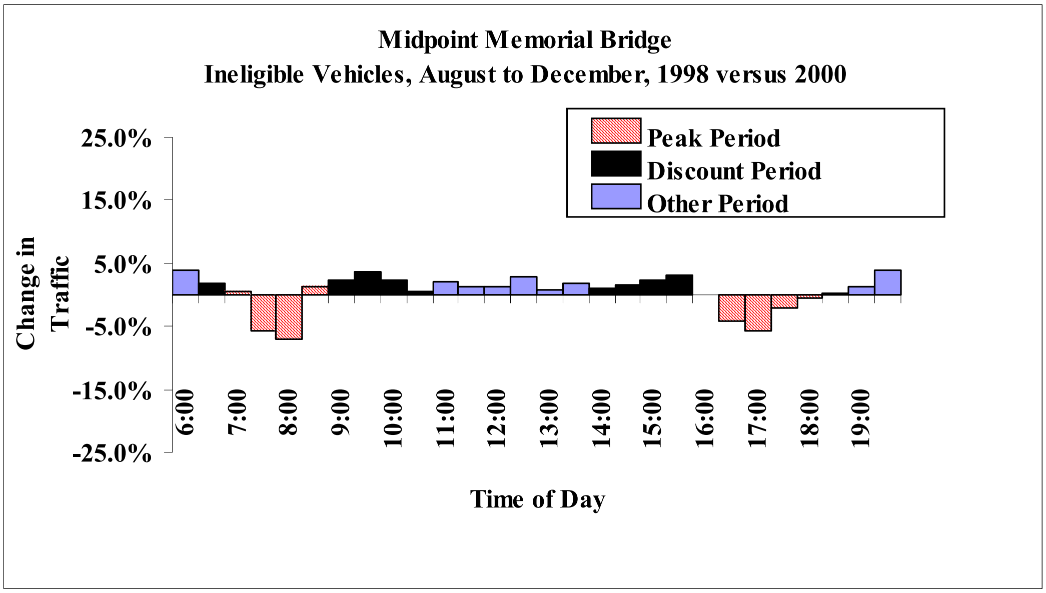

FIGURE B-19 Ineligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 2000)

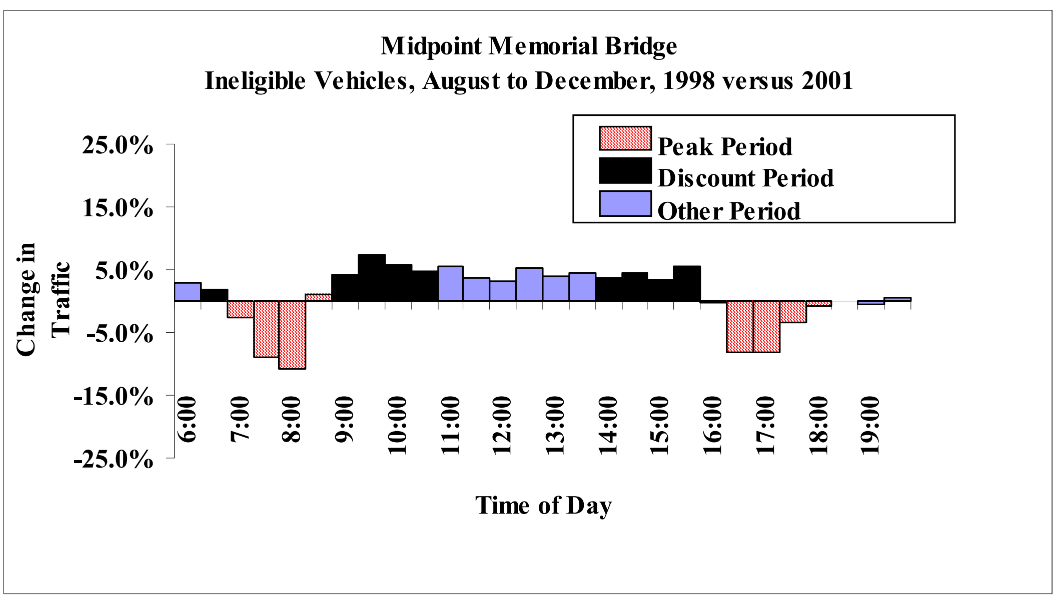

FIGURE B-20 Ineligible traffic pattern changes on Midpoint Memorial Bridge (August-December, 1998 versus 2001)

APPENDIX C

TELEPHONE SURVEY QUESTIONNAIRE

Lee County Variable Pricing 2001 Telephone Survey

Lee County Variable Pricing 2001 Telephone Survey

Time Started _______
Time Ended _______

Note date of survey, phone number, zip code, and tag number.

