CHAPTER 14

TCRP

REPORT 95

TRANSIT COOPERATIVE
RESEARCH PROGRAM

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Road Value Pricing

Traveler Response to Transportation System Changes

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TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 95

Traveler Response to Transportation System Changes

Chapter 14—Road Value Pricing

JOHN E. (JAY) EVANS, IV
Lead Chapter Author

KIRAN U. BHATT

and

KATHERINE F. TURNBULL
Contributing Chapter Authors

RICHARD H. PRATT, CONSULTANT, INC.
Garrett Park, MD

TEXAS TRANSPORTATION INSTITUTE
College Station, TX

JAY EVANS CONSULTING LLC
Washington, DC

PARSONS BRINCKERHOFF QUADE & DOUGLAS, INC.
Baltimore, MD and San Francisco, CA

CAMBRIDGE SYSTEMATICS, INC.
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New Haven, CT

K.T. ANALYTICS, INC.
Bethesda, MD

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA; the National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

Special Notice

The Transportation Research Board, the National Research Council, the Transit Development Corporation, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

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FOREWORD

By Stephan A. Parker
Staff Officer,
Transportation
Research Board

This chapter focuses on automobile-oriented pricing, including discussion of its impact on other travel modes. The emphasis is on areawide, corridor, and individual facility pricing schemes for urbanized areas, although one particularly instructive example of an intercity value pricing project is offered. Toll roads with static pricing are not considered within the realm of road value pricing or the scope of this chapter, but are looked to for specific relevant lessons. Pricing of parking, which can have similarities to road value pricing, is covered in *TCRP Report 95: Chapter 13, Parking Pricing and Fees*.

TCRP Report 95: Chapter 14, Road Value Pricing will be of interest to transit and transportation planning practitioners; educators and researchers; and professionals across a broad spectrum of transportation agencies, MPOs, and local, state, and federal government agencies.

The overarching objective of the *Traveler Response to Transportation System Changes Handbook* is to equip members of the transportation profession with a comprehensive, readily accessible, interpretive documentation of results and experience obtained across the United States and elsewhere from (1) different types of transportation system changes and policy actions and (2) alternative land use and site development design approaches. While the focus is on contemporary observations and assessments of traveler responses as expressed in travel demand changes, the presentation is seasoned with earlier experiences and findings to identify trends or stability, and to fill information gaps that would otherwise exist. Comprehensive referencing of additional reference materials is provided to facilitate and encourage in-depth exploration of topics of interest. Travel demand and related impacts are expressed using such measures as usage of transportation facilities and services, before-and-after market shares and percentage changes, and elasticity.

The findings in the *Handbook* are intended to aid—as a general guide—in preliminary screening activities and quick turn-around assessments. The *Handbook* is not intended for use as a substitute for regional or project-specific travel demand evaluations and model applications, or other independent surveys and analyses.

The Second Edition of the handbook *Traveler Response to Transportation System Changes* was published by USDOT in July 1981, and it has been a valuable tool for transportation professionals, providing documentation of results from different types of transportation actions. This Third Edition of the *Handbook* covers 18 topic areas, including essentially all of the nine topic areas in the 1981 edition, modified slightly in scope, plus nine new topic areas. Each topic is published as a chapter of TCRP Report 95. To access the chapters, select "TCRP, All Projects, B-12" from the TCRP website: http://www4.national-academies.org/trb/crp.nsf.

A team led by Richard H. Pratt, Consultant, Inc. is responsible for the *Traveler Response to Transportation System Changes Handbook, Third Edition*, through work conducted under TCRP Projects B-12, B-12A, and B-12B.

REPORT ORGANIZATION

The *Handbook*, organized for simultaneous print and electronic chapter-by-chapter publication, treats each chapter essentially as a stand-alone document. Each chapter includes text and self-contained references and sources on that topic. For example, the references cited in the text of Chapter 6, “Demand Responsive/ADA,” refer to the Reference List at the end of that chapter. The *Handbook* user should, however, be conversant with the background and guidance provided in *TCRP Report 95: Chapter 1, Introduction*.

Upon completion of the *Report 95* series, the final Chapter 1 publication will include a CD-ROM of all 19 chapters. The complete outline of chapters is provided below.

Handbook Outline Showing Publication and Source-Data-Cutoff Dates

	U.S. DOT Publication		**TCRP Report 95**	
General Sections and Topic Area Chapters (TCRP Report 95 Nomenclature)	**First Edition**	**Second Edition**	**Source Data Cutoff Date**	**Estimated Publication Date**
Ch. 1 – Introduction (with Appendices A, B)	1977	1981	2003[a]	2000/03/04[a]
Multimodal/Intermodal Facilities				
Ch. 2 – HOV Facilities	1977	1981	1999	2000/04[b]
Ch. 3 – Park-and-Ride and Park-and-Pool	—	1981	2003[c]	2004[d]
Transit Facilities and Services				
Ch. 4 – Busways, BRT and Express Bus	1977[e]	1981	2003[c]	2004[d]
Ch. 5 – Vanpools and Buspools	1977	1981	1999	2000/04[b]
Ch. 6 – Demand Responsive/ADA	—	—	1999	2000/04[b]
Ch. 7 – Light Rail Transit	—	—	2003	2004[d]
Ch. 8 – Commuter Rail	—	—	2003	2004[d]
Public Transit Operations				
Ch. 9 – Transit Scheduling and Frequency	1977	1981	1999	2000/04[b]
Ch. 10 – Bus Routing and Coverage	1977	1981	1999	2000/04[b]
Ch. 11 – Transit Information and Promotion	1977	1981	2002	2003
Transportation Pricing				
Ch. 12 – Transit Pricing and Fares	1977	1981	1999	2000/04[b]
Ch. 13 – Parking Pricing and Fees	1977[e]	—	1999	2000/04[b]
Ch. 14 – Road Value Pricing	1977[e]	—	2002–03[f]	2003
Land Use and Non-Motorized Travel				
Ch. 15 – Land Use and Site Design	—	—	2001–02[f]	2003
Ch. 16 – Pedestrian and Bicycle Facilities	—	—	2003	2004[d]
Ch. 17 – Transit Oriented Design	—	—	2003[d]	2004[d]
Transportation Demand Management				
Ch. 18 – Parking Management and Supply	—	—	2000–02[f]	2003
Ch. 19 – Employer and Institutional TDM Strategies	1977[e]	1981[e]	2003	2004[d]

NOTES: [a] Published in TCRP Web Document 12, *Interim Handbook* (March 2000), without Appendix B. The "Interim Introduction" (2003) is a replacement. Publication of the final version of Chapter 1, "Introduction," as part of the TCRP Report 95 series, is anticipated for 2004.

[b] Published in TCRP Web Document 12, *Interim Handbook*, in March 2000. Available now at http://www4.nas.edu/trb/crp.nsf/All+Projects/TCRP+B-12. Publication as part of the TCRP Report 95 series is anticipated for the second half of 2004.

[c] The source data cutoff date for certain components of this chapter was 1999.

[d] Estimated.

[e] The edition in question addressed only certain aspects of later edition topical coverage.

[f] Primary cutoff was first year listed, but with selected information from second year listed.

CHAPTER 14 AUTHOR AND CONTRIBUTOR ACKNOWLEDGMENTS

TCRP Report 95, in essence the Third Edition of the "Traveler Response to Transportation System Changes" Handbook, was prepared under TCRP Projects B-12, B-12A, and B-12B by Richard H. Pratt, Consultant, Inc. in association with the Texas Transportation Institute; Jay Evans Consulting LLC; Parsons Brinckerhoff Quade & Douglas, Inc.; Cambridge Systematics, Inc.; J. Richard Kuzmyak, L.L.C.; SG Associates, Inc.; Gallop Corporation; McCollom Management Consulting, Inc.; Herbert S. Levinson, Transportation Consultant; and K.T. Analytics, Inc.

Richard H. Pratt is the Principal Investigator. Dr. Katherine F. Turnbull of the Texas Transportation Institute assisted as co-Principal Investigator during initial Project B-12 phases, leading up to the Phase I Interim Report and the Phase II Draft Interim Handbook. Lead Handbook chapter authors and co-authors, in addition to Mr. Pratt, are John E. (Jay) Evans, IV, initially of Parsons Brinckerhoff and now of Jay Evans Consulting LLC; Dr. Turnbull; Frank Spielberg of SG Associates, Inc.; Brian E. McCollom of McCollom Management Consulting, Inc.; Erin Vaca of Cambridge Systematics, Inc.; J. Richard Kuzmyak, initially of Cambridge Systematics and now of J. Richard Kuzmyak, L.L.C.; and Dr. G. Bruce Douglas, Parsons Brinckerhoff Quade & Douglas, Inc. Contributing authors include Herbert S. Levinson, Transportation Consultant; Dr. Kiran U. Bhatt, K.T. Analytics, Inc.; Shawn M. Turner, Texas Transportation Institute; Dr. Rachel Weinberger, Cambridge Systematics and now of URS Corporation; and Dr. C. Y. Jeng, Gallop Corporation.

Other research agency team members contributing to the preparatory research, synthesis of information, and development of this Handbook have been Stephen Farnsworth, Laura Higgins, and Rachel Donovan of the Texas Transportation Institute; Nick Vlahos, Vicki Ruiter, and Karen Higgins of Cambridge Systematics, Inc.; Lydia Wong, Gordon Schultz, and Bill Davidson of Parsons Brinckerhoff Quade & Douglas, Inc.; and Laura C. (Peggy) Pratt of Richard H. Pratt, Consultant, Inc. As Principal Investigator, Mr. Pratt has participated iteratively and substantively in the development of each chapter. Dr. C. Y. Jeng of Gallop Corporation has provided prepublication numerical quality control review. By special arrangement, Dr. Daniel B. Rathbone of The Urban Transportation Monitor searched past issues. Assistance in word processing, graphics, and other essential support has been provided by Bonnie Duke and Pam Rowe of the Texas Transportation Institute; Karen Applegate, Laura Reseigh, and Stephen Bozik of Parsons Brinckerhoff; others too numerous to name but fully appreciated; and lastly the warmly remembered late Susan Spielberg of SG Associates.

Special thanks go to all involved for supporting the cooperative process adopted for topic area chapter development. Members of the TCRP Project B-12/B-12A/B-12B Project Panel, named elsewhere, are providing review and comments for what will total over 20 individual publication documents/chapters. They have gone the extra mile in providing support on call including leads, reports, documentation, advice, and direction over what will be the 8-year duration of the project. Four consecutive appointed or acting TCRP Senior Program Officers have given their support: Stephanie N. Robinson, who took the project through scope development and contract negotiation; Stephen J. Andrle, who led the work during the Project B-12 Phase and on into the TCRP B-12A Project Continuation; Harvey Berlin, who saw the Interim Handbook through to website publication; and Stephan A. Parker, who is guiding the entire project to its complete fruition. The efforts of all are greatly appreciated.

Continued recognition is due to the participants in the development of the First and Second Editions, key elements of which are retained. Co-authors to Mr. Pratt were Neil J. Pedersen and Joseph J. Mather for the First Edition and John N. Copple for the Second Edition. Crucial support and guidance for both editions was provided by the Federal Highway Administration's Technical Representative (COTR), Louise E. Skinner.

In the *TCRP Report 95* edition, John (Jay) Evans is lead author for this volume: Chapter 14, "Road Value Pricing." Contributing authors for Chapter 14 are Dr. Kiran U. Bhatt and Dr. Katherine F. Turnbull.

Participation by the profession at large has been absolutely essential to the development of the Handbook and this chapter. Members of volunteer Review Groups, established for each chapter, reviewed outlines, provided leads, and in many cases undertook substantive reviews. Though all Review Group members who assisted are not listed here in the interests of brevity, their contribution is truly valued. Those who have undertaken reviews of Chapter 14 are Wayne Berman, Tom Rye, Myron Swisher, and Johanna Zmud. In addition, Bridget Wieghart and Steve Wilson stepped in to provide needed chapter reviews.

Finally, sincere thanks are due to the many practitioners and researchers who were contacted for information and unstintingly supplied both that and all manner of statistics, data compilations, and reports. Though not feasible to list here, many appear in the "References" section entries of this and other chapters.

CHAPTER 14—ROAD VALUE PRICING

CONTENTS

14 – Road Value Pricing

OVERVIEW AND SUMMARY

Roadway value pricing employs market forces to allocate limited highway capacity among users by their need to travel and their willingness to pay. The concept, akin to what has been known as congestion pricing, involves charging higher prices for roadway use during peak travel periods, much as telephone companies charge more for calls during peak calling periods. Drivers may choose not to travel or select an alternative time, route, or mode of travel if they are unwilling to pay. Drivers who pay receive the value of being able to drive, when they choose to, with reduced congestion. The concept takes advantage of the differing values people place on making a particular trip at a particular time on a particular route (Federal Highway Administration, 1999).

This "Overview and Summary" section presents:

- "Objectives of Road Value Pricing," which highlights goals, objectives and related perspectives.
- "Types of Road Value Pricing" which uses a taxonomy employed in several congestion pricing studies to categorize applications.
- "Analytical Considerations," which discusses the limitations of available information and the conclusions which may be drawn from it.
- "Traveler Response Summary," which provides highlights of the findings presented in the remainder of the chapter.

Following the "Overview and Summary" are sections on:

- "Response by Type of Road Value Pricing," providing traveler response coverage of most of the road value pricing applications actually in place today.
- "Underlying Traveler Response Factors," examining value pricing interactions from a travel behavior perspective, and summarizing price sensitivities in the form of elasticities.
- "Related Information and Impacts," covering issues of equity, implementation, and mode share impacts among others.
- "Case Studies," expanding on three road pricing application examples.

This chapter focuses on automobile-oriented pricing, including discussion of impact on other travel modes. The emphasis is on pricing for urbanized areas, although one particularly instructive example of intercity value pricing is offered. Toll roads with static pricing are not considered to be within the realm of road value pricing or the scope of this chapter, but are looked to for specific relevant lessons. Otherwise, a broad definition of value pricing is used, one inclusive of most existing congestion pricing. Pricing of parking, an action with certain similarities to road value pricing, is covered in Chapter 13, "Parking Pricing and Fees."

Objectives of Road Value Pricing

Road value pricing projects have been put forward with a number of objectives in mind including:

- Reducing congestion impacts by providing less congested roadway systems, or express lanes to bypass congestion, for those willing to pay.
- Achieving better utilization of special lanes, such as by opening under-utilized high occupancy vehicle lanes to appropriately tolled lower occupancy vehicles.
- Raising revenues for transportation improvements and possibly other uses.
- Encouraging shifts to ridesharing and transit, both by increasing the relative cost savings of using these modes, and optionally by applying toll revenues to their betterment.
- Encouraging fewer and shorter trips, and shifting of trips out of peak periods.
- Achieving reductions in overall congestion.[1]

Economists have long advocated value pricing to encourage more efficient utilization of scarce transportation capacity. Nobel Prize winner William Vickrey argued for pricing to be applied to a range of facilities, and for charges to reflect as closely as possible the marginal social cost of each trip in terms of the impacts on others. In this view, pricing would recognize explicitly both the cost of providing the transportation system capacity to users and the adverse impact users have on each other by using the capacity during congested periods. To the extent user charges exceed the marginal social cost of trip making, the revenues would be returned to the public trust as an added benefit (Vickrey, 1992). For example, revenue from road pricing could be used to fund additional road capacity or transit service. Congestion pricing is viewed as offering greater economic efficiency, in the sense of increasing the net benefits to society, whereas congestion causes significant costs to society (U.S. Environmental Protection Agency, 1998).

Roadway transportation is a relative latecomer to the idea of peak-period pricing. In the U.S., projects began to be implemented after the Federal Highway Administration (FHWA) started funding pilot projects in the 1990s. Many industries employ similar pricing concepts to better manage capacity utilization (and enhanced revenue). Airlines and hotels charge more for peak tourist season seats and rooms. Utilities charge more for energy delivered during peak periods. Charging higher prices for roadway travel during peak periods similarly seeks to manage capacity by providing an incentive to shift some trips to off-peak times, less congested routes, or alternative modes, or to combine some lower-valued trips with other trips, or forgo them (Spock, 1998). Those who choose to pay the higher rates

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[1] The characteristics of highway traffic flow are such that "a shift in a relatively small proportion of peak-period trips can lead to substantial reductions in overall congestion" (Federal Highway Administration, 1999).

receive less congestion and, in a number of roadway applications, access to premium high-speed lanes.

Types of Road Value Pricing

There are many ways to implement the concept of charging more for using transportation facilities when demand is high, and where there is a desire to provide a premium, less-congested option. Direct applications of the concept to existing tolled facilities may seem the most obvious, but to date have not outpaced other types of value pricing applications. Several types of road value pricing have been identified in the literature. Existing projects fall into the four categories presented below.

Areawide Value Pricing. Areawide pricing strategies include charging fees for entering an area, assessing cordon-crossing charges, or levying charges for traveling on a network of routes within a defined area. The manner in which the charges are applied may be a matter of policy or technology. For example, some projects have deployed electronic toll collection using transponders, while some proposed projects would involve the use of payments at the gasoline pump. The Singapore Area License Scheme and the Norwegian toll rings each involve areawide value pricing and are discussed in this chapter.

Value Pricing on a Single Highway Facility, Route or Corridor. This type of pricing involves putting peak-period surcharges at "key traffic bottlenecks, single traffic corridors or highway facilities, including bridges and tunnels" (Federal Highway Administration, 1999). The priced facilities may be within a system context that provides free alternatives or may be the only option across a geographic barrier. Value pricing on facilities in Lee County, Florida, New York/New Jersey, Toronto, Canada, and Seoul, Korea, are among those discussed here.