Hello, I'm ________ of Phase V Research, a local research firm. We are conducting a survey on transportation issues. This is a legitimate public opinion survey; it is not a sales call. We are gathering information to improve transportation in Lee County. I need to speak with the person in your household who drives across the toll bridges the most. (WHEN RESPONDENT IS ON LINE, RE-INTRODUCE SELF AS NECESSARY)

BLOCK I - Travel Behavior & Respondent Qualification

Q.1 During the last week (Monday through Friday only), counting each direction of travel, how many times did you cross …

a) the Cape Coral Bridge (older toll bridge off College Parkway) _____
b) the Midpoint Memorial Bridge (new toll bridge off Colonial Blvd.) _____

Q.2 How long have you been traveling across either one of these bridges?

_____ years (if less than 1 year enter 0)

Q.3 Do you have a LeeWay transponder and PrePay account (where your tolls are paid electronically – add if respondent is unsure of what a PrePay account is)?

Yes 1 No 2 **

*** If* "NO", *thank,* ***GO TO Q.36*** *and terminate the interview*

Q.4 How long have you had your LeeWay Transponder and PrePay account?

_____ years (if less than 1 year enter 0)

Q.5 On a scale of 1 to 10, with 10 being "*very important" and 1 being* "*not important*" how important were each of the following reasons for getting a LeeWay PrePay account with your transponder?

	very important	somewhat important	not important
	(10)	(5)	(1)
i) ease of use	_______		
ii) part of the 50 cents & unlimited trips discount programs	_______		
iii) toll discount during variable pricing hours	_______		
iv) monthly statement	_______		
v) go through toll plaza quickly	_______		
vi) Other : ______________________	_______		

BLOCK II- Variable Pricing Participation

Q.6 Did you know that Lee County offers a variable pricing program where you can get toll discounts during certain times of the day on the Cape Coral and Midpoint Bridges?

-Yes 1 (if yes go to Question 10)
- No 2

Q7. This variable pricing program offers a 50% toll discount for travel in specific off-peak periods (6:30 to 7:00 and 9:00 to 11:00 in the morning; 2:00 to 4:00 and 6:30 to 7:00 in the afternoon). Now that you know about the program, how likely is it that you will take advantage of the toll discounts. 10=definitely, 1=never
Answer ___________ (1 to 10) (if respondent says 1 go to Q. 9)

Q.8 How often do you think you will drive during the discount periods?

_____ times per weekday (Monday thru Friday)

Q.9 The purpose of the variable pricing toll discount is to reduce peak period traffic by encouraging some drivers to shift the times they drive out of the peak periods. How do you rate the variable pricing program in achieving this goal? (*read off categories*)

- Very effective 1
- Somewhat effective 2

- Somewhat ineffective	3
- Very ineffective	4
- [NO OPINION]	5

<u>All respondents go to Question 25</u>

<u>Q.10</u> During the last week (Monday through Friday) did you choose the time of day you made a trip because of the variable pricing toll discounts?

-Yes	1
- No	2

If yes: How many times did you choose to travel during variable pricing discount periods last week? ______ (note discount periods are from 6:30-7 a.m., 9-11 a.m., 2-4 p.m. and 6:30-7 p.m.)

If no: Have you ever chosen to travel during variable pricing discount periods? ______ (note discount periods are from 6:30-7 a.m., 9-11 a.m., 2-4 p.m. and 6:30-7 p.m.) → If no go to Q. 21, otherwise:

For both yes and no answers above: If respondent answered 0 to question 2 or 4 then → go to Q. 15. Otherwise continue with Q. 11

<u>Q.11</u> Are you taking advantage of the variable pricing toll discounts more often than last year?

-Yes	1
- No	2 (if no go to Question 13)
- Don't Know	3 (if don't know go to Question 13)

Including Monday thru Friday only, and counting each direction of travel as one trip: How many more trips per week do you drive during discount periods now as compared to last year? ________

How many more trips were during the early morning (6:30 to 7:00 a.m.) discount period? ________

How many more trips were during the late morning (9:00 to 11:00 a.m.) discount period? ________

How many more trips were during the early afternoon (2:00 to 4:00 p.m.) discount period? ________

How many more trips were during the late afternoon (6:30 to 7:00 p.m.) discount period? ________

Q.12 Why are you making more trips during the variable pricing discount periods?

____

Q.13 Are you taking advantage of the variable pricing toll discounts less often than last year?

-Yes 1
- No 2 (if no go to Question 15)
- Don't Know 3 (if don't know go to Question 15)

Including Monday thru Friday only, and counting each direction of travel as one trip: How many fewer trips per week do you drive during discount periods now as compared to last year? ________

How many fewer trips were during the early morning (6:30 to 7:00 a.m.) discount period? ________

How many fewer trips were during the late morning (9:00 to 11:00 a.m.) discount period? ________

How many fewer trips were during the early afternoon (2:00 to 4:00 p.m.) discount period? ________

How many fewer trips were during the late afternoon (6:30 to 7:00 p.m.) discount period? ________

Q.14 Why are you making fewer trips during the variable pricing discount periods?

- I cannot change my time of travel ……………... 1
- I cannot remember the times of the discounts …. 2
- The discount is not large enough for me to change my time of travel ……………….…………….……… 3
- I have an unlimited trip program …………..…… 4
- the program seems too complicated……..……… 5

- cannot see how it can benefit me…….………… 6
- in a rush /hurry …….………… 7
- just don't think about the toll discounts……...… 8
- forgot about the toll discounts……..…………… 9
- My schedule changed……………………………..….. 10

Other ____

Q.15 Why did you consider the variable pricing toll discount when you chose the time of your travel across the bridges?
(Ask question only, do not give categories, circle best answer)
Write in detail of "other" response

- Save money ……………….………… 1
- Less Traffic ……………………….….. 2
- Contribute to better flow of traffic…….. 3
- Good for the environment………………... 4
- Already drive during those hours ……… 5
- [NO OPINION]………………………… 6
- Other (SPECIFY BELOW) …………… 7

____

Q.16 Do you remember the last time you intentionally drove during the variable pricing times?

Yes 1 >> GO TO Q.19 **No 2 >> GO TO Q.17**

Q.17 In general then, when you *have* chosen to travel in the variable pricing times, what is the usual purpose of that trip?
(Ask question only, do not give categories, circle best answer)

- Commuting between home and work 1
- delivering/transporting packages/goods 2
- Work-related (sales calls, business appointments) 3
- To and from school 4
- Shopping 5
- Airport 6
- Personal/family/social/recreational 7
- Drop off/pick up person/package (not airport) 8
- Other 9

Q.18 On those trips you drove during the variable pricing discount periods were you generally:

- driving alone in a passenger car? 1

- in a 2-person car or vanpool? 2
- in a 3-or-more-person car or vanpool? 3
- in a transit bus? 4
- in a truck or other commercial vehicle? 5
- Don't know 6

>>>>Skip to Question 20

<u>Q.19</u> What was the primary purpose of that trip?
(<u>Ask question only</u>, do not give categories, circle best answer)

- Commuting between home and work 1
- delivering/transporting packages/goods 2
- Work-related (sales calls, business appointments) 3
- To and from school 4
- Shopping 5
- Airport 6
- Personal/family/social/recreational 7
- Drop off/pick up person/package (not airport) 8
- Other 9

<u>Q.20</u> Were you:

- driving alone in a passenger car? 1
- in a 2-person car or vanpool? 2
- in a 3-or-more-person car or vanpool? 3
- in a transit bus? 4
- in a truck or other commercial vehicle? 5
- Don't know 6

Now >> GO TO Q.25

<u>"Non-variable pricing users" ALTERNATE QUESTION SEQUENCE</u>
Use this sequence when drivers have not heard of variable pricing (Q 5)

<u>Q. 21</u> Why didn't you drive during the variable pricing toll discount periods when you drove over the bridges during the last week?
(<u>Ask question only</u>, do not give categories, circle best answer)

- I cannot change my time of travel …………….... 1
- I cannot remember the times of the discounts …. 2
- The discount is not large enough for me to change my time of travel …………………….………… 3
- I have an unlimited trip program …………..…… 4

- the program seems too complicated……..……… 5
- cannot see how it can benefit me……..………… 6
- in a rush /hurry ……..………… 7
- just don't think about the toll discounts……..…. 8
- Other (*SPECIFY BELOW*) ………………….…. 9

other: ____

Q. 22 Did you use to drive during the variable pricing discount periods?

Yes 1 No 2 (skip to Q. 23)

Including Monday thru Friday only, and counting each direction of travel as one trip: How many more trips per week did you use to drive during discount periods? ________

Of those trips, how many were during the early morning (6:30 to 7:00 a.m.) discount period? ________

How many were during the late morning (9:00 to 11:00 a.m.) discount period?