Value Pricing on Single or Multiple Highway Lanes. This type of pricing charges for the use of certain highway lanes during peak traffic periods. Probably the most widely known example of this type of pricing is High Occupancy Toll (HOT) lanes. HOT lanes enable entry to high occupancy vehicle (HOV) lanes by vehicles not meeting prescribed HOV occupancy requirements, namely low occupancy vehicles (LOVs), through the payment of a fee. LOVs typically but not always include single occupant vehicles (SOVs) (Federal Highway Administration, 1999). Value pricing on I-15 in San Diego and Houston's Katy Freeway are HOT lane projects discussed in this chapter. SR 91 in Orange County, California, a hybrid project featuring an express roadway with HOV pricing differentiated from non-HOV pricing, is also covered.

Vehicle Use Pricing Programs. A number of innovative pricing programs are being implemented that do not fit within the facility classifications above. Each of these programs seeks to convert fixed vehicle ownership costs to variable usage costs. Addressed in this section are pay-by-the-mile insurance projects in Houston and car sharing projects in Switzerland and San Francisco, California.

Analytical Considerations

Experience with roadway value pricing is relatively limited in the U.S. at present, though greatly increased in the past five years because of FHWA project sponsorship. The pilot projects under this program are designed to provide before and after results and examine a variety of impacts, but in a number of cases, the literature reports only preliminary findings at this point in time. Examples from Europe and Asia raise the inevitable questions of to what extent findings are transferable to the U.S. context.

Prior to these federally sponsored projects, numerous theoretical discussions, assessments and modeling exercises were undertaken to explore the likely impacts of congestion pricing schemes. Some of these provide a helpful backdrop to the results now coming from actual pilot projects, and offer some additional insight into the traveler response mechanisms at play. This preparatory research also attempts to address related impacts that may not be directly measurable in the pilot programs themselves, for example emissions effects.

In whichever case, whether relying on preliminary results from pilot projects, findings from overseas applications, or conclusions from modeling, the practitioner should use due caution in drawing broad conclusions. Each project sits within a fabric of community and political attitudes towards pricing, and unique demographic and economic attributes, that may not be encountered in every locale. Each project's design, relationship to other facilities, and geographic context likely plays an important role in its degree of success. The same project in a different environment may yield different results. The small number of project experiences to draw upon, and the preliminary nature of many findings, suggests that extra care be used in efforts to generalize outcomes or transfer results.

Additional evaluation and measurement issues to be alert to in any synthesis of findings are covered in Chapter 1, "Introduction." Within the "Use of The Handbook" section of Chapter 1, see the four subsections titled "Degree of Confidence Issues," "Impact Assessment Considerations," "Demographic Considerations" and "Concept of Elasticity."

A technical note regarding road pricing elasticities: Most or all of the reported project-specific user sensitivities to domestic (U.S.) road pricing were originally calculated in the manner of *shrinkage ratios*, to use an historic term of the transit industry, even though presented as "elasticities" and even "arc elasticities," or as "point elasticities [that] are approximated."[2] The difference is most important in the case of the Lee County Demonstration Project results; employment of shrinkage ratios to describe increases in use being particularly problematical. The Handbook authors have provided arc elasticity recalculations for Lee County, and in the "User Cost" discussion of this chapter's "Underlying Traveler Response Factors" section, for other projects. In this chapter, any elasticity not described as "mid-point arc elasticity" or "log arc elasticity" is of unknown mathematical derivation, unless noted otherwise.

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[2] A true road pricing arc or point elasticity of -0.2, for example, indicates a 0.2 percent decrease (increase) in roadway use in response to each 1 percent price increase (decrease) in price, calculated in infinitesimally small increments. Shrinkage ratio type calculations are, in contrast, calculated in whatever increment is defined by the "before" and "after" prices, which can make a significant difference in the case of large price changes, and also produces different absolute values for price increases versus price decreases of equal amounts. In either case, a negative sign indicates that the effect operates in the opposite direction from the cause. An elastic value is -1.0 or beyond in the case of arc or point elasticities, and indicates a demand response which is more than proportionate to the change in the impetus. (For additional background, see "Concept of Elasticity" in Chapter 1, "Introduction," and Appendix A, "Elasticity Discussion and Formulae.")

Traveler Response Summary

Roadway transportation is a latecomer, relative to utilities, airlines and hotels, to the application of variable or peak-period pricing. In the United States, projects only began to take hold after the FHWA started funding demonstrations in the 1990s. Value pricing clearly impacts traveler behavior. When observed traveler sensitivities to value pricing are expressed as price elasticities, most fall in the range of nil to -0.5, similar to but marginally less than sensitivities to transit fare. Short-term trip-making adjustments made by travelers in response to pricing include changes in route choice, time of travel, mode choice, trip frequency and selection of activity and destination. Route choice adjustments predominate when free highway alternatives are available. Long-term effects are less certain; road value pricing may influence not only further decisions about trip-making, but potentially also automobile ownership and location choice for residences, employers, and activities.

The United States has seen public reluctance to implementing areawide value pricing projects, and they have not been common internationally. The major example of longest standing is the Singapore Area License Scheme (now Electronic Road Pricing), in effect since 1975 within Singapore's central area. Initiated with an AM peak period auto entry fee equivalent to almost 5 percent of a car-owning household's average income, with 4-plus occupant HOVs free, the pricing cut morning traffic entering the zone by over 40 percent and greatly increased transit use and carpooling. Enhancements over the years have kept this island state's central area traffic under control. Three Norway cities have for a decade or more charged autos US $0.80 to $1.75 during workday hours for crossing a ring around their central areas. The traffic reduction obtained by diverting some travelers to other modes or hours was on the order of 5 to 10 percent. Early results from a new £5 (about $8) congestion charge for entering central London between 7:00 AM and 6:30 PM indicate a 20 percent reduction in entering traffic. No U.S. areawide projects are in place.

Some North American examples of corridor pricing have been implemented, but most so recently that their evaluations are still incomplete. Typically, tolling was already in place, and the value pricing is applied as either an off-peak discount or peak-period surcharge. A bridge toll demonstration in Lee County, Florida, has seen a $0.25 (50 percent) shoulders-of-the-peak discount attract drivers away from the peak hours enough to reduce AM peak hour traffic of eligible drivers by 7 percent, with a much lesser effect in the PM. A newly instituted off-peak E-ZPass savings of $1.00 (20 percent), relative to peak E-ZPass crossings from New Jersey into New York, may be producing comparable peak hour reductions. In all of the cases, U.S. and international, there is a clear sensitivity of motorists to peak pricing, and the expected effect of shifting traffic away from periods with the highest charges has been commonly observed.

The United States has three major projects of the lane pricing variety, the SR 91 Express Lanes tollway and I-15 HOT Express Lanes projects in California, and the lower-key Katy Freeway HOT lane project in Houston. Pricing has been successfully used to maintain good levels of service on the premium lanes, while enhancing their use in the case of the HOT lanes, and financing construction and operation in the case of the SR 91 tollway. Only a minority of paying customers elect to use the special lanes regularly, as compared to only occasionally electing to pay in preference to traveling on adjacent free lanes. The LOV toll option has not detracted from use of the HOT lanes by HOVs, indeed, I-15 Express Lanes usage by HOVs grew by more than 20 percent over "before" volumes during three demonstration years. Transit use has not been adversely affected, but questions remain concerning impact on overall highway corridor vehicle occupancy. While users come from all income groups, more affluent travelers pay their way onto the lanes more frequently than lower income motorists.

Innovative value pricing programs including car sharing and variable insurance offer promise as another way to introduce the congestion relief benefits of pricing to regions. These programs seek to convert the largely fixed costs of driving into variable costs and in the process make motorists more aware of the costs of driving. A few demonstration projects of this type are underway in the United States and experience overseas suggests these programs may become more significant in the next decade.

RESPONSE BY TYPE OF STRATEGY

Road value pricing has the potential to alter travel behavior in significant and lasting ways. The following sections explore more than a dozen project experiences and are intended to highlight the key traveler response findings from each.

Response to Areawide Value Pricing

Areawide roadway value pricing as contemplated in this chapter refers to charging motorists for traveling in a certain geographic area, either by distance traveled or simply for crossing a boundary into the area. There are parallels between this concept and areawide parking charge programs, and thus the reader is encouraged to consult Chapter 13, “Parking Pricing and Fees,” for related traveler response information. Key differences, though, are that with true value pricing the charges vary by time of day in at least a crude reflection of traffic demand, and in any case apply to all targeted roadway users — through traffic included — not just those parking in controlled facilities.

The United States has seen a reluctance to implement areawide value pricing projects, though several cities have studied the potential for implementation. Boulder, Colorado, contemplated a pilot demonstration involving areawide value pricing, but faced media and political pressure to stop the project. Outside the United States, electronic road pricing feasibility pilot applications were tried in Hong Kong between 1983 and 1985 and again in 1997, but there, too, the efforts were ultimately deemed politically unworkable (Zen, 1999). In contrast, Singapore and Norway have working, fully established, areawide roadway pricing strategies in place. More recently, areawide road pricing applications have been implemented in Rome and in an historic area of Durham, United Kingdom. Even newer is a major project in central London.

Singapore’s Area Licensing Scheme

Singapore’s Central Area pricing scheme provides over a quarter century of experience. On the one hand, transferability of Singapore’s results to North American conditions is made difficult by economic and social differences ranging from auto ownership (one car for every 16 persons in 1975; one car for every 9 persons in 2002) to style of government. On the other hand, however, the available data is sufficiently stratified to give indication of what might occur in comparable programs. For example, certain results of the initial implementation are available for vehicle-owning households separate from non-vehicle owning households.

Singapore originally put its Area License Scheme (ALS) into place in 1975. The ALS has been modified over time, and now employs electronic payment systems, but was originally implemented using colored paper licenses displayed in windshields. The system involves charging a fee to motorists entering a restricted zone in the Central Area of the city. The zone has about 30 entry points over which gantries with flashing lights indicate the need for the area license. For many years the entry fee was a fixed amount, applying only during peak hours, but now the fee is varied by time of day and covers more hours. The original 1975 restricted zone was 620 hectares (2.4 square miles) in extent, but has been expanded (Menon, Lam and Fan, 1993; Gomez-Ibanez and Small, 1994; World Bank, 2000).

Initial Implementation and Results. The 1975 implementation saw fees set at S $3 per day or S $60 per month (approximately US $1.30 and US $27, respectively, at the time). For perspective, the initial monthly entry fee was itself almost 5 percent of mean reported monthly household income for vehicle owning households. Travel outside the morning peak or in carpools with four or more occupants (HOV 4+) was free. Motorcycles were exempted, and initially taxicabs were also. A S $50 fine was imposed on violators. Parking rates were raised by S $10 to S $20 in conjunction with ALS implementation, resulting in S $50 to S $60 monthly parking costs at government owned lots. Entry fees have been raised several times since, and in 1988 were 18 percent higher in Singapore constant dollars than in 1975 (Watson and Holland, 1975 and 1978; Gomez-Ibanez and Small, 1994).

A supplemental shuttle bus service from 10,000 park and ride spaces outside the restricted zone to the central area was introduced concurrently with the ALS. It was initially priced at S $30 per month for both shuttle bus and parking, but in response to poor usage, the shuttle fares were reduced to match conventional city bus fares. The shuttles' lack of popularity quickly led to their extension to reach adjacent major housing areas, after which a ridership of 2,500 per day was achieved. As of 2002, these housing area shuttles still operate as part of a larger bus system (Watson and Holland, 1975; Pratt, Pedersen and Mather, 1977; Singapore Shuttle Bus, 2002). In contrast to park-and-ride shuttle use, conventional bus transit ridership rose immediately, up 15 percent 3 months after ALS implementation compared to 3 months before, and continued to increase in the longer term (Watson and Holland, 1975; Gomez-Ibanez and Small, 1994).

The initial 7:30 AM to 9:30 AM ALS application produced significant vehicular congestion after the restricted hours, resolved by extension of the restricted period to 10:15 AM (Watson and Holland, 1975). Motorized vehicle traffic entering the restricted zone during the 7:30 AM to 10:15 AM period dropped 44 percent, from 74,000 to 41,200 vehicles per day, comparing 3 months before with 3 months after. The car traffic component, including carpools, plunged from 42,800 to 11,400 — down 73 percent (Watson and Holland, 1978). The vehicular traffic reduction was attributable to travelers shifting to HOV 4+ carpools and conventional city buses and also to travelers changing their routes and hours of travel (Watson and Holland, 1975; Gomez-Ibanez and Small, 1994).

Mid-point arc price elasticities of demand for restricted zone entry during the restricted hours were computed for private and company automobiles in combination. Response to the initial fee was elastic, in economists' terms, with a computed mid-point arc elasticity to the sum of area license fee, parking charges and auto operating costs of -2.95.[3] Response to

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[3] Negative signs have been added to these midpoint arc elasticities by the Handbook authors, indicating reaction (*decrease* in traffic) that is opposite to the stimulus (*increase* in price).

increases in the fee later in the year was inelastic, computed to be -0.33, indicating that the proportional effect was then less than the proportional price increase. These results match traditional economic expectations that demand will become less elastic as the price increases (Watson and Holland, 1978). They may also reflect the fact that the fee increases in the second stage were focused more on company cars.

Table 14-1 shows the changes in travel to work mode which occurred in 1975 with ALS implementation. The shift to alternative modes was greatest among inbound commuters from vehicle-owning households who worked in the restricted zone. From those households, the proportion commuting in non-HOV 4+ autos dropped from 48 to 27 percent, while commuting in HOV 4+ carpools increased from 8 to 19 percent. The corresponding proportion who used buses increased from 33 to 46 percent, including 3 percent on the new park-and-ride shuttles (Gomez-Ibanez and Small, 1994).

Table 14-1 Changes in Travel Mode for Home to Work Trips in Singapore, 1975

	Work in Restricted Zone		**Work Beyond Restricted Zone**	
	Before ALS	**After ALS**	**Before ALS**	**After ALS**
Vehicle Owning Households				
Car driver [a]	32%	20%	37.5%	31%
Car passenger [a]	16	7	10	5
Carpool (HOV 4+)	8	19	5	14
Bus	33	46 [b]	31.5	40
Motorcycle	7	6	13	9
Other	4	2	3	1
Non-Vehicle Owning Households				
Car passenger [a]	1%	3%	n/a	n/a
Carpool (HOV 4+)	0	2	n/a	3%
Bus	88	89 [c]	90%	85
Bicycle	5	4	3	9
Taxi	3	0	n/a	n/a
Walk	2	2	n/a	n/a
Other	n/a	n/a	6	3

Notes: [a] Excludes carpools of 4 or more persons.

[b] Includes 3 percent who used the shuttle bus service from the new park-and-ride lots.

[c] Includes 2 percent who used the shuttle bus service from the new park-and-ride lots.

n/a indicates data not applicable or not available (presumably included in "Other").

Some columns do not add to 100 because of rounding.

Source: Gomez-Ibanez and Small (1994).

Some motorists started their trips earlier to avoid the 7:30 AM to 10:15 AM restricted hours. Car drivers who started their home to work trips before 7:30 AM went up from 28 to 42 percent for those who worked in the restricted zone, and from 50 to 60 percent for those who worked beyond. The shift to earlier hours accounted for around 5 percent of the reduction in auto traffic during the restraint hours (Gomez-Ibanez and Small, 1994). Total vehicular traffic in the half hour before the restrictions rose 13 percent, but not to the point of causing notable problems (Watson and Holland, 1975 and 1978).

No fees were initially applied in the evening peak period. Contrary to the expected mirroring of morning impacts, 1975 evening peak volumes fell only 3 to 4 percent. This result was attributed in part to existence of a larger through traffic component than had been realized. In the morning, these through trips changed their route to avoid the restricted zone. As seen in the last two columns of Table 14-1, among vehicle owning households, the percentage of commuters traveling to work beyond the zone in non-HOV 4+ cars declined from 48 to 36 percent. This was about half the reduction made by their counterparts working in the zone. The proportion of car drivers commuting to jobs beyond the zone who passed through the zone declined from 88 to 66 percent (Gomez-Ibanez and Small, 1994).

Development of comparative before and after travel speeds and times was adversely affected by various measurement difficulties. As best as can be determined, the reduction in auto commuting to the Central Area may have increased average morning speeds by 20 percent or more inside the restricted zone, and by 10 percent on inbound radials leading to the zone. On the ring bypass road, however, vehicular speeds probably declined by about 20 percent in response to the increase in through commuters circumventing the restricted zone. Conventional bus transit service speeds improved correspondingly within the zone but not on inbound radials. Household surveys indicated that average door to door travel times for morning commuters did not change discernibly, except for generally expected travel time consequences of switching modes. Overall the impression is that commuter travel time benefits were at best modest, with considerable time losses by some groups, particularly those changing to bus travel (Watson and Holland, 1978; Gomez-Ibanez and Small, 1994).

The disappointing travel time results in 1975 have been largely blamed on insufficient public transit options and perhaps too high an ALS fee. Over time, persons initially disadvantaged have been better served. An expressway opened in 1981 provides an alternate bypass route around the Central area, a rail Mass Rapid Transit system was introduced in stages from 1987 through 1990, and the bus fleet was expanded by 95 percent between 1974 and 1990. The bus fleet expansion — perhaps the most important improvement — reduced overcrowding and associated delays, and facilitated expansion of express and premium services (Gomez-Ibanez and Small, 1994).

Longer Term Results through 1988. Table 14-2 shows the mode used by commuters to the restricted zone as revealed in home interview surveys from 1975 through 1988. Unfortunately neither the HOV 4+ carpool mode nor other carpooling is distinguished from automobile use in general. The volume of HOV 4+ carpools as a percentage of all car traffic entering the restricted zone during the restricted hours peaked at 54 percent in the early 1980's. It has since declined, likely as a result of major improvements in the public transport system. While the decreasing automobile mode share was not enough to prevent a 24 percent increase in absolute volumes of traffic entering the restricted zone during the morning restraint hours, from immediately after ALS introduction to 1988, that increase was only one-third of the 72 percent rise in the car population (Menon, Lam and Fan, 1993; Gomez-Ibanez and Small, 1994).

Table 14-2 Mode Used by Commuters to Singapore's Restricted Zone, 1975-1988

Mode	Before ALS	1976	1983	1988
Automobiles	56%	46%	23%	23%
Bus	33	46	69	55
Rail Transit	–	–	–	11
Motorcycle	7	6	6	8
Other	4	2	2	3

Source: Gomez-Ibanez and Small (1994).

Post-1988 Changes and Results. In June 1989, two major changes were made to the ALS: the elimination of the truck, motorcycle and HOV 4+ carpool exemptions and the introduction of charges in the evening peak period. Prior to this change, significant levels of casual carpoolers were observed outside the restricted zone, picked up by drivers to obtain the necessary occupants. Most of the casual carpoolers appear to have used buses for the return trip in the evening, as demonstrated by a 1988 survey showing that inbound carpools in the morning restricted hours totaled 34 percent while the outbound figure was only 3.6 percent (Menon, Lam and Fan, 1993).

The expansion of hours to include the evening peak period caused a significant reduction in traffic, as when the original ALS was introduced. During the evening period, entering traffic declined by 54 percent and exiting traffic declined by 34 percent between May 1989 (just before the changes) and May 1990. Over the same time span, during the morning hours, total entering traffic volumes dropped by 14 percent. In 1994, the hours of restraint were expanded further to include the midday period and much of the day on Saturday (Gomez-Ibanez and Small, 1994).

In 1998, an electronic tolling system covering an expanded area replaced the manual system. Now referred to as the "ERP," standing for "Electronic Road Pricing," the system utilizes in-vehicle transponder units (IU) that accept stored-value CashCards for payment (Willoughby, 2000). The current restricted zone tolling scheme is applied on weekdays from 7:30 AM to 7:00 PM and varies from free (10:00 AM to 12:00 PM) to S $2.50 (8:30 AM to 9:00 AM) according to a fixed schedule. There are also AM peak period tolls on various expressways that vary by half hour (Land Transport Authority, 2002). With the ERP system in place, weekday traffic volumes entering the Restricted Zone dropped 20 to 24 percent from 271,000 vehicles per day to between 206,000 and 216,000 after new traffic patterns stabilized. With the lower volumes, average traffic speeds in the zone increased from 30-35 km/h to 40-45 km/h (World Bank, 2000). More on the ERP system is presented as a "Singapore Electronic Road Pricing" case study toward the end of the chapter.

The Singapore ALS demonstrates that congestion pricing can produce large reductions in vehicle use and that the traffic reductions can be sustained over time. Moreover, albeit in a Asian context, the ALS has not appeared to stifle restricted zone business activity. Between 1975 and 1989, employment in the zone grew by 30 percent. Yet even with the 72 percent increase in the automobile fleet, the total inbound traffic during the restricted hours has been capped at below 70 percent of the 1975 pre-ALS volumes. The transit share of work trips to the restricted zone increased from 33 percent in pre-ALS years to 69 percent in 1983, and was about the same in 1993 (Gomez-Ibanez and Small, 1994; Menon, Lam and Fan, 1993).

Norwegian Toll Rings

Several cordon toll programs are operational in Scandinavian cities. The first of these "toll rings" was established in 1986 in Bergen, Norway's second most populous city (population 300,000). The idea subsequently spread to Oslo, Norway's capital (population 700,000), in 1990, and to Trondheim, Norway's third largest city (population 140,000) in 1991 (Gomez-Ibanez and Small, 1994). At least one additional Scandinavian installation, in Stavanger, Norway, has been added since.

The primary motivation behind the Norwegian toll rings has been revenue generation rather than congestion mitigation, and each features relatively low tolls that do not vary much by time of day. They are significant, though, in being the first citywide applications of road pricing outside Singapore (Gomez-Ibanez and Small, 1994).

Bergen. Bergen's system charged motorists about NOK 5 (US $0.80) as of 1994 to enter the central area except during night hours and on weekends. The small number of access routes to Bergen, three being bridges, facilitated toll ring implementation. Just seven toll stations handle about 70,000 vehicles per day. Nearly 60 percent of car crossings are by vehicles that have passes and are thereby allowed to traverse dedicated lanes. Despite the low charge, Bergen's tolls appear to have restrained weekday traffic growth slightly, and to have lowered vehicle crossings by perhaps 6 to 7 percent during hours of operation. Traffic during hours of free passage increased by about 10 percent (Gomez-Ibanez and Small, 1994).

Oslo. Oslo charges a toll of about NOK 11 for crossing the cordon at all times of the day. Surrounding mountains and water concentrates traffic entering the city into three corridors. The system uses electronic toll collection to ensure minimal delays. Consistent with its intent to simply raise revenue, the toll ring has had a small impact on traffic. Estimates of the reduction in cordon crossings in response to the toll average some 5 percent. Most of the drop was during off-peak periods, implying that mainly non-work trips were eliminated or diverted. Many peak-period trips are subsidized. Just over 60 percent of car crossings are covered by monthly subscriptions, and 60 percent of those are paid by employers. Effects of the toll on business and land use could not be discerned (Gomez-Ibanez and Small, 1994).

Trondheim. The Trondheim toll ring opened in 1991 and features toll rates that vary somewhat based on the time of day. During the morning peak period the toll is around NOK 10 and during the midday it is around NOK 8. After 5:00 PM and on weekends there is no charge. Surveys before implementation indicated that 91 percent of the area's residents had some alternative to paying the toll—riding the bus, changing destinations, or changing work hours. Respondents indicated a willingness to shift a trip ten minutes earlier or later in order to save NOK 5.70 in toll charge. Table 14-3 illustrates the impact of implementation as reflected in panel surveys of residents living outside the ring conducted before and after implementation (Gomez-Ibanez and Small, 1994).

Shopping trips appeared to be the most influenced by the toll. Shopkeepers contributed to this by lengthening hours to enable free access after 5:00 PM, and about 19 percent of inbound shopping trips shifted as a result. No decrease in downtown retail revenues was observed, though costs probably increased with the extended shopping hours. Work trips exhibited a lesser shift. Some 3 percent of inbound home-to-work trips and 13 percent of work-to-home trips shifted in time to cross the cordon after 5:00 PM (Gomez-Ibanez and Small, 1994).

Table 14-3 Trondheim Panel Survey: Change in Behavior Due to Toll

Trip type	Percentage of respondents reporting a change in behavior	Primary changes in behavior
Work Trips	20%	Mode change Time shift
Shopping Trips	45%	Time shift Destination change Trip frequency change
Other Trips	35%	n/a

Source: Gomez-Ibanez and Small (1994).

Overall, inbound traffic during the toll period declined by 10 percent, while traffic during the non-toll period increased by 9 percent. Weekday bus travel increased by 7 percent (Federal Highway Administration, 1996). According to the panel surveys, the toll ring impacted the frequency of use of the automobile as the commute mode for residents outside the cordon (see Table 14-4). While a small portion of commuters shifted completely away from the car, a large portion began using alternatives some of the time.

Table 14-4 Trondheim Panel Survey: Frequency of Use of Automobile to Commute

	Before Toll Ring (1990)	After Toll Ring (1992)
Commuters never using the car	5%	7%
Commuters using a mode other than car at least *some* days	63%	89%

Source: Gomez-Ibanez and Small (1994).

United Kingdom City Center Congestion Charging

The first application of city center congestion charging under the U.K.'s Transport Act of 2000 was in the unique peninsular shopping and historic area of central Durham. Pre-implementation surveys had found daily visitation by an average of 17,000 pedestrians and 3,000 cars. Half the autos were serving passengers running quick errands. Early reports indicate the £2.00 (roughly $3.00) exit fee reduced daily traffic on the first day, October 1, 2002, to some 1,500 to 2,000 cars — as expected. By the third day, however, volumes were down 95 percent, to 150 cars (Urban Transportation Monitor, 2002). Subsequent newspaper reports suggest stabilization at a 90 percent traffic reduction, with the project regarded as a success, albeit a money loser. Emulation in U.K. national parks is under consideration.

In London, a congestion charge of £5 (about $8) for entering the 8 square mile city center was put into effect on February 17, 2003. The area is the heart of business, government, media and heritage for the United Kingdom, and encompasses roughly 1 million workers. Payment of the charge may be made up through the day of entry via a wide variety of means and for several time periods from daily to annual. Residents of the zone receive a 90 percent discount, and total exemptions include disabled persons, motorbikes, taxis, transit vehicles, and certain public service workers/vehicles. The pricing has been supported by addition of 300 buses to the London fleet, a 7 percent increase, along with other transit service enhancements (Urban Transportation Monitor, 2003b; Fairholme, 2003). It should be noted that an emergency closure of the London Underground's Central Line subway extended into the time frame of initial congestion charging application.

Results for the first week (a school holiday) showed a 20 to 25 percent decrease in traffic flowing in, and a revenue take of over £2.5 ($3.7) million, 92 percent of expectations. A retail monitoring company reported sales down 3 percent within the zone, balanced by gains outside the center. Privatized bus and train operators appeared to be securing increased profits (Urban Transportation Monitor, 2003b).

By the end of the sixth week it appeared that the reduction in traffic entering the zone was stabilizing at about 20 percent, with entry payments per 7:00 AM – 6:30 PM charging day (weekdays only) ranging from 94,000 to 101,000. Access route congestion and payment enforcement reports were mixed at this early stage, but with buses and other traffic clearly moving better within the city center (Transport for London, 2003; Urban Transportation Monitor, 2003a). An opinion survey made at about this time, by the London Chamber of Commerce, has been taken as an indication of negative impact on the retail sector. Three-quarters of surveyed businesses reported a sales downturn over the past year. Survey respondents were offered five plausible reasons for the loss of business: the congestion charging, the Central Line closure, terrorism threats, competition, or the general downturn in the economy. Blame was placed on the congestion charge by 60 percent of the businessmen reporting a decline in business (Urban Transportation Monitor, 2003c).

A few additional weeks of experience have confirmed the 100,000 vehicle average entry total and the 20 percent reduction in entry traffic. Sampling indicates a corresponding 16 percent traffic reduction within the zone, with intra-zone general traffic speeds increased by 10 to 15 percent. No increase in Inner Ring Road volumes and no significant change in traffic levels outside the zone have been noted. There has been a 50 percent reduction in scheduled weekday bus-kilometers of service not operated due to traffic delays, both in the zone and on the Inner Ring Road, compared to a year previous. Zone and Inner Ring Road bus speeds are up by some 7 percent, and excess passenger wait time, a measure of reliability problems, is down by about one-third. Peak hour bus patronage has increased by 14 percent, and public transit has been able to handle the load of persons shifting from auto use (Fairholme, 2003).

Stuttgart, Germany, Pricing Simulation

Stuttgart, Germany, an industrial city of 600,000 persons, conducted a real-life areawide value pricing experiment between May 1994 and February 1995. The purpose was to test individual behavioral responses. Participants received a block allocation of funds intended to more than cover any expected toll payments, and could keep any difference. A cordon line was established across the three southern routes into the city center and a varied toll structure was applied to crossing motorists in the program. Toll collection was similar to Singapore's new ERP system, using an on-board unit and a stored value card (Federal Highway Administration, 1997; Small, 1997).

When one of the three routes entering the city was charging a differential of up to US $2.50 compared to the other two, about 12.5 percent of drivers switched from their usual route to a cheaper one. A similar proportion shifted from peak to off-peak travel when faced with large price differentials by time of day. Motorists also chose to shift to transit and carpools rather than face the tolls. The shift to transit varied from around 5 percent for weekday trips to up to 15 percent for weekend trips. New carpools garnered about 7 percent of participant trips by the end of the experiment. Trip chaining and destination shifts were less common, occurring more for weekend than weekday trips. Participant responses were sensitive to the magnitude of the automobile tolls, but elasticities were not reported (Small, 1997).

The participants were surveyed from three months prior to the pricing to one month after the pricing. Interestingly, several participants continued their "modified" travel patterns after the trial ended. Thus demand for park and ride facilities and public transit remained higher after the study. The researchers found that simply providing information on alternative transportation options, in conjunction with a reason for trying them out, enhanced their acceptance as viable options (Federal Highway Administration, 1997; Small, 1997). This latter finding meshes with transit marketing experience (See Chapter 11, "Transit Information and Promotion," under "Traveler Response by Type of Program" — most particularly the "Targeted Promotion" section).

Response to Value Pricing on a Single Highway Facility, Route or Corridor

Road value pricing on a single highway facility, route, or corridor is the approach most closely identified with traditional toll facilities. The key difference is that value pricing features different fees depending on the time of day or real-time travel demand. The priced facilities may be within a system context that provides free alternatives, such as on Route 407 in Toronto or the Autoroute in France, or may be the only option — or only reasonable option — for crossing a geographic barrier. Examples of both types are discussed here.

Toronto, Canada, Route 407

Toronto's Route 407ETR is a 108-kilometer (67 mile) toll road project, built and operated as a public-private partnership, that runs through Metropolitan Toronto. The highway, opened in several phases, features electronic road pricing technology enabling it to operate without toll booths — an approach known as "open road tolling." Most cars carry transponders, which allow use of the road without incurring an added fixed charge per trip. Cars without transponders are tracked using digital-video-based technology that matches the license plate against the Motor Vehicle Registry's database and sends a monthly bill (407 International, 2002). Until a change implemented at the start of 2002, the pricing on the road varied by time of day.

Under the variable pricing schedule, road use by passenger cars and other light vehicles cost CAD $0.10 per kilometer during peak weekday periods, CAD $0.07 per kilometer during non-peak and weekend daytimes, and CAD $0.04 per kilometer at nighttime (Shiller, 1998). Effective January 1, 2002, it costs a flat CAD $0.115 per kilometer (US $0.12 per mile) at all times, with an added CAD $2.65 (US $1.70) per trip processing charge for use without a transponder. Traffic volume has risen steadily since the road opened, and as it has been lengthened, and now stands at over 300,000 trips per weekday (407 International, 2002). When first opened, the highway operated without tolls for about four months, attracting a daily volume of about 300,000 vehicles to the open segment. When the tolls were first introduced, the traffic declined by over one third to less than 200,000 per day.

Intercity Congestion Pricing in France

Although this chapter is concerned with pricing strategies for urbanized areas, this example is interesting in that it focused on using pricing to spread the peak period of weekend non-work traffic. It also provides a straightforward example of a successful application of a variable toll schedule for congestion pricing purposes. In 1992, peak-period surcharges were introduced on Autoroute du Nord A1, which connects Paris with Lille, France. On Sunday afternoons, peak prices were set 25 to 50 percent higher than base rates and off-peak rates were reduced by 25 to 50 percent. The differential between the reduced rate and the surcharge rate varied between 10 francs (US $1.90) for the shortest trips and 26 francs (US $4.94) for the longest trips. The pricing schedule was designed to be and is very close to revenue neutral in the sense of not increasing average toll on what was already a toll road.

The toll structure caused traffic to spread out over a much longer peak period and decreased congestion, despite overall growth in weekend traffic since 1992. A comparison of traffic levels on the same 30 Sundays in years before and after variable toll implementation showed a 1.3 percent increase in total daily traffic, but a 4.4 to 8.2 percent decline in peak-period travel. About 20 percent of those traveling in the discount periods said they shifted trip timing in response to the change in tolls. Initially designated as an experiment, the Sunday variable pricing program has been extended, "given its public acceptance and apparent effectiveness in smoothing traffic flow" (Gomez-Ibanez and Small, 1994).

Lee County, Florida, Off-Peak Bridge Toll Discount

From 1980 to 1996, Lee County, Florida, experienced a population growth of 82 percent and now has a population approaching 400,000. Located in southwestern Florida, the county includes the cities of Fort Myers and Cape Coral. Fort Myers is an employment center and Cape Coral is more of a residential community. Separating the cities is the Caloosahatchee River, which most residents cross using either the Midpoint or Cape Coral toll bridges. Free alternatives over the river are US 41 and I-75, but both are north of the cities and not as convenient for most residents (Burris and Swenson, 1998).

In 1998, a demonstration program was implemented on both the Midpoint and Cape Coral bridges to encourage users to avoid crossing during the peak period. The bridges carry an average of 75,000 vehicles per day. The pre-existing toll structure encouraged frequent users to purchase a discount pass ($40.00 per year), offering a toll of $0.50 per crossing. The majority of users with discount passes were commuters who traveled during peak periods. Thus, planners faced the dilemma that peak-period users were paying the least to use the bridge, and getting them to shift trips from the peak without raising tolls would be difficult (Burris and Swenson, 1998; Center for Urban Transportation Research, 2000).

Planners decided to offer a 50 percent savings for traveling during specific discount periods focused on the shoulders of the peaks. The toll discounts were underwritten by a Federal grant and limited to participants in the LeeWay electronic toll account program. Approximately 25 percent of total bridge traffic became eligible for the variable pricing discount. Of the eligible travelers, 93 percent pay for the annual discount pass. Therefore, the vast majority of eligible users only save $0.25 by traveling in the discount periods (Cain, Burris and Pendyala, 2001).

Looking at the same six-month period before and after implementation, traffic volume data provided little evidence of any active peak spreading effects at the bridge and the basic patterns of the daily demand profiles remained unchanged. This is best explained by the fact that the number of commuters subject to the discount was small relative to the total number of vehicles crossing the spans. However, at the disaggregate level, among users eligible for the discount, positive shifts in demand were observed within all discount periods, and negative shifts in demand were observed during peak periods. The strongest response occurred in the morning at the Midpoint Bridge, where an 18 percent increase in eligible traffic was observed during the 6:30 to 7:00 AM discount period, associated with a 7 percent decrease during the non-discount period from 7:00 to 9:00 AM. In surveys, approximately 38 percent of eligible bridge travelers indicated that they had altered their travel since the program began to take advantage of the discounts, and 50 percent indicated they took the discounts into consideration when planning trips across the bridges. Of those modifying their travel, 84 percent changed their time of travel, 9 percent changed their route, and 6 percent changed their number of trips (Cain, Burris and Pendyala, 2001; Center for Urban Transportation Research, 2000).

Analyses of project data provide estimates of the responsiveness of traffic to the travel cost changes. Because there has been little travel time advantage gained from traveling during the off-peak period, the response likely represents the sensitivity to value pricing toll cost changes alone. The project researchers calculated demand sensitivities (characterized as "elasticities") on the basis of percent change in traffic during the relevant period divided by the percent change in toll cost (Federal Highway Administration, 2001a; Cain, Burris and Pendyala, 2001). These shrinkage-ratio-like sensitivities are shown in Table 14-5 for each of the bridges, along with corresponding log arc elasticities computed by the Handbook authors.

Table 14-5 Price Elasticities Observed in Lee County Demonstration Project

	Midpoint Bridge				Cape Coral Bridge			
Discount Period	**Percent Change in Price**	**Change in Demand**	**Elastici-ties per source** [a]	**Log Arc Elastici-ties**	**Percent Change in Price**	**Change in Demand**	**Elastici-ties per source** [a]	**Log Arc Elastici-ties**
Pre-AM peak	-50.0%	17.8%	-0.36	-0.24	-50.0%	10.0%	-0.20	-0.14
Post-AM peak	-50.0	5.6	-0.11	-0.08	-50.0	5.4	-0.11	-0.08
Pre-PM peak	-50.0	5.6	-0.11	-0.08	-50.0	5.4	-0.11	-0.08
Post PM peak	-50.0	2.7	-0.05	-0.04	-50.0	1.3	-0.03	-0.02

Note: [a] Percent change in traffic divided by the percent change in toll cost, a shrinkage-ratio-like measure.

Source: Cain, Burris and Pendyala (2001), with log arc elasticities computed by Handbook authors.

Seoul Congestion Charge on Namsan #1 and #3 Tunnels

Seoul, Korea, is one of the 20 largest cities in the world, with a population of 15 million. In 1996, its metropolitan government implemented congestion pricing on the downtown Namsan #1 and #3 tunnels (Federal Highway Administration, 1998b). Although only about 20 percent of daily trips in Seoul are by passenger car, the road system experiences heavy congestion. Other trips are by bus (32 percent), subway (29 percent), taxi (10 percent), and other modes (9 percent). The pricing approach placed a 2,000 won (US $1.50) toll on one and two occupant vehicles from 7 AM to 9 PM weekdays and from 7 AM to 3 PM on Saturdays. For the 20 years prior to this, the toll was 100 won (Son and Hwang, 2001).

The new pricing approach resulted in a significant change in tunnel traffic composition, and a 25 percent initial reduction in daily vehicular volume. Table 14-6 presents highlights from before and after measurements. Travelers reacted to the toll through mode choice, departure time, and route changes (Son and Hwang, 2001; Federal Highway Administration, 1998b).

Table 14-6 Traffic in Namsan Tunnels #1 and #3 Before and After Congestion Toll

Statistic	Nov. 1996 (Before)	Nov. 1996 (After)	Nov. 1997	Nov. 1998	Nov. 1999	Nov. 2000
Tunnel Performance						
All-day volume (vehicles)	90,404	67,912	78,078	80,784	87,886	94,494
Speed (km/h)	21.6	33.6	29.8	31.9	30.6	37.6
Traffic Composition						
Toll-charged vehicles [a]	29,358	16,260	16,964	14,691	14,807	15,370
Toll-free vehicles [a]	13,511	20,924	25,491	29,613	34,112	37,229
SOV, HOV 2 vehicles [b]	17,571	9,082	10,470	9,671	9,768	11,138
HOV 3+ vehicles [b]	1,057	2,792	2,598	2,589	2,151	1,840
Buses [a]	792	825 [c]	1,148	1,285	1,592	1,546
Bus Passengers [b]	11,131	n/a	15,146	19,537	20,235	19,566
Time of Traversal						
Vehicles just before (6-7 AM)	5,159	5,773	6,472	5,812	n/a	n/a
Vehicles just after (9–10 PM)	5,369	7,136	6,581	7,806	n/a	n/a
Alternate Routes [d]						
Volume	11,721	12,538	12,008	12,862	11,303	11,108
Speed (km/h)	24.5	27.4	30.0	27.6	28.9	31.6

Notes:
[a] Figures are for period 7 AM to 9 AM and 5 PM to 9 PM.
[b] Figures are for period 7 AM to 9 AM and 5 PM to 7 PM.
[c] Figure is for December 1996.
[d] Figures are for period 7 AM to 9 AM, 1 PM to 3 PM, and 5 PM to 9 PM.
n/a indicates data not available.

Source: Son and Hwang (2001).

Many motorists shifted to transit or HOV 3+ carpool alternatives to avoid the toll. In the first year, the peak period volumes of carpools and buses increased by 146 percent and 45 percent, respectively. In the 4 years following implementation, the peak period number of bus passengers increased over 75 percent, with an overall increase in number of persons carried through the tunnels of nearly 58 percent. Table 14-6 also shows modest changes in departure times and route choice resulting from the congestion toll. The larger volume change during the late evening period compared to that during the early morning period can be attributed to differing levels of flexibility in the start versus end time of working hours.

There are several alternative routes for the Namsan #1 and #3 tunnels, so there were some concerns about spillover congestion resulting from the congestion tolls. However, this did not materialize. Instead, the pricing incidentally better distributed traffic at signalized intersections, resulting in more efficient use of the transportation system. Average speeds on alternate routes actually went up. Four years after implementation, the traffic volume on these alternate routes is reported to be less than before the congestion toll was implemented (Son and Hwang, 2001; Federal Highway Administration, 1998b). Information on the possibility of external factors having influenced these results is unavailable.

The before and after data for the Namsan Tunnels may be used to estimate a price elasticity of demand for one and two passenger cars under the local conditions. Even though the elevated toll is applied from 7 AM to 9 PM, the data only allow elasticity computation for the combined 7 AM to 9 AM and 5 PM to 9 PM periods. The result, as computed by the Handbook authors, is a log arc price elasticity of -0.20.

New York and New Jersey Value Pricing

Several entities in New York and New Jersey have begun implementing peak-period pricing programs, including the New York State Thruway Authority, the New Jersey Turnpike Authority, and the Port Authority of New York and New Jersey. Most of these programs have only recently been introduced and so very few results are available. The Federal Highway Administration (FHWA) is funding a comprehensive evaluation of the New Jersey Turnpike and Port Authority programs. It is useful to review each of these efforts, as they are each likely to provide important value pricing lessons in the United States.

New York State Thruway Authority. The New York State Thruway Authority (NYSTA) is the operator of the 3.1 mile long Tappan Zee Bridge in Westchester County, over the Hudson River. It carries over 132,000 vehicles per day (New York State Thruway Authority, 2001). The nearest alternative river crossing is 17 miles to the south. In 1997, the Authority initiated a peak-period toll increase for trucks and undertook a study of similar peak-period pricing on the bridge for non-commercial vehicles (Adler, Ristau and Falzarano, 1999).

Although truck travel is generally outside the scope of this Handbook, it is instructive to note the Tappan Zee Bridge truck pricing response. The 1997 increase doubled tolls for trucks, from $10 to $20, except for those trucks using electronic toll payment and avoiding the peak period. A modest decrease in truck traffic was observed. A toll plaza survey indicated that improving outreach and achieving higher penetration of electronic toll payment among trucking companies would improve the results. Only 24 percent of cash-paying drivers were aware of the discount program and many said their management was responsible for acquisition of transponders. Some 27 percent of respondents said that they would have changed their travel time if they had known about the discounts and had the transponder (Tri-State Transportation Campaign, 1998).

The incentive pricing study incorporated a stated preference survey that suggested only 28 percent of automobile travelers had no flexibility in their travel time. Of the remainder, 17 percent could shift their trip either more than 30 minutes later or more than 30 minutes earlier. The survey indicated that many travelers would actively consider time-of-day shifts when peak-period prices increased (Adler, Ristau and Falzarano, 1999).

New Jersey Turnpike Authority. In September 2000, the New Jersey Turnpike Authority raised tolls on the Turnpike and implemented a variable pricing program. The new approach increased cash tolls for cars by 20 percent, and by 8 percent for E-ZPass holders that travel during the weekday peak hours of 7:00 to 9:00 AM or 4:30 to 6:00 PM, or on weekends. E-ZPass holders traveling during off-peak hours do not pay an increase (Parry, 2000).

Early results show that the toll changes have shifted traffic out of the peak period. Most of the recent growth in traffic on the Turnpike has been in the off-peak hours. Total traffic is up by around 7 percent, but morning peak and afternoon peak traffic is only up by 6 percent and 4 percent, respectively. The proportion of daily traffic accounted for by the morning peak dropped from 14.0 to 13.8 percent, and the afternoon peak's share of traffic dropped from 14.7 to 14.3 percent (Federal Highway Administration, 2001b).

In November 2001, the Garden State Parkway operator, the New Jersey Highway Authority, followed suit and made some movement toward adopting off-peak discounts for its E-ZPass users. However the amount of the discount is very small. The peak-period toll, collected at each of 11 toll plazas up and down the Parkway, is $0.33 versus $0.30 for discount off-peak travel (Tri-State Transportation Campaign, 2001). For an E-ZPass user traveling the 173-mile length of the Parkway, the total savings for off-peak travel would be $0.33. This small change is not expected to have a large effect on behavior.

Port Authority of New York and New Jersey. In March 2001, the Port Authority put into place a congestion-pricing system on its bridges and tunnels. About 350,000 vehicles use the six facilities each day, counting only the one direction in which tolls are collected, inbound toward New York City. Passage is free in the return direction. The new toll schedule gives a discounted toll to E-ZPass users of $5 during peak hours and $4 during off-peak hours, while applying a $6 rate at all hours to cash users. The toll changes are intended to speed traffic, spread out the peak traffic flow, and raise funds for capital needs (Smothers, 2001).

Two months after the toll change, preliminary statistics showed greater use of E-ZPass and transit cards and some increases in travel during off-peak hours. During a typical weekday in May 2001, 7 percent more motorists used the facilities between midnight and 6:00 AM as compared to a similar day in May 2000. Nearly half this increase was evident in the 5:00 to 6:00 AM hour. In addition, while traffic levels have remained relatively stable overall, traffic reductions were seen in the morning (7 percent) and evening peak periods (4 percent) (Federal Highway Administration, 2001b).

Response to Value Pricing on Single or Multiple Highway Lanes

This type of pricing applies toll charges to the use of specific highway lanes, typically lanes offering a premium service, during (or higher during) peak-traffic periods. In most applications, a free alternative is immediately adjacent, though it generally is operating with more congestion. Two high-profile variable pricing projects of this type are the I-15 Express Lanes in San Diego, a High Occupancy Toll (HOT) lanes project, and the SR 91 Express Lanes tollway in Orange County, California. This section examines these projects and a

HOT program on the HOV facility of Houston's Katy Freeway. Additional background and detail is given on the California projects in the Case Studies "I-15 Value Pricing Demonstration Project, San Diego" and "SR 91 Express Lanes, Orange County, California."

San Diego's I-15 "FasTrak" Express Lanes

Two barrier separated reversible lanes, approximately 8 miles in length, were built in the median of I-15 north of downtown San Diego in 1988. They were opened as peak period, peak direction HOV lanes with a two person (HOV 2+) occupancy requirement. The restricted Express Lanes operated with extra capacity, while the regular lanes were highly congested. Air quality concerns, among other issues, led to interest in converting the lanes to HOT lanes allowing HOV lane entry to single occupant vehicles for a fee (Spock, 1998). An added impetus was desire, on the part of an enroute community's representative, to fund bus service between the community and downtown San Diego.

A demonstration project was undertaken in 1996 with objectives that included testing of value pricing as a method of managing demand on the Express Lanes, funding expanded transit and ridesharing services in the corridor, mitigating congestion on the freeway, and enhancing regional air quality (San Diego Association of Governments, 1997). Pricing was introduced to the I-15 Express Lanes in two phases. The first phase, labeled ExpressPass, employed a monthly permit system allowing permit holders to use the lanes in addition to carpools, vanpools and buses, which have continued to have free use throughout. The second phase, dubbed FasTrak, introduced transponders and variable pricing (Hultgren and Kawada, 1999). The project is generally considered a success, attested to by State legislative approval for continued operation of FasTrak following the demonstration period (Supernak et al., 2001a; Federal Highway Administration, 2000a).

ExpressPass Phase. During the ExpressPass phase, customers paid a flat monthly fee for unlimited use of the HOV lanes. The program began with a low fee, which was increased as demand indicated. The monthly fee was first set at $50 in December 1996 when the first 500 permits were offered on a first-come, first-serve basis, all of which were sold. In February 1997, the fee was increased to $70. Although 115 individuals (16 percent) left the program at the time of the fee increase, there was no trouble finding willing replacement purchasers. A waiting list of 200 to 600 persons desiring permits was maintained during the entire ExpressPass phase (Hultgren and Kawada, 1999).

The preliminary assessment of the ExpressPass portion of the project showed a 12 percent increase in traffic throughput on the lanes in the first three months. The majority of the gains, however, came from new carpools rather than single occupant vehicles. The violation rate for single occupancy vehicles dropped by 85 percent. The weekday traffic composition before ExpressPass was 7,900 HOVs (85 percent) and 1,400 single occupant vehicles (SOVs) illegally using the facility (15 percent). After the ExpressPass program implementation, 9,300 HOVs (88 percent), 1,025 SOV permit users (10 percent), and 200 illegal SOVs (2 percent) used the facility daily (San Diego Association of Governments, 1997; Federal Highway Administration, 1998c).

Reduction in HOV violations throughout the course of the project has been attributed to increased enforcement paid for by the permit fees (Federal Highway Administration, 2000a). An added factor could well be the availability, which did not previously exist, of a legal SOV option for using the lanes.

Theories have been offered as to why there was an increase in HOV use accompanying the introduction of the pricing program. One explanation is that the increase in carpooling was caused by drivers getting, as a result of the pricing program, a more tangible sense of the cost savings offered by carpooling. Another is that the increased enforcement encouraged drivers to join carpools more than to pay to drive in the lanes. A third explanation is that people were more willing to commit to carpools because they knew they could still occasionally obtain time savings without a passenger by buying into the lanes through a permit purchase (Federal Highway Administration, 2000a). The third explanation meshes with the observation that some 45 percent of the permits were used on a periodic or infrequent basis (Hultgren, Kawada and Lawrence, 1998), but still seems hard to reconcile with the non-availability of a daily permit during the ExpressPass phase.

FasTrak Phase. After a transition period, the FasTrak phase began in April 1998. In this phase, variable, electronically collected fees for single occupancy vehicle use of the HOV lanes were tested. The fee was and is related to the quality of traffic flow in the HOV lanes, recalculated every six minutes to maintain Level of Service (LOS) C or better, with a refinement instituted in late 1998 emphasizing shoulder-of-the-peak discounting relative to the peak-of-the-peak. The toll may thus be different at the same time on different days, and is displayed prior to the point where a motorist must decide between using the premium lanes or the free general lanes. The toll generally changes in $0.25 increments and, under normal traffic conditions, ranges from $0.50 to $4.00. Under the demonstration project protocol, the toll did not exceed preset maximums for any time period except during severe congestion, in which case it could go as high as $8.00 before the lanes were closed to non-HOV traffic (Hultgren, Kawada and Lawrence, 1998; Supernak et al., 2001a).

The FasTrak pricing structure made it much easier and more economical to be an occasional paid SOV user than with the monthly ExpressPass. The usage rate per month per customer dropped to where 53 percent bought their way onto the lane only one to five times per *month*. Survey and focus group results indicated that some registrants use the lanes on a very selective basis, in response to personal needs, traffic levels and other influences. Nevertheless, even by the end of 1988, use of the Express Lanes was well over 30 percent above pre-demonstration volumes (Hultgren, Kawada and Lawrence, 1998; Schumacher, 1999; Kawada, 1998; Hultgren and Kawada, 1999).

The FasTrak program increased the number of single occupant vehicles (and therefore total vehicles) making use of the special lanes with what appeared to be only minor influence, if any, on the number of Express Lane HOV users. During the ExpressPass phase, Express Lane HOV volumes had increased even after the initial jump, and despite a slight decline during FasTrak, they remained higher than both before and after the start of the project. HOV usage of the general purpose lanes, for no clear reason, declined throughout the project (Supernak et al., 2001a). Table 14-7 shows the change in Express Lane traffic composition from March 1998, just before FasTrak implementation, to February 1999.

The I-15 project appears to have succeeded in making better use of the existing capacity while maintaining free-flow traffic conditions on the HOV lanes through pricing and the FasTrak use of dynamic pricing. It also generates $1.2 million in annual revenues, about one-half of which is used to support transit service in the corridor. Daily traffic volumes on the lanes have grown to 16,900 as of February 2000, about 20 percent of which are FasTrak users (Federal Highway Administration, 2001a). That total may include violators. Further project details and results, as already noted, are provided under "Case Studies" — "I-15 Value Pricing Demonstration Project, San Diego."

Table 14-7 Trends in I-15 Express Lanes Weekday Traffic Composition During FasTrak Implementation

User Type	March 1998	August 1998	September 1998	February 1999
Paid SOV vehicles	910	1,701	2,272	3,102
HOV vehicles	10,790	10,785	10,629	10,652
Total vehicles	11,700	12,557	12,990	13,838

Notes: FasTrak implemented at the beginning of April 1998. Shoulders-of-the-peak toll reduction at the beginning of September 1998. Violators appear to be wrapped into the HOV volumes.

Source: Hultgren and Kawada (1999).

SR 91 Express Lanes in Orange County, California

The SR 91 Express Lanes (91X) are ten miles of privately financed four-lane divided express highway built in the median of the Riverside Freeway (SR 91) in Orange County, California. The 91X toll lanes opened December 27, 1995, and feature pricing that varies by time of day and day of week according to a published schedule. The 91X lanes give motorists on the congested parallel roadway the option to pay to use dedicated lanes that normally provide a faster trip. In addition, HOV 3+ users can use the 91X lanes at a 50 percent discount (originally for free). There are no on or off ramps on the express facility (Sullivan, 1998).

The toll schedule has been adjusted and has become more complex over time. Since the 91X toll collection system is fully automated, the tolls can be readily varied throughout the day. The private operator, who sets the tolls, has done so in response to demand. As of 2001, 16 different toll amounts were charged based on time of day and day of week. The Eastbound toll at 6:00 PM, for example, was different each weekday. The 2001 tolls ranged from $1.00 off-peak, to a high of $4.75 during the evening peak (Sullivan, 1998; California Private Transportation Company, 2001). The operator decided to use a published schedule rather than a dynamic, congestion-based toll because of market research indicating that drivers would prefer the predictable tolls (Spock, 1998). A subscription discount pass became available in January 1997 that reduces the total tolls for persons making more than 25 express lane trips per month, but a survey in June 1997 showed only 5 percent of peak period users had signed up for it (Sullivan, 1998).

The opening of the 91X lanes provided additional capacity in the corridor and resulted in a lessening of congestion on the free lanes as well as a minimization of delays for users of the express facility. Typical peak-hour delays on the original lanes fell from over thirty minutes to less than ten minutes (Small, 2001).

Roadside counts during the period of free passage for HOV 3+ vehicles showed a 40 percent increase in the number of carpools and vanpools in the corridor (toll lanes and general purpose lanes) from before the opening of the toll road to June 1997. SOV use increased at a greater rate, however, as a result of both occupancy shifts among SR 91 travelers and SOV diversion from local streets. This produced an initial decline in the average vehicle occupancy of the free and toll lanes together (Sullivan, 1998), which has not been reversed (Sullivan, 2002). Further information on the mode shifts in the corridor is provided under

"Related Information and Impacts" — "Travel Mode Impacts and Shifts" — "SR 91 Express Lanes in Orange County, California." When HOV 3+ vehicles began to be charged a 50 percent toll, there was some movement of HOVs between the toll and free roadways, but no change in overall corridor HOV use. Both HOV 2 and HOV 3+ vehicles are more likely to choose the 91X toll lanes than are SOVs (Sullivan, 2002).

Survey results indicate travelers are very selective about using the SR 91 toll lanes. In June 1997, nearly 90 percent of peak-period travelers in the corridor had FasTrak transponders. Almost 80 percent of these obtained their transponders during the first six months of operation. Although most commuters were thus equipped to use the lanes, most did not do so every day. Nearly half of toll lane users drove the lanes once per week or less (Sullivan, 1998). Only one third of commuters used the express lanes on a daily basis (Spock, 1998). Over time, the proportion of commuters reporting use of the 91X lanes has generally increased (28 percent in 1996, 42 percent in 1999), but among users, the proportion doing so for half or more of their peak trips has declined (Sullivan, 2002).

The frequency of toll lane use is related to, among other things, congestion levels, trip length, and income. The majority of travelers in 1996 indicated choosing to use the express lanes to save time on their commute. Some 45 percent of users said that time savings were the only reason for using the lanes. Travelers with long commutes of 60 to 90 minutes used the toll lanes for a greater proportion of their trips (30 percent) than did travelers with short commutes of up to 30 minutes (20 percent) (Sullivan, 1998).

Users from all income groups regularly make use of the facility, but it is clearly more readily selected as the route of choice by higher-income travelers. Some 70 percent of lower income travelers in the corridor report not having the transponders enabling usage of the 91X toll lanes. Commuters in the high income group (more than $100,000 annual household income) were two-and-one-half times as likely as commuters in the lower income group (less than $40,000 annual household income) to have used the 91X toll lanes for their most recent SR 91 corridor trip in 1996, or to have used a toll facility (91X or the new Eastern Toll Road) for their most recent comparable trip in 1999. Nevertheless, roughly 20 percent of the lowest income travelers had chosen a tolled route for their most recent trip in both years.

The highly selective use by commuters affects peaking patterns but does not diminish the importance of the SR 91 Express Lanes to corridor carrying capacity. On one hand, the 91X tolled express lanes have half as many lanes as the mixed traffic regular lanes (33 percent of the total) and carried only 14 percent of daily traffic at their highest volumes recorded during evaluation, in September 1998. On the other hand, in peak periods, 91X carries 33 percent of the vehicular traffic — its proportional share, or the same volume per lane as the regular lanes. Moreover, the 91X lanes carry this same peak period volume per lane at free flow speeds, without congestion, while the regular lanes are running at 30 mph or less.[4] In terms of peaking, the regular lanes carry 12 to 15 percent of their daily traffic in the 4-hour PM peak. Use of 91X is much more sharply peaked, with about 40 percent of daily traffic occurring during 4-hour PM peak (Sullivan, 2000).

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[4] The ability of the SR 91X lanes to carry equal volume without congestion presumably results from the deterrence of variable tolls having kept express lane volumes from pushing traffic density out of the realm of stable (and highly efficient) traffic flow. Conversely, unpriced regular lane traffic demand may be presumed to have elevated the traffic density past the critical point and into the inefficient and delay-producing realm of unstable traffic flow where congestion results in both reduced speeds and reduced capacity to carry traffic.

As previously noted, additional information is provided under "Case Studies" — "SR 91 Express Lanes, Orange County, California." Price elasticities have been estimated for 91X and the SR 91 corridor that range from effectively zero elasticity to borderline elastic (vicinity of -1.0). These are presented from different perspectives in the case study and in the "User Cost" discussion of the "Underlying Traveler Response Factors" section.

Houston's I-10W Katy Freeway QuickRide Program

The I-10W Katy Freeway HOV facility in Houston is a one-lane, barrier separated, reversible lane located in the freeway median. The facility was opened in stages between 1984 and 1990, and is now 13 miles in length. The vehicle occupancy requirement on the lane was gradually liberalized, stabilizing in 1986 at buses, vanpools, and 2+ carpools. However, in October 1988, a 3+ occupancy requirement was reinstated for the peak of the peak period in response to high volumes and a corresponding decline in speeds and travel time reliability. By late 1991, after fine tuning, the HOV 3+ requirement applied from 6:45 to 8:00 AM and from 5:00 to 6:00 PM.

The I-10W Katy Freeway HOV lane facility is the only HOV lane in the country that uses occupancy requirements that vary by hour (Stockton, McFarland and Ogden, 1998). For more specifics on the lane's eligibility requirements, refer to Chapter 2, "HOV Facilities," under "Traveler Response by Type of HOV Application" — "Response to Changes in Vehicle Occupancy Requirements" — "Katy (I-10W) HOV Lane, Houston." Additional background on the overall I-10W HOV facility is found in the same "Traveler Response by Type of HOV Application" section under "Response to Exclusive HOV Lanes" — "Houston HOV Lanes," and in the "Houston HOV System" case study, also in Chapter 2.

The reinstated HOV 3+ restriction resulted in excess lane capacity, and as traffic on the regular lanes of the facility worsened, pricing was considered as a way of making more effective use of the HOV facility. A demonstration project was implemented in January 1998 that allowed a limited number of two person carpools to use the HOV lane for a fee during the HOV 3+ restricted hours. The system uses electronic toll collection and charges a $2.00 fee for each HOV 2 trip allowed (Shin and Hickman, 1999a).

In little more than a year, 650 transponders were issued and between 150 and 200 tolled trips were made on the facility daily during both peak periods combined. Most people only use the facility occasionally. About 25 percent of the registered *QuickRide* participants used their tag on a given day and only 6.5 percent of enrolled tags produced five or more trips per week (out of a maximum of ten). Six months into the program, approximately 25 percent of the registered tags had never been used at all, but many of these (40 percent) were second tags owned by a single household. Original concerns that the number of potential *QuickRide* participants might need to be capped at 600 were not borne out as a result of the low number of trips per registrant. While it may be inappropriate to draw strong conclusions from a low-key demonstration without strong marketing, it appears that many enrollees view having an electronic tag as insurance for the occasional need and opportunity to ensure a quick trip (Stockton, McFarland and Ogden, 1998; Stockton and Smith, 1998; Shin and Hickman, 1999a and b; Federal Highway Administration, 2000b).

Morning *QuickRide* usage is heavier than evening usage and it builds during the week, with the lightest usage on Mondays, and the heaviest usage on Thursdays and Fridays. Complex travel changes among *QuickRide* participants, involving time, spatial and mode shifts, are outlined under "Related Information and Impacts" — "Travel Mode Impacts and Shifts" —

"Houston's I-10W Katy Freeway QuickRide Program." *QuickRide* appears to have had some effect in encouraging carpools, but the small number of users has caused observed changes in person throughput to be statistically insignificant and rendered its effect on congestion in the corridor negligible (Shin and Hickman, 1999a). The program continues and consideration has been given to expanding the scope to include other HOV facilities in the area (Federal Highway Administration, 2000b).

Response to Vehicle Use Pricing Programs

A number of innovative value pricing programs are being implemented that do not fit within the toll system classifications above. Each of these programs seeks to convert fixed vehicle costs to variable usage costs. Each thereby holds promise as a travel demand management strategy to reduce vehicle miles traveled. Addressed in this section are a pay-by-the-mile insurance project in Houston, and car sharing projects in Switzerland, Portland, Oregon, and San Francisco.

Variable Insurance

Insurance costs represent about 20 percent of the vehicle expenses associated with operating an automobile in the U.S. on average (Litman, 2001). Although crash risk is related to miles driven, traditional insurance policies currently employ very little variation in rates relative to this metric. Low mileage drivers in effect subsidize the coverage of high mileage drivers in many situations.

In 1998, the Progressive insurance company conducted a pilot project in Houston, Texas, called Autograph. The system used GPS units in cars to track the time, speed and location of miles driven as the basis for calculating insurance billings. Although there was still a fixed component to the insurance cost, the variable component encouraged participants to reduce their mileage more than 13 percent. They thereby saved on insurance relative to conventional pricing (Litman, 2001).

Progressive's pilot project proved the technology could work and that consumers would accept the idea, at least as an opt-in program. However, no real-time "before" data was available for customers of the program, thus its full impact on driving patterns is not known. Further pricing experiments starting with baseline data to facilitate before and after analyses will be required in order to more reliably examine impacts on travel behavior, including trip making by time of day.

Additional approaches considered for possible testing include provision of insurance savings for lowering crash exposure not only by reducing vehicle miles traveled, but also by reducing driving during congested periods, avoiding unsafe driving behavior, and cutting down on driving in dangerous corridors and at risky times. Means considered for transmitting the savings range from pay-as-you-drive insurance to use of payments or fixed premium refunds based on preferred driving performance as measured in practice (Federal Highway Administration, 2001b). The objective shaping such approaches is to make insurance usage-and-performance-based so that the insured parties have the option to reduce overall, peak-period, or unsafe driving to save on insurance costs, and thereby contribute less to congestion and accidents.

Car Sharing

Car sharing is the term that has been given to automated hourly or mileage-based neighborhood car rentals that can provide a substitute for car ownership. It has been estimated that over 70 percent of the costs of driving a privately owned auto in the United States are fixed (Litman, 2001). Once a person has a car, therefore, there is little incentive not to use it heavily. The presence of car sharing options in a transportation system may reduce the need for car ownership. Moreover, car sharing, as a pay as you go mobility option, converts transportation costs from mostly fixed to mostly variable. Therefore, car sharing could also encourage individuals to reduce their driving, since they would incur costs according to their usage. There is even a built-in congestion charge in that car sharing pricing schemes tend to incorporate a time component, which results in increased user cost for driving in congestion.

Europe has several car sharing operations in place and growing. Mobility CarSharing Switzerland, for example, had 1,700 cars in 900 locations serving 350 communities and 43,000 customers as of October 15, 2001 (Mobility CarSharing, 2001). Asian and North American car sharing activities are more limited, but several cities have car sharing franchises, including Singapore, Montreal, Vancouver, Boston, Portland, San Francisco, and Seattle. Former car owners in Switzerland who became Mobility CarSharing customers reduced their annual miles driven by 72 percent. To meet their travel needs, they use public transportation, bicycling or motorcycling more frequently than before, and they also travel less overall. In general, they have been observed to adopt the same travel behavior as Mobility CarSharing customers who did not own a car before joining the organization. Also, clients who participate longer drive less than new clients, possibly because the transparency of the cost of using a car versus other modes leads participants to constantly search for less expensive transportation alternatives (Muheim, 1998).

Whether car sharing will influence travel behavior on a large scale is unknown. While most studies indicate reductions in per capita driving similar to those reported from Switzerland, typically in the range of 40 to 60 percent, car sharing tends to attract users who are already relatively low mileage drivers. Total travel reductions thus tend to be small (Victoria Transport Policy Institute, 2002a). FHWA's Value Pricing Pilot Program is funding an extensive evaluation of the car sharing program in San Francisco over the next two years to learn more (Federal Highway Administration, 2001b). The San Francisco program charges around $2.50 per hour and $0.45 per mile for rentals, insurance and gasoline included. Rentals can usually be arranged as late as one hour in advance. Vehicle reservations and pickups are handled through automated processes (City Car Share, 2001).

UNDERLYING TRAVELER RESPONSE FACTORS

Value pricing can affect — in the short term — many dimensions of traveler behavior, including selection of route, mode and time-of-day of travel, and choice of personal activity and destination location (Mastako et al., 2002). Over the long term, it can influence auto ownership, residential and employment location, and land use patterns (Deakin et al., 1996). Although most existing transportation models are not capable of addressing the influence of pricing along all of these dimensions, an understanding of the underlying response factors is nevertheless emerging. Research efforts in this area center on identifying the different formulations and choice sets for modeling priced auto travel environments and on estimating income-stratified variable coefficients for research and forecasting models incorporating pricing (Mastako et al., 2002; Deakin et al., 1996).

For priced alternatives in general and for toll lanes in particular, especially where free options exist, the value that travelers place on time is a critical factor in determining the usage (Urban Transportation Monitor, 2000). In the context of areawide, corridor or facility pricing, the user normally gains reduced or more reliable travel times in return for paying the usage fee. In the context of variable insurance and car sharing, some or all of the cost of driving gets converted into a variable cost, which may then be bought into or avoided according to user desires and needs. In the toll lanes context, if the value of the time savings offered by the priced option is greater than its cost, then a user is more likely to choose to use the priced option. The overall cost of passage, anticipated time savings and reliability, trip purpose, demographics and alternatives available all influence the decision to use a priced option or to travel at all when tolls or variable costs must be paid. These factors are the focus of this section. "Travel Mode Impacts and Shifts" are covered, under that subheading, in the "Related Information and Impacts" section which follows.

User Cost

The behavioral options listed at the start of this section allow travel to be responsive to price, and the empirical evidence shows that there is indeed such a response. Even the most rigidly constrained employee has some freedom to modify his or her conditions of travel to avoid an unacceptable toll. There is a significant spread of price elasticities available from analysis of both value-priced highway facilities and conventionally tolled facilities — though most are well within the inelastic range — reflecting different degrees of response among subgroups, transportation system context, and related socioeconomic and locational circumstances (Harvey, 1994).

Tables 14-8 and 14-9 list price elasticities and similar cost sensitivities derived empirically from instances where conventionally priced toll roads have had their tolls increased. The findings in Table 14-8 cover both toll bridges and roads, and are accompanied by identification of key accompanying behavioral responses. Table 14-9 provides additional values for toll bridges, tunnels and roads.

Table 14-8 Automobile Price Elasticity Experience for Conventional Toll Increases

Type of Price Change (Date)	Accompanying Behavioral Responses	Demand Elasticity
Golden Gate Bridge toll increase from $2.00 to $3.00 (1992)	Some diversion to bus and ferry, and a residual net decline in corridor trips	-0.15
San Francisco Bay Bridge toll increase from $0.75 to $1.00 (date n/a)	No discernable long-run effect — small drop seen in time series daily volumes	Smaller than -0.05
Everett Turnpike (NH) toll increase from about $0.04 to $0.08/mi. (1988)	Significant diversion to convenient parallel arterials (rural)	-0.1

Source: Harvey (1994); dates from Wilbur Smith Associates (2000).

Table 14-9 1988-1992 Conventional Toll Increase Effects, Expressed as Shrinkage Ratios

Location	Area and Facility Type	Competition	Traffic Loss	Normal Growth	Net Impact	Toll Increase	Sensitivity
Triborough Bridge and Tunnel Authority (New York City)							
Triborough Bridge							
Bronx Plaza	Urban bridge	Low	-4.7%	-2.0%	-2.7%	22.1%	-0.122
Manhattan	Urban bridge	Medium	-5.6	-1.0	-4.6	22.1	-0.028
Bronx-Whitestone	Urban bridge	Low	-2.2	-0.5	-1.7	22.1	-0.077
Throgs Neck	Urban bridge	Low	-3.2	-1.3	-1.9	22.1	-0.086
Henry Hudson	Urban bridge	Medium	-2.1	1.7	-3.8	22.1	-0.172
Queens Midtown	Urban tunnel	High	-5.2	-1.2	-4.0	22.1	-0.181
Brooklyn Battery	Urban tunnel	High	-2.9	—	-2.9	22.1	-0.131
Verrazano-Narrows	Urban bridge	Low	-1.7	-0.5	-1.2	22.1	-0.054
Marine Parkway	Urban bridge	Medium	-2.1	2.5	-4.6	22.1	-0.206
Cross Bay	Urban bridge	Medium	0.8	5.0	-4.2	22.1	-0.190
Massachusetts Turnpike							
Initial Turnpike	123 mi. rural	Low	-3.2%	1.0%	-4.2%	34.0%	-0.124
Boston Extension	11 mi. urban	Medium	-4.9	1.0	-5.9	41.0	-0.144
New Jersey Turnpike	122 mi. rural and urban	Medium	-5.7	1.6	-7.3	70.0	-0.104
Richmond, VA Expressways	6 mi. urban/ suburban	Medium/ High	-1.7	4.0	-5.7	16.7	-0.341

Notes: Calculated using annual data for toll transactions and estimated normal growth.

The sensitivity values, reported in the source as "elasticities," were calculated as percent change in transactions divided by percent change in toll, a shrinkage-ratio-like measure.

Only passenger car toll findings are shown for the Massachusetts and New Jersey Turnpikes. All other findings are for passenger cars and commercial vehicles combined.

Source: Wilbur Smith Associates (2000).

Available evidence indicates that the value to a potential user of a priced highway option is normally based heavily, although not exclusively, on the time savings it offers (Sullivan, 1998). It is this value that the potential user must balance against the price in making the choice to use or not use. Most toll adjustments on variable-priced facilities have been focused on creating the proper threshold level to ensure smooth-flowing traffic. This requires the price to be high enough to make the lanes or restricted area not so attractive as to become clogged, but low enough so as to not forgo revenue or face political ramifications as a result of overly-reduced usage, giving rise to underutilized capacity and seeming "exclusivity" of the tolled facility.

Table 14-10 summarizes and categorizes the various road value pricing (and conventional toll pricing) elasticities already presented in this chapter. To allow more accurate comparison, log arc elasticities (or mid-point arc elasticities where already available) are provided where possible. In some cases the original manner of "elasticity" computation is not known and the information is not available for a log arc elasticity to be computed. These cases are footnoted.

Table 14-10 Summary of Road Value Pricing and Conventional Toll Pricing Log Arc Price Elasticities

Category/Instance	Notes/Observations	Source Value Range	Log Arc Elasticity Range	Log Arc Elasticity Median
Areawide Pricing in Singapore Central Area	First introduction of pricing (all central area drivers affected)	-2.95 [a]	-2.95 [a]	-2.95 [a]
	Toll raised (only drivers already choosing to be tolled affected)	-0.33 [a]	-0.33 [a]	-0.33 [a]
Partial Cordon Pricing (bridges) in Lee County	Shoulders-of-peak-toll reduced (previously tolled drivers affected)	-0.03 to -0.36	-0.02 to -0.24	-0.08
Variable Pricing on CA SR 91 Express Lanes	Estimated using 3 research models (all corridor drivers sampled)	-0.72 to -0.90	-0.79 to -0.99	-0.82
	Toll raised (only drivers already choosing to be tolled affected)	Zero to -0.5	— [b]	— [b]
Congestion Charge on Namsan Tunnels, Seoul	7 AM to 9 PM (drivers affected previously paid a very small toll)	—	-0.20	-0.20
Principal San Francisco Bay Area Bridges	Conventional tolls raised (previously tolled drivers affected)	<-0.05 to -0.15	— [c]	— [c]
New York City Bridges and Tunnels	Conventional tolls raised (previously tolled drivers affected)	-0.05 to -0.21	-0.06 to -0.24	-0.15 or -0.17
Rural, Suburban, and Urban U.S. Toll Roads	Conventional tolls raised (previously tolled drivers affected)	-0.1 to -0.34	— [d] to -0.38	-0.15

Notes:

[a] Mid-point arc elasticity. These values and the elasticity from the Namsan Tunnels, Seoul, Korea, constitute non-domestic examples. See text for related discussion of Singapore case.

[b] Method of source elasticity value computation unknown. Reported sensitivities to three roughly equal toll increases were -0.4 to -0.5 for the first, and indiscernible impact (essentially zero elasticity) for the second and third, an average of -0.15.

[c] Method of source elasticity value computation unknown. The average of the two reported sensitivities, the least being smaller than -0.05, is smaller than -0.1.

[d] Method of source elasticity value computation unknown, but the low end of the range expressed as a log arc elasticity must lie between -0.1 and -0.14.

Sources: Watson and Holland (1978); Cain, Burris and Pendyala (2001); Yan, Small and Sullivan (2002); Parsons Brinckerhoff, Hunt and Sullivan (2000); Son and Hwang (2001); Harvey (1994); and Wilbur Smith Associates (2000); with log arc elasticities computed by Handbook authors.

The log arc price elasticities presented in Table 14-10 for increasing conventional tolls range from -0.06 to -0.38. This result is comparable to modeling work findings that have suggested road pricing elasticities of "about -0.10 to -0.15 at the low end to -0.30 to -0.40 at the high end depending on the charge, the current costs of travel and the capacity of alternative roads and transit systems" (Bhatt, 1994).

When all instances in Table 14-10 of changing *pre-existing* toll rates are included — conventional and value pricing, and increases and decreases, but excluding the first introduction of Singapore pricing and the California SR 91 model results — the elasticity range expands. It becomes zero to approximately -0.5. Even though broader, however, the range remains centered on the results of conventional toll increases and stays solidly in the inelastic domain. It also forms a tighter range than exhibited by price elasticities for transit fare changes. Transit fare elasticities, admittedly from a much larger number of observations, range from nil to on the order of -1.0 (see Chapter 12, "Transit Pricing and Fares").

There are two outliers in Table 14-10. One is the mid-point arc elasticity of -2.95 for initial introduction in 1975 of Singapore's morning peak period areawide pricing for the central area. The other is the set of log arc elasticities, spanning from -0.79 to -0.99, developed from travel behavior models of Orange County, California, SR 91 corridor travelers — toll lane users and non-users alike, for peak period travel. Neither of these instances are based on response to rate changes applied to a pre-existing toll or value pricing system. Both represent substantial pricing relative to the available alternatives, a free HOV 4+ carpooling option and extensive, cheap public transit in Singapore, and the parallel freeway lanes alternative in the California SR 91 corridor. In the Singapore instance, the newly imposed monthly fee was also equivalent to almost 5 percent of the average monthly income of car-owning households, a far higher proportion than could conceivably be encountered in North American applications.

The two outliers are from such disparate environments and analytical approaches that not too much should be made of them. Still, it is provocative that both are examinations of the actual (Singapore) or estimated (SR 91) response of total peak period populations in a travel market, as compared to populations that have been pre-screened by their willingness to pay a not insubstantial previous toll. Further research might show there are two road pricing elasticity modalities, one — solidly inelastic — that pertains to toll-paying populations subjected to a *change* in the toll, and another — approaching elastic response — that pertains to the willingness of the traveling public at large to incur toll costs at all when there are free or comparatively cheap alternatives. There is a possible alternative explanation — at least in part — for the SR 91 findings, however, which is that they are based on revealed preference disaggregate travel data and modeling as compared to representing aggregate demand elasticity, the case with the rest of the elasticity estimates found in Table 14-10.

The Leeway project in Florida is an example of previously tolled travelers introduced to a value pricing toll adjustment. The demonstration offered an opportunity to observe the importance of cost savings as a fairly isolated traveler response factor. The Leeway bridges are basically uncongested during the peak period as well as during the off-peak. Therefore, any observed change in traveler behavior is more easily attributable to the change in pricing on the facility. As was discussed earlier in this chapter, the monetary incentive was only 25 cents for most participants, a small discount in absolute terms. Nevertheless, significant changes in behavior were observed (Cain, Burris and Pendyala, 2001). Price elasticities varied more by time of day than between the two bridges involved (see Table 14-5), ranging from log arc elasticities of -0.02 in the post-PM-peak-hour shoulder of the peak (Cape Coral Bridge) to -0.24 in the pre-AM-peak-hour shoulder (Midpoint Bridge).

A 1999 telephone survey of Leeway demonstration participants explored their motives and travel responses. As detailed earlier under "Response by Type of Strategy" — "Response to Value Pricing on a Single Highway Facility, Route or Corridor" — "Lee County, Florida, Off-Peak Bridge Toll Discount," saving money was their primary reason for participating in the variable pricing demonstration program. Shifting travel times was the most obvious and most frequently chosen means of saving money, as reasonable travel alternatives to use of the Leeway bridges are limited. A few participants reported changing their route or number of trips (Center for Urban Transportation Research, 2000; Cain, Burris and Pendyala, 2001).

The Orange County, California SR 91 Express Lanes research has produced estimates that speak directly to the choice between the priced facility and other options. Based on modeled responses to sensitivity tests of uniform percentage toll changes, as further described under "Case Studies" — "SR 91 Express Lanes, Orange County, California," the *approximated* point elasticity to price for using the SR 91 facility during the 3-hour period of heaviest use in each direction was in the range of -0.7 to -0.9 for the three alternative model structures tested and the two directions of travel (Yan, Small and Sullivan, 2002), equating to log arc elasticities of -0.8 to -1.0. For the peak one hour, price elasticities roughly -0.2 greater than for the 3-hour peaks were observed (Sullivan, 2002).

Additional sensitivity test evaluations demonstrated that these high sensitivity estimates, nearing an elastic response, reflect primarily route choice response to toll changes. When the amount of mode shifting amongst different auto occupancy levels was examined, the log arc price elasticity for SOV vehicles in the corridor was a rock bottom -0.01. The comparable elasticity for HOV 3+ vehicles was +0.06 to +0.08 (indicating an increase in HOV 3+ vehicles with increased tolls), still fairly low. Bus and commuter rail options in the SR 91 corridor attract less than one percent mode share each, and were not modeled. Corridor time of day sensitivities were estimated to be similarly muted, with log arc price elasticities for peak hour travel of -0.05 to -0.08 (Yan, Small and Sullivan, 2002; arc elasticity conversions by the Handbook authors). The primary agent in SR 91 Express Lanes price elasticity appears to be choice of route, with very modest contributions by choice of mode and time of day to travel.

The impact on subgroups of users may vary, but the SR 91 observations and research suggest considerable price sensitivity when a free, parallel alternative is available. The price sensitivity would seem closely tied to driver selectivity in their use of value-priced facilities. While the proportion of commuters using the SR 91 Express Lanes has generally increased over time, the proportion who use it for half or more of their peak trips, never particularly high, has actually decreased (Sullivan, 2002).

Both the SR 91 and I-15 projects feature a parallel free roadway as an alternative to the tolled lanes. It has been argued that the success of these facilities depends on the presence of congestion. Indeed, the SR 91 concession agreement included a non-compete clause that restricted the State's ability to build additional capacity in the corridor (Small, 2001). The congestion allows the toll schedule to be set high enough to generate significant revenues while restricting use of the tollway to maintain a service level advantage over the free lanes.

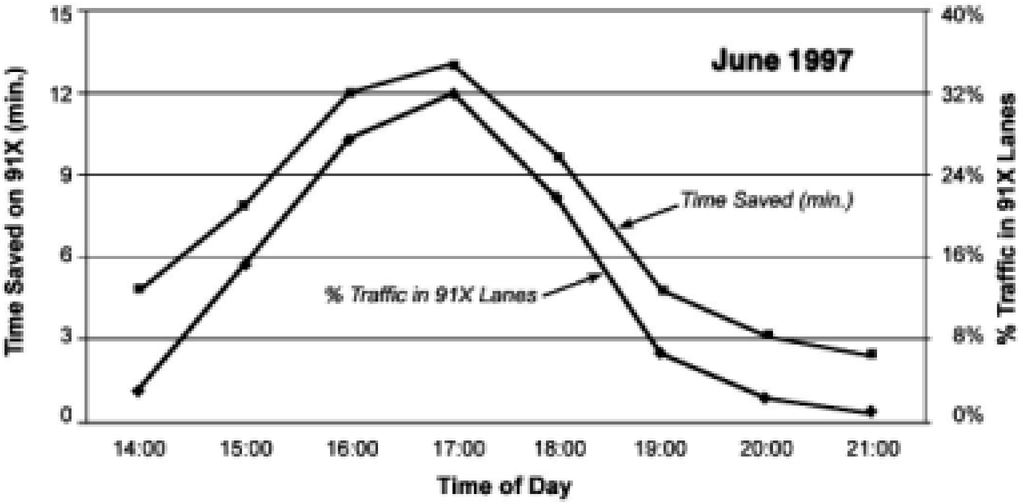
Travel Time Savings

Travelers, at least in the case of value-priced highway lanes, have been found to be very selective about using value-priced options. The Orange County, California, SR 91 Express Lanes investigations provide evidence that at any given time of day the likelihood and frequency of use is closely related to perceived travel time savings (Sullivan, 2002). Figure 14-1 illustrates the relationship between choice of the lanes and the actual travel time savings offered.

Although travelers appear to accurately judge the relative magnitude of their travel time savings, they typically overestimate the actual absolute time savings. Numerous examples are given in Chapter 2, "HOV Facilities," within that chapter's "Underlying Traveler Response Factors" — "Travel Time Savings" — "HOV Lanes" discussion. In the case of the SR 91 Express Lanes, the overestimation is generally larger than reported for HOV lanes, namely, in amounts concentrated between 5 and 30 minutes of overestimation. The magnitudes of perceived time savings increased between 1996 and 1999 (Sullivan, 2002).

Some researchers have wondered if HOV and HOT lane user overestimation of travel time savings relates to reliability. Support comes from San Diego I-15 FasTrak findings. In the Fall of 1999, FasTrak users estimated their time savings on the Express Lanes at 16 and 22 minutes for the AM and PM peaks, respectively. On the one hand, relative to average actual conditions, this was another overestimate. On the other hand, the I-15 demonstration project team estimated, based on comprehensive Fall of 1999 speed and delay field observations and analysis, that — on average — twice a year total ramp and on-line delays of 14.7 and 20.2 minutes could be expected, AM and PM respectively, on the general purpose lanes (Supernak et al., 2001b). These worst case delays closely match the user estimates of their time savings.

Figure 14-1. SR-91 Express Lanes (91X) time savings versus relative use by hour



Source: Sullivan (2002).

Values placed on time have been estimated for users of value-priced facilities. The already discussed SR 91 corridor research models have been employed to estimate implied values of time on the order of $13 to $16 an hour (Yan, Small and Sullivan, 2002). This is an unusually high value of time estimate for travel choice decisions in general, but the SR 91 corridor is of above-average income, and those who elect to use the 91X toll lanes tend to have higher incomes overall than the average corridor traveler. Many toll project studies employ a value of time for passenger car motorists of 40 to 60 percent of the average wage (Urban Transportation Monitor, 2000).

A study of peak period pricing options for Portland, Oregon, estimated average SOV in-vehicle values of time to be $5.34, $7.36, and $11.12 per hour for low income ($0 to $30,000 annual individual income), medium income ($30,000 to $60,000) and high income (over $60,000) individuals, respectively, based on mid-1990s stated preference experiments. The report notes, however, that considerable variation can be expected within an income class, and further points out that "the value of time that an individual household might apply in a particular circumstance may be different at different times" (Metro and Oregon DOT, 2000). It can readily be imagined that a parent leaving work and rushing to avoid a stiff day-care child pick-up deadline penalty would have a higher value of time than the same parent with no commitment other than to pick up milk on the way home.

It would seem logical that variability in value of time (and thus, presumably, value of travel time reliability as well) is closely tied with the high observed incidence of occasional use of actual facilities such as the SR 91X premium facility and the I-15 HOT lanes. It could also relate in part to the observation reported in the SR 91X studies that some toll lane users chose the 91X under traffic conditions where the "expected value" of their time savings was obviously less than the tolls paid. SR 91X survey responses indicate, however, that the primary factors entering into the choice for these particular users were driving comfort and a perception of greater safety, with travel time reliability a distant third (Sullivan, 2002).

In any case, the avoidance of unexpected delay — travel time reliability — is clearly a factor influencing the use of priced facilities. Researchers using stated-preference questions have estimated that travelers value improved travel-time reliability more than twice as much as overall travel time improvements. Trip purpose and income level were found to influence the importance of travel time reliability to individual travelers, as would be expected. Reliability is valued more among higher income travelers, and on work trips as compared to non-work purpose trips (Small et al., 1999).

Trip Purpose

Trip purpose factors into traveler decisions on whether or not to incur priced roadway travel, and on what action to take if the decision is negative. Purpose clearly affects traveler assessments of their value of time. Commute and business trips are generally viewed as more important, less discretionary, and higher valued than non-work trips. Accordingly, individuals are more likely to use a priced option as part of a work-purpose trip than for a non-work trip. In contrast, shopping trips — as an example — are more sensitive to price (Deakin, 1994). The destination, timing and possible trip linking of a shopping or other non-work trip may be much easier to alter than in the case of a work trip. Changes in these travel parameters are thus logical options for response by non-work trip makers to value pricing, the likely underlying cause of higher non-work trip price sensitivity. In the case of a work trip, travelers have less timing flexibility and little immediate choice about their origin and destination, and must deal with the priced option head-on. Of course, over time, a worker could move his or her residence or change employers to avoid pricing (Harvey, 1994).

Congestion pricing is a basically peak-period phenomenon. The degree to which it will apply to non-work trips is lessened because many trips made on express highways during congested times are work or work related, particularly during the morning peak period. These are the most inflexible trips. As congestion increases, more flexible trips are diverted to other destinations, routes, or times (Giuliano, 1994), the same as in the face of pricing. Likewise, if congestion is reduced, non-work trips tend to increase. For example, when the Orange County, California, SR 91 Express Lanes opened there was an increase in peak-period non-work travel in the general purpose free lanes, apparently induced by the increased capacity and reduced congestion. However, as general purpose lane congestion increased over the next several years, particularly in the evening peak, non-work trips decreased (Sullivan, 2002). In Lee County, users making work trips were less likely to time-shift to take advantage of the toll discount, reflecting higher price elasticity for non-work trips (Burris, Pendyala and Swenson, 2002). Finally, business trips are considered even less price sensitive than commute trips (Urban Transportation Monitor, 2000).

Similar observations have been made about the difference between work and non-work elasticities among transit trips. Non-work transit trips are more sensitive to fares than work transit trips. One researcher reports work transit trips as having fare elasticities of between -0.1 and -0.19, with peak fare elasticities in the range of -0.04 to -0.32. In contrast, the corresponding transit shopping trip fare elasticities are identified as being between -0.32 and -0.49, with off-peak fare elasticities between -0.11 and -0.84 (Gillen, 1994). Similar comparisons are reported in Chapter 12, "Transit Pricing and Fares," under "Response by Type of Strategy" — "Changes in General Fare Level" — "Time of Day" and also "Underlying Traveler Response Factors" — "Trip Purpose."

Characteristics of Users

Demographics, most particularly income, strongly influence the decision of whether or not to make use of a priced option. Higher income travelers in particular are more likely to choose tolled routes of travel (Giuliano, 1994). Because demographics and equity — and perceptions thereof — are often closely linked, the characteristics of users of value priced options are discussed jointly with equity issues. This combined discussion is found under the title "Equity and User Characteristics" in the "Related Information and Impacts" compilation to follow.

Transportation System Context

The demand for a priced option depends, to a large extent, on the geographic and transportation system context in which it operates. Congestion on alternatives is a key ingredient to making a less-congested priced option attractive. Obviously the lack or presence of alternatives is a major factor. On the California SR 91 and I-15 projects, motorists could choose to use a parallel free roadway instead of paying for using the express lanes. In cases where no such alternative exists, motorists may seek out different modes or times to travel more readily, or the pricing may simply affect revenue more than travel demand. Singapore saw increases in transit use when pricing was introduced, but in that case, transit service not only existed but was substantial and comprehensive.

In addition to untolled freeway alternatives, the presence of unpriced arterials and local streets may induce motorists to use them instead of the priced option. Although traffic calming strategies could make such alternatives less attractive, the potential for increased travel distance by motorists could have the unintended consequences of poorer air quality (U.S. Environmental Protection Agency, 1998). In the case of SR 91, however, studies suggest that traffic has come to the combined free and toll facilities from parallel city streets rather than vice versa. Over 20 percent of the traffic increase when the Express Lanes opened was attributable to such migration. This trend has not been substantially reversed even as congestion has increased in the corridor (Federal Highway Administration, 2001a; Sullivan, 2002).

RELATED INFORMATION AND IMPACTS

Equity and User Characteristics

Like any transportation strategy, road value pricing applications have equity implications. "Equity" here refers to any change in the distribution of costs and benefits, relative to the existing distribution, resulting from the introduction of pricing options (Giuliano, 1994). The importance of comparing equity implications of a pricing project with alternative approaches to achieving the same objectives is worthy of note. Alternatives may, of course, range all the way from construction of new unpriced highway projects to enhancing alternative travel modes, to a combination of approaches, or doing nothing.

There are some key considerations to keep in mind in discussing equity impacts. It is first of all important to recognize that traditional transportation financing has its own inequities; most commonly used forms of transportation tax revenue generation have been identified as being regressive (Giuliano, 1994). It is then essential to distinguish actual equity impacts — the burden of costs and receipt of benefits — from perceptions of equity by individuals. It is also useful to understand the different perspectives of equity. The so-called horizontal equity perspective looks at incidence of costs and benefits by geographic area or by users and non-users. Vertical equity is concerned with differential incidence of benefits and payment burden by advantaged and disadvantaged groups such as those defined by income, race or disability. From either perspective, the equity impacts are real and can be estimated using value-neutral analyses involving estimation of differential incidence of costs and benefits among the subgroups of concern. This process is sometimes referred to as a "winners and losers" analysis.

The "Horizontal" Equity Perspective

The horizontal equity perspective is concerned with fairness among like individuals and like classes, in other words, persons and groups with similar resources and needs (Litman, 1996). Thus, in the case of a pricing project, concern with horizontal equity leads to examination of costs and benefits by geographic area, or by users and non-users. A geographic view would seek to compare benefits and payment burdens by persons from different geographic locations in the region. A user versus non-user view would aim to estimate what benefits are received and payments made by users of the tolled facility versus those with similar travel needs and desires who opt for alternatives to paying the toll.

Since road pricing typically makes the users who benefit pay for most of (or more of) the costs of improvements, it is inherently likely to be more equitable from the horizontal perspective than most other approaches to congestion reduction or capacity expansion. This type of argument has contributed to generating support for the I-15, SR 91X and Toronto-407 road pricing projects.

The "Vertical" Equity Perspective

The perspective on equity often referred to as vertical equity is the viewpoint concerned with differential effects on groups defined by socioeconomic factors such as income and gender, or other measures of inherently advantaged or disadvantaged status. The associated benefit and cost assessments often turn out to be complex since one must start with current travel behavior and burdens by these different segments of population and then estimate differential impacts of pricing on these same segments. Existing forecasting and accounting methodologies are often incomplete in addressing these issues.

Studies of the equity implications of congestion pricing, an approach with many of the same equity issues as value pricing, make three points. First, the net effect depends on how toll revenues are spent. If revenues are redistributed, congestion tolls need not result largely in gains for higher-income groups and losses for lower-income groups. Second, the net benefits are likely to be greater for higher-income groups under any but the most progressive redistribution schemes. Third, even with a revenue redistribution scheme it is impossible to ensure that all travelers within a particular income class are compensated. Thus, a revenue redistribution scheme cannot completely ensure equity (Giuliano, 1994). Realistically, of course, very little is completely equitable.

The Role of User and Non-User Characteristics

With the preceding points regarding equity in mind, the observations made possible by the various pricing demonstration projects and applications are explored here. Demographics, including income and gender, appear to be a significant factor in the decisions travelers make about whether to and how frequently to make use of a priced option. As a result, equity issues do emerge when dealing with pricing projects. In the basic value pricing scenario, a toll is applied with the intention of shifting low-valued peak trips off of critical facilities or out of critical periods, speeding high-valued trips, and providing new options for all kinds of travel. The equity question is how are the costs and benefits spread across income classes.

Value of Time. One expression of a traveler's income is his or her value of time. As stated previously, many toll facility studies employ a value of time for passenger car motorists of 40 to 60 percent of the average wage (Urban Transportation Monitor, 2000). The value of time for individual travelers influences their willingness to pay tolls to save time. Some road pricing equity research has focused on user value of time rather than on income directly.

In one such winners and losers analysis, computer simulations were conducted to evaluate the differential effects of value pricing, relative to a previously free road. The research concluded that people with intermediate values of time, rather than the lowest values, are burdened the most or gain the least. The explanation provided is that a priced option like the Orange County, California, SR 91X Express Lanes offers users only two choices, thereby catering only to people at the high and low ends of the time value distribution. Intermediate value users cannot justify paying for the priced facility, but are forced to sit in greater congestion as a result of the priced facility having been created (Small, 2001). This last conclusion may be challenged from at least the particular perspective of the SR 91 project by noting that without the added 91X lanes financed by the pricing, the local lanes would be even more congested than they are with the tolled Express Lanes in place. Those not paying to use the 91X lanes may endure more congestion than those who do pay, but they still face less congestion than in the "no build" alternative.

The utilization of the value pricing options in the research simulations was dependent on the presence of congestion. The researchers found that from an equity perspective, the value pricing worked best when "the price charged and the quality offered were both on the low side." In this scenario, lower prices attracted more users to the lanes and lowered the "quality" to the extent of increasing the traffic density of the express lanes. More traffic was attracted away from the main lanes, improving their quality. Overall, the throughput on the corridor was higher than in a scenario where the price and quality of the Express Lanes was higher. Irrespective of price, the benefits of pricing were strongly dependent on the diversity of the users. The more users' time values differed from each other, the more benefits the simulated value pricing scenarios provided. In scenarios where all users had very similar time values, the Express Lanes were either extremely underutilized or overwhelmed, depending on the price charged (Small, 2001).

Income. Early 1990s studies suggested that individuals most likely to be negatively affected by value pricing projects would be those in the middle and lower income brackets. These are often the workers and households with the least flexibility to make changes (Giuliano, 1994). In practice a wide range of income groups have been observed to use value priced facilities, though at differing frequencies. Income equity effects depend on project parameters. Arguably the income equity issue may in many cases be more one of higher income individuals receiving greater benefits, than one of negative effects on any group.

In the case of SR 91, an early-on study of socioeconomic characteristics found the profiles of 91X Express Lane users to be similar to those for SR 91 general-purpose lane users (Ungemah and Baskett, 1999). However, subsequently reported surveys of commuters in the corridor do show a marked difference in 91X usage between high- and low-income travelers. To repeat findings presented earlier, high-income commuters (household income greater than $100,000) are more than twice as likely to be frequent toll lane users (using the lanes for more than 50 percent of their peak trips) and nearly half as likely to be non-users than are low-income commuters (incomes below $40,000). Paralleling the usage pattern, 72 percent of low-income commuters lack the transponders that allow them use of the Express Lanes, versus 31 percent of the highest income travelers. Comparing surveys conducted in 1996 and 1999, the association between income and usage of the lanes was found to have remained largely stable. However, relative usage by middle income commuters dropped in the later survey, presumably reflecting a greater sensitivity to the price increases — for that initially large user group — compared to other income groups (Sullivan, 2002).

San Diego's I-15 FasTrak project found that FasTrak customers, compared to travelers on the free lanes, were generally from higher income households and were more highly educated, more likely to be home owners, and more likely to be from two vehicle households (Supernak et al., 2001a). Correspondingly, in Lee County, Florida, high-income users exhibited less interest in shifting their travel out of the fully priced peak period to save a few cents (Burris, Pendyala and Swenson, 2002).

Some solutions have already been applied, or proposed, to address fairness concerns. Noted earlier is the use that has been made of revenues from I-15 value pricing in San Diego for express bus service in the corridor. The service attracted 525 daily express bus passengers in 1999, two-thirds of whom were reverse commuters (Federal Highway Administration, 2000a). (For further details see "Underlying Traveler Response Factors" — "Travel Mode Impacts and Shifts" — "San Diego's I-15 'FasTrak' Express Lanes" and the case study "I-15 Value Pricing Demonstration Project, San Diego.") Given that the reverse commute bus riders lack the option of using the reversible, peak direction I-15 HOT lanes, their attraction in effect represents an income transfer to persons otherwise not benefited.

A proposal in the case of the San Francisco-Oakland Bay Bridge was that a lifeline auto toll be provided, whereby low-income travelers would be exempt from higher peak-period tolls. The proposed specifics were to qualify motorists using the same criteria established for the guaranteed service programs of gas and electric utilities (Hattum and Zimmerman, 1996).

Another proposed approach, conceived especially for existing congested freeway facilities, is expected to undergo pilot study under the rubric "Fast and Intertwined Regular (FAIR) lanes." This proposal is a variant of separating lanes into fast lanes and regular lanes. Both fast and regular lanes would be electronically monitored. Pricing would be such that the fast lanes would be electronically tolled with rates set in real time, to ensure free-flowing traffic. Regular lane users, while continuing to face congested conditions, would receive toll credits as long as their vehicles were equipped with electronic toll tags. The credits would compensate for giving up the fast lanes, and could be applied to future toll charges or transit fares. The credits form the basis for the assertion that FAIR lanes would be more publicly acceptable than simply taking existing lanes for tolled use, especially if any net toll revenues were to be applied towards enhanced transportation alternatives in the priced corridor (Federal Highway Administration, 2001b; DeCorla-Souza, 2000).

Studies of road pricing in Portland, Oregon, which after winnowing down alternatives focused primarily on individual facility applications involving new highway capacity, concluded that peak period pricing would in the preferred alternatives provide economic benefits to all income classes, and actually be progressive in its distribution of effects among classes. This study outcome was heavily reliant on the assumption of directing toll revenues toward substantially improved public transit services, which were of greatest benefit to lower income groups.[5] Low and middle income groups also received monetary benefit from reduced auto travel, particularly SOV travel. The investigations were not taken to the point of ascertaining the full implications of concomitant choice to take transit or travel less; whether travel and activity needs were satisfactorily accommodated or the change represented loss in quality of life (Metro and Oregon DOT, 2000).

Gender and Age. Usage of value-priced facilities has been found to be influenced by driver gender and age, but the implications for equity remain an open question lacking explicit determination of whether the users and non-users within the gender and age classifications

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[5] In the absence of price changes, when a travel mode is improved the greatest benefits generally accrue to individuals who were prior users of it, with lesser benefits coming to mode shifters attracted to it. With no transit price changes assumed in the Portland studies, full benefit would be gained by persons already using transit before improvement, and the normal lesser benefit would be retained by persons attracted by the improvements themselves independent of road pricing. All transit riders in those categories would be "winners." The road tolls per se would induce even more mode shifters, but this added increment of diverted travelers would be among the "losers."

are being benefited or disbenefited. Studies have looked at the potential for pricing to have different effects on men and women, and on the young, elderly, and intermediate-aged.

On the SR 91 Express Lanes, 42 percent of female commuters versus 28 percent of male commuters report being frequent users as measured by using the tolled lanes for more than 50 percent of their corridor trips (Sullivan, 1998). One of the modeling efforts based on the SR 91 corridor suggested that gender was a more important variable than income group in predicting whether a traveler will use the Express Lanes (Sullivan, 2000). Several studies have documented women's greater reliance on the automobile as a result of household-related constraints on travel choices (Giuliano, 1994). It may be that in certain instances this reliance carries over to heightened interest in securing the travel time savings or reliability offered by the value priced facilities.

Conflicting findings come from the Lee County demonstration. There it was found that female travelers were more likely to take advantage of the off-peak discounts (Center for Urban Transportation Research, 2000), in other words, they were less likely to choose use of fully priced peak hour travel. Another of the modeling efforts that examined the choice sets of commuters in the SR 91 corridor found that 28 percent of women versus 17 percent of men consider all of the available mode, route and time of day alternatives in making travel choices (Mastako et al., 2002).

The I-15, SR 91 and Lee County projects also examined possible association between motorist age and response to pricing options. In each case, intermediate aged travelers were the most willing to pay to travel during the peak period. I-15 FasTrak customers were predominantly 35-54 years old and less likely to be 65 or older (Supernak et al., 2001a). On SR 91, toll lane use appears to increase with age up to the 50-60 age range and then decline, however the relationship was weak and not statistically significant (Sullivan, 2000). In Lee County, the percentage of eligible users not changing their travel time to capture the discount was highest for travelers aged 35-54 (Burris, Pendyala and Swenson, 2002). Again, the equity implications of these findings are not obvious, but the information may have other uses, as in design of promotions.

Individual Perceptions of Equity and Appropriateness

Individual perceptions about fairness of pricing, in contrast to impacts that can be estimated directly, are subjective and can only be assessed with user and non-user surveys or focus group techniques. This is not to say that perceptions are not important for, indeed, they are. Perceptions will strongly influence whether a project becomes feasible or not. Perceptions can sometimes be changed, however, with education and outreach. In fact, in California's I-15 and SR 91 projects, education and outreach have played a critical role in achieving high rates of favorable views among users and non-users. The high ratings obtained have allowed these projects to continue with public blessings (Regan, 2002). On the other hand, in Minnesota and in the San Francisco area, road pricing projects with promises of large benefits and revenue potential were not allowed to proceed due to negative perceptions, even though actions that should have safeguarded equitable impacts were incorporated.

Demographics, including gender and income, appear to have little to do with whether individuals support congestion pricing concepts (Adler, Ristau and Falzarano, 1999). A late 2001 public opinion survey in San Diego's I-15 corridor, of both users and non-users of FasTrak, showed overwhelming support for the HOT lane operations, pricing, revenue use and facility extension proposals. This support cut across both user and non-user groups, as well as all socioeconomic groups (Regan, 2002). Among SR 91 corridor commuters (tolled express and free main lanes), no significant difference in the level of approval was recorded among income groups (Sullivan, 2000). A survey of travelers on the mixed (free) traffic lanes of Houston's Katy Freeway (I-10W) revealed low knowledge of the *QuickRide* HOT lane demonstration program, but 55 percent thought the approach was fair, 67 percent viewed it as effective for the HOV lanes, and 85 percent perceived a benefit for the regular lanes. In actuality, the low *QuickRide* usage has not resulted in any significant changes in person throughput on the freeway (LKC Consulting Services, Inc., and Texas Transportation Institute, 1998; Shin and Hickman, 1999a).

Other studies haven't explicitly compared attitudes among user groups, but show a generally high level of approval in the case of HOT lanes and other situations where a free alternative is available. In earlier I-15 corridor attitudinal studies, over 70 percent of commuters indicated a belief that the congestion pricing policies were fair to users of both the FasTrak lanes and the main lanes (Hultgren and Kawada, 1999). In contrast, the Norwegian public's general response to area pricing in the form of toll rings in cities has been quite mixed. In Bergen, public opinion shifted from 13 percent in favor and 54 percent opposed one month before implementation to 50 percent in favor and 36 percent opposed a year later. Public opinion in Oslo was 29 percent for and 65 percent against just before implementation, gradually shifting to a still-negative 39 percent for and 56 percent against four years later.

A key objective in the Norwegian toll ring applications has been revenue generation for transportation improvements. From this perspective, the attitude surveys in Trondheim provide special insight. Public attitudes toward the toll ring per se were worse than in either Bergen or Oslo; 7 percent for and 72 percent against five months prior to implementation, and 20 percent for and 48 percent against two months after. However, when the question was phrased to ask about the package of toll ring and improvements it was designed to finance, positive responses tied negatives before implementation, and shifted to 32 percent positive versus 23 percent negative after start-up (Gomez-Ibanez and Small, 1994).

Implementation Challenges and Lessons

Past value pricing projects have faced substantial technical and political implementation challenges. Now that there are more implemented projects, the technical hurdles have greatly diminished. The current generation of hardware and software, at least, is proven. Singapore has implemented electronic pricing on a sub-regional scale. Toronto and Melbourne have each implemented fully-automated open-road highway-speed tolling systems (DeCorla-Souza, 2000). Only the technology for large-scale mileage charge applications remains lacking, not expected to be ready until 2010 (Castellani et al., 2002).

Aside from the mechanics of toll collection, projects entail a complex process addressing appropriateness for the geographic area and its transportation system, setting of tolls, enforcement, privacy, and estimation of the impacts of alternatives. These items can be addressed, however, with appropriate planning and design efforts (DeCorla-Souza, 1993).

Political hurdles are another matter. Issues such as interjurisdictional cooperation and public acceptance are less easily resolved (DeCorla-Souza, 1993). Important lessons about such implementation challenges can be drawn from both value pricing projects that have been operating successfully over the past several years and from projects that have failed or are waiting for approval. Each of these projects and their pre-implementation studies, whether or not they eventually evolved into operational applications, has made important contributions to the understanding of value pricing and the process of implementation. While it is not the purpose of this particular Handbook to address implementation issues in any detail, a few points and examples from experience and research will serve to illustrate.

Concerns of the Public

Studies sponsored by the European Commission have identified three major groups within the broader public that are the foci of concern about road pricing applications and outcomes (Castellani et al., 2002):

- *Motorists*, as the main group directly affected (Public Acceptability).
- *Politicians*, as key decisionmakers concerned about re-election (Political Acceptability).
- The *business community*, representing private financial interests (Business Acceptability).

These groups are observed not to act in isolation, but to be intertwined in a complex array of interdependent relationships amongst themselves and associated lobbies of persons affected (including automobile and employer associations), environmental groups, other interest groups, and the media. To make matters even more complex, "acceptance" of road pricing in the approval-gaining phase involves target groups who often have not experienced the proposed measures. This requires "the prospective judgment of measures to be introduced in the future" by the target groups, thereby "making 'acceptability' an attitude construct." This is in contrast to "acceptance" after implementation, which then involves informed experience and includes behavioral responses to the pricing.

The same research has delineated seven key issues involved in achieving acceptance of road pricing (Castellani et al., 2002):

- **Perception** (of a current problem) — identified as a necessary precondition for regarding corrective actions as important, but not guaranteeing that road pricing will be taken as a suitable approach.

- **Social Norms** — found by some but not all researchers to be important, in conjunction with social pressure, for acceptance of road pricing by individuals.

- **Knowledge** — believed to be important in heading off opposition, with distribution of information on program objectives, costs, benefits, and distributional effects (winners and losers) particularly influential.

- **Perceived Effectiveness** — found by many studies to be an influential predictor of acceptability, but needing to be paired with appropriate goals to minimize unintended individual citizen reactions.

- **Fairness/Equity** — viewed as a key issue by most groups (see discussion in the "Equity and User Characteristics" subsection above)

- **Revenue Allocation** — closely tied to equity issues, with the potential to influence who are the winners and losers, and to compensate parties disadvantaged by the road pricing.

- **Case-Specific Characteristics** — clearly crucial to each individual proposal, with specifics including the pricing scheme, accompanying transportation improvements, availability and cost of travel alternatives, and other factors often unique to the project.

Value pricing is frequently objected to over concerns that the tolls are simply a new tax on the citizenry and may go beyond the ability of lower income users to pay the charges. In cases where the proposal is to price existing facilities, there tends to be a feeling among commuters that they are being charged for roads that they have already paid for through their fuel taxes (DeCorla-Souza, 2000). The general public has been found not to believe that pricing and taxation measures will solve congestion, air pollution, and related problems (Castellani et al., 2002). These perceptions are confirmed in the case example of Minnesotans queried in 13 focus groups, including nine held in the Minneapolis-St. Paul metropolitan area. The Minnesota focus group participants also added the concern that pricing would simply divert the congestion problem to unpriced side streets not intended for longer-distance travel (Wilbur Smith Associates, 1997).

The public may have trouble seeing benefits from the charges. Even when funds are dedicated to transportation purposes, public support is far from guaranteed. In the Trondheim, Norway, example, while stated support for their toll rings increased when survey respondents were reminded that the revenues would be used to provide specific facilities, over two out of every five persons with an opinion still opposed the tolls (Wachs, 1994; Gomez-Ibanez and Small, 1994). Public acceptance of various Travel Demand Management (TDM) measures was found in one European survey to be least for road pricing, receiving rankings of 84 to 91 percent "not acceptable" versus 16 to 9 percent "acceptable" (Castellani et al., 2002). In the Minnesota focus groups, however, road pricing — although unpopular — was not tarred with the nearly unanimous unfavorable reaction received by a mileage-based road use tax alternative (Wilbur Smith Associates, 1997).

A synthesis of public opinion polls conducted between 1993 and 1996 provides several observations concerning value pricing support. First is that pricing must be packaged appropriately for public acceptance. Support is lower for pricing projects that are described as simply reducing congestion than for projects whose descriptions also make clear other benefits will occur. Second, support for congestion pricing is greatest when specific rather than general transportation purposes are cited as the use of the revenues. Third, traditional equity concerns, such as income, may be less important than perceived inequities for such groups as people with long commutes and people requiring daytime use of their vehicles. Fourth, support for congestion pricing as a transportation funding mechanism appears lower than for gas taxes (Spock, 1998).

The Boulder, Colorado, Example

In the mid 1990's, Boulder, Colorado, embarked on a pilot project to demonstrate the application of peak-period pricing. The project was to introduce the concept of value pricing to one neighborhood, simulating an areawide pricing scheme, which would be the longer range objective. The project was modeled after the Stuttgart demonstration discussed earlier, with charges ranging from $0.50 to $2.00. As plans to install the equipment for automatic vehicle identification technology were initiated, a media firestorm erupted and city council members failed to express majority support. As a result, the transportation agency decided to abandon the demonstration (Federal Highway Administration, 1998b).

The Boulder project's failure offers a number of lessons in navigating the implementation challenges of value pricing. First, internal transportation agency acceptance of pricing as a viable and worthwhile transportation strategy is needed to enable the agency to voice support for the plan. The Boulder effort was not well integrated into the transportation planning process, and thus had few advocates when things did not go well. Second, public outreach and education are critical to achieving buy-in to any program. The project received unexpected negative media coverage and was never able to recover. Third, frequent discussions with elected decision makers are important when dealing with such a politically charged topic as raising user fees. Although some council members thought pricing would make technical sense for Boulder, many did not believe the city was politically ready, even for a pilot demonstration. Finally, thought must be given to the study area's place in the region under a pricing program regimen. Many concerns were expressed about competitiveness within the region were Boulder the only city in the area to adopt such a bold proposal areawide (Ungemah and Baskett, 1999).

Other Implementation Observations

The European research already noted found institutional barriers to implementation to include fragmented transportation planning, revenue generation mechanisms, stakeholder organizations and decisionmaking; senior government policies in conflict with pricing; insufficient and conflicting legislation; opposition — founded upon contradictory advice from stakeholders, academics, and the like — from interest groups within the government; and opposition from non-government interest groups (Castellani et al., 2002). Parallels with U.S. experience seem fairly evident.

Additional key lessons regarding implementation challenges, derived primarily from U.S. implementation experiences, include the value of:

- Attending to local concerns.
- Bringing all parties to the table.
- Focusing on coalition building.
- Nurturing support from political leaders.
- Finding solutions to address adverse impacts.
- Packaging pricing as part of a program of improvements.

It is also important to recognize the very clear lesson that there will always be political controversy associated with efforts to establish a new way of charging for highway use. This may mean that supporters of pricing need to place special emphasis on educational efforts before value pricing projects are introduced. They may also need to accept gradual introduction of value pricing, perhaps through undertaking a pilot demonstration before launching more comprehensive initiatives. This in turn will introduce a need for maintaining a vision for moving from piecemeal applications to a comprehensive approach. Addressing political concerns may also require that value pricing be combined with some form of compensation to adversely affected travelers (Federal Highway Administration, 1998c).

Travel Mode Impacts and Shifts

Impacts of road value pricing on alternative travel modes such as carpooling and transit, and the travel mode shifts involved, have already been noted in the "Response by Type of Strategy" section. Also reported have been the route choice phenomena in instances where unpriced highway alternatives exist. Highway route choice tends to be the travel decision most sensitive to changes in auto travel times and costs (Metro and Oregon DOT, 2000). Normally the predominant travel shifts will be from one highway route to another when new time and cost differentials are introduced in the presence of alternatives. Where there are no or limited highway alternatives, trip makers will turn more to public transit and other options already identified at the start of the "Underlying Traveler Response Factors" section.

It is thought that road pricing in and of itself encourages ridesharing and use of transit in general. In the case of Singapore's central area licensing scheme, where good transit alternatives existed while highway route alternatives were available only to through travel, large increases in ridesharing and transit use were observed. In the United States, where alternatives to auto use are mostly not as well developed, the shift to alternative modes in response to pricing alone has been much less pronounced. For example, no mode shift effects have been noted for the Lee County project in Florida, where the bridge toll discounting could conceivably have engendered shift away from alternative modes.

When in some manner new roadway capacity is made available, the transit use and ridesharing situation becomes less straightforward. Where existing HOV lanes are opened to lower occupancy tolled vehicles, applying the HOT lane concept, the possibility of negative transit and HOV use impacts seems logical. There have been some not easily attributable changes in HOV use, ranging from near-neutral to positive on the priced facilities themselves, to near-neutral to negative on parallel general purpose lanes.

It is therefore noteworthy that transit ridership has apparently not been hurt by these types of projects. Over the long term, as congestion increases, the specific impact of pricing on transit usage in the corridors involved may become more apparent. The fact that transit results have not been more marked may in part be attributable to the location of all of the U.S. facility-related projects in suburban areas that tend to be more affluent, with ready access to automobiles. It may be found, however, that there is a more fundamental determinant of transit ridership's resiliency in the form of low sensitivity of mode shifts to road pricing, relative to travel options such as choice of route. Low sensitivities are hinted at by commonly encountered demand model structures and the partial change of mode findings (no results for the transit mode per se) of SR 91 corridor modeling (see "Underlying Traveler Response Factors" — "User Cost").

This subsection focuses on those situations where new roadway capacity is opened up for priced travel, either by means of new construction or through opening HOV lanes to tolled lower occupancy vehicles. In these cases a new premium service has been offered to priced vehicles, such as in provision of new tolled highway capacity, or the opening of an HOV lane to priced SOVs or LOVs, as in HOT lane applications to existing HOV facilities. The three projects examined further are San Diego's I-15 "FasTrak" Express Lanes; Orange County, California's SR 91 Express Lanes; and Houston's *QuickRide* Program on the I-10W Katy Freeway HOV facility. In addition, modeled results from the Portland, Oregon, peak period pricing studies are reported.

San Diego's I-15 "FasTrak" Express Lanes

In the I-15 corridor, opening of the HOV lanes to priced SOVs had no apparent impacts on park and ride lot use. HOV usage on the HOT lanes increased some 16 percent immediately upon introduction of pricing accompanied by increased enforcement. Express Lanes HOV usage then grew another 7 percent overall during the 3-year demonstration, actually growing faster during the initial ExpressPass phase, followed by a slight decline during the FasTrak phase. During the same three years, however, there was a major decline noted in the AM peak period share of HOVs in the general purpose lanes (Supernak et al., 2001a and b), an observation with no really satisfactory explanation. Phase I surveys in the Fall of 1997 indicated only 5 percent of ExpressPass users had shifted from HOVs, as compared to 95 percent from SOVs (Hultgren and Kawada, 1999).

The I-15 project, alone among the U.S. value pricing demonstrations, reports some success in actually promoting bus usage. Surplus Express Lane revenues provide funding for express bus service in the corridor. In April 1999, this service averaged 525 daily passengers, two-thirds riding in the reverse commute direction. The new route gave faster service to existing transit users, but did not attract much ridership from peak direction travelers in the I-15 main lanes (Federal Highway Administration, 2000a). The new ridership was not enough to keep this corridor from falling behind the region in transit ridership expansion. Corridor ridership grew 9 percent over the span of the demonstration project, compared to 23 percent for the region (Supernak et al., 2001a). Clearly, that bus use growth which occurred was largely a second-order effect. The value pricing has provided revenues, for new service, and it is the new service that has attracted most riders.

SR 91 Express Lanes in Orange County, California

In the Orange County, California SR 91 corridor, opening of the Express Lanes did not produce the degree of negative effect on ridesharing that some feared (Sullivan, 2002; Federal Highway Administration, 2001a), but there was some net loss in the proportion of persons carpooling. On the one hand, when the toll lanes opened with free HOV 3+ passage, HOV 3+ vehicles in the corridor (free and toll lanes) jumped more than 40 percent, albeit from a small base number. The fall 1996 survey (the 91X lanes were opened at the end of 1995) found that among corridor travelers in the survey sample, about 25 percent of HOV commuters had switched from SOV, and about 15 percent of SOV commuters had switched from HOV. On the other hand, because there were many more SOVs than LOVs, the net effect was actually 7 percent reduction in the use of the HOV mode on a commuter count basis (Sullivan, 1998). The 1999 surveys showed no further significant shifts (Sullivan, 2000). Correspondingly, but involving additional factors as discussed in the Case Study "SR 91 Express Lanes, Orange County, California," opening the 91X lanes led to a decrease in average vehicle occupancy (AVO), which stabilized and has remained thus since (Sullivan, 2002).

HOV commuters are more likely than SOV commuters to use the Express Lanes, perhaps as a result of the combined effect of the HOV 3+ toll relief and the opportunity to split the toll among occupants (Sullivan, 2002). When the 50 percent toll was added for HOV 3+ users, carpooling in the corridor did not decline, but fewer carpools chose to use the toll lanes (Federal Highway Administration, 2001a).

The SR 91 Express Lanes have had no discernable effect on either commuter bus or commuter rail ridership (Federal Highway Administration, 2000a). Analysis is clouded by events, including the opening of Metrolink commuter rail service in the corridor two months prior to opening of the 91X lanes, and an unrelated sharp reduction in express bus frequency at about the same time (Sullivan, 2000). The 1996 survey of SR 91 corridor free and toll lane users found essentially no shifts from transit modes to highway use during the year. Transit surveys also taken in 1996 showed, in contrast, that over 95 percent of Metrolink commuters had been attracted from highway use. A third of the riders on the express bus — not a new service — reported being highway users the year before. Of the Metrolink riders shifting from highway, seven out of ten had been SOV drivers, as had three out of four shifting from highway to bus (Sullivan, 1998). Subsequent bus ridership tracked frequency of the express service provided about as one would expect. Metrolink ridership grew as the commuter rail operation became established (Sullivan, 2000), but whether and how much it might have grown faster without the 91X lanes is of course unknown.

Houston's I-10W Katy Freeway QuickRide Program

The *QuickRide* program on Houston's I-10W Katy Freeway HOV facility appears to have had some effect in encouraging carpools, and negligible adverse impact on usage of higher occupancy vehicles including public transit. *QuickRide* registrants — persons "buying in" for two person carpool use of the lane during periods of 3+ occupant eligibility requirement — were surveyed in the initial months of the pricing demonstration (Shin and Hickman, 1999a and b; LKC Consulting Services, Inc., and Texas Transportation Institute, 1998). The small number of *QuickRide* trips involved raises questions about transferability of findings, but the exploration of prior modes of travel provided is the only such information presently available for HOV lanes having a value pricing application differentiated by HOV occupancy level.

Complex travel changes among *QuickRide* participants, involving time, spatial and mode shifts, are indicated by the survey results. Some two-person *QuickRide* carpoolers went from using the HOV lane in the shoulders of the peak (2+ occupant eligibility requirement) to the peak (3+ occupant normal requirement). This and other options open to *QuickRide* trip makers apparently contributed to roughly a 20 percent increase in peak trips by *QuickRide* participants. There was also significant movement of two-person carpools from the general purpose lanes to the HOV lane. New carpools were also formed. Survey responses suggest that a quarter to a third of *QuickRide* trips on any given day were previously drive alone trips on the freeway. In contrast, diversion of bus, vanpool and 3+ occupant carpoolers to *QuickRide* usage appeared to be limited in total to approximately 5 percent, and certainly no more than 8 percent, of the small number of *QuickRide* trips (Shin and Hickman, 1999a and b; LKC Consulting Services, Inc., and Texas Transportation Institute, 1998).

QuickRide registrant carpool composition was among the data obtained in the early surveys. Family members comprised 49 percent of reported members (37 percent adults and 12 percent children). Co-workers accounted for 41 percent of carpool members, followed by neighbors at 6 percent, and other at 4 percent (LKC Consulting Services, Inc., and Texas Transportation Institute, 1998). These results, representing carpools prepared to pay $2.00 for entry onto the HOV lanes during the periods of HOV 3+ occupancy requirement, exhibited lower percentages of family members and higher percentages of co-workers than typical of Houston HOV lane users (see Chapter 2, "HOV Facilities" — "Underlying Traveler Response Factors" — "Carpool Composition and Longevity") and differed from those obtained in previous surveys of Katy carpoolers and vanpoolers. The 1990 survey indicated that 56 percent of Katy HOV lane carpools were formed with family members, 32 percent with co-workers, and 12 percent with friends and neighbors (Bullard, 1991).

Portland, Oregon, Peak Period Pricing Studies

Results from peak period pricing studies for Portland, Oregon, are of special interest among estimated impacts because of the extensive travel demand modeling underlying them. A complete set of new activity based travel demand models structured around trip maker tours and day-long activity patterns was developed in cooperation with FHWA's Travel

Model Improvement Program (TMIP). They were based on a 1994 large-scale household survey plus stated preference experiments designed with road pricing evaluation in mind. Tests were run to explore model elasticities.

The test parameters did not allow computation of elasticities for shifts in route choice in response to pricing, expected to exhibit the highest sensitivity. Elasticity to 24-hour pricing for mode shifts away from SOV driving was estimated to be a relatively low -0.06 for work/school-based tours and -0.10 for non-work tours. These values are actually somewhat higher than estimated for actual response in the case of California SR 91X (see "Underlying Traveler Response Factors" — "User Cost."). Corresponding Portland elasticities for reductions in vehicle miles of travel (VMT) for the SOV mode were -0.15 for work-based tours and -0.21 for non-work tours, interpreted as implying changes in destination choice, which could fully occur only as a long-term effect.

In the tests, all day and peak period SOV driving (VMT) were reduced by roughly 14 percent in the case of work/school tours for a universal doubling of total automobile variable costs. When the cost doubling was applied only in the peak periods, the equivalent peak period SOV VMT reductions stayed roughly the same, but 24-hour SOV VMT decreased only 8 percent. The corresponding reductions for non-work tours were greater by about one-half in the case of 24-hour cost doubling, but less in the case of peak period only application, with only a 3 percent SOV VMT reduction over the full day. No elasticities were reported