____

How many were during the early afternoon (2:00 to 4:00 p.m.) discount period?

____

How many were during the late afternoon (6:30 to 7:00 p.m.) discount period?

____

Q. 23 If the toll during discount periods was reduced to (free / 10 cents (ask 50% of respondents the free response and 50% the 10 cent response)), would that make you change some of your trips to the discount times?

Yes 1 No 2

Q. 24 If the toll discount periods were longer, would that make you change some of your trips to the discount times?

Yes 1 No 2

>>>NOW GO TO Q.25

BLOCK IV - Employment Structure

Q.25 Are you employed full time, employed part time, retired, or not employed right now?

- Full time ……………….……… 1

- Part time ……………….……… 2
- Retired (**GO TO Q. 29**) ……………... 3
- Not employed (**GO TO Q. 29**) ……… 4
- [REFUSED] (**GO TO Q. 29**) ……….. 5

<u>Q.26</u> Does your employer allow flexibility in employee daily arrival and departure times (Does your employer offer Flextime)?

- Yes 1
- No 2 **(GO TO Q.29)**

<u>Q.27</u> Do you participate in your employer's flextime program?

- Yes 1
- No 2 **(GO TO Q.29)**

<u>Q.28</u> What would best describe your main reason for participating in the flextime program?
(<u>Ask question only</u>, do not give categories, circle best answer)

- Avoid congestion during rush hours ………..…..… 1
- Variable pricing discount, toll discounts ………….. 2
- Family/chores/recreation …………………………... 3
- Other ……………………………………..…….. 4

<u>BLOCK V - Demographics</u>

<u>Q.29</u> How many people live in your household? ____

<u>Q.30</u> How would you describe your household type?
(*read off categories*)

- Single Adult …………………...... 1
- Unrelated Adults (e.g. roommates) …. 2
- Married without Children………..… 3
- Married with child(ren) ……………. 4
- Single Parent Family ……………… 5
- Other ……………………………..… 6

- [REFUSED] ……………………...… 7

Q.31 How many months of the year do you live in Lee County? ________ months
(*if all year, write 12 months*)

Q.32 What is the last year of school you have completed?
(*read off categories*)

- Less than high school…………. 1
- High school graduate …………. 2
- Some college/vocational………. 3
- College graduate………………. 4
- Post-graduate degree………….. 5
- [REFUSED] …………………… 6

Q.33 Please stop me when I mention the category that includes your age:

- 16 - 24 years………………………. 1
- 25 - 34 years ……………….….…. 2
- 35 - 44 years ……………….…….. 3
- 45 - 54 years …………….……..… 4
- 55 -64 years ………….……….…... 5
- 65 years and older ………………… 6

Q.34 Sex

- Male ……………………………….. 1
- Female …………………………….. 2

Q.35 How would you group your total household income for the year 2000?
(*read off categories*)

- Under $16,000………………. 1
- $16,001 to $30,000 …………. 2
- $30,001 to $50,000………….. 3
- $50,001 to $75,000………..… 4
- Over $75,000 ………………... 5
- [REFUSED] ………………… 6

<u>Q. 36.</u> That completes our interview. Thank you for talking with us today and helping to improve transportation in Lee County. Are there any comments you would like to make regarding the variable pricing program?

37. NOTE PHONE #: ________________________________

VITA

Karun K. Konduru was born in India. He received Bachelor of Science degree in civil engineering in 1999 from Sardar Vallabhbhai National Institute of Technology (S.V.N.I.T), India. Mr. Konduru received a merit scholarship for two consecutive years in 1996 and 1997 from South Gujarat University, India.

Mr. Konduru began his graduate studies at Texas A&M University in September 2001. While attending Texas A&M, he was employed as a graduate research assistant in the Department of Civil Engineering. His university affiliations include the Institute of Transportation Engineers and the American Society of Civil Engineers. He received his Engineer in Training Certificate from Texas in June 2003.

After graduation, Mr. Konduru plans to work in the transportation consulting field and his primary interests are transportation planning and transportation economics.

The permanent mailing address for Mr. Konduru is: Sharada Nilayam, Opposite: SFS School, Palasa, Andhra Pradesh, India –532222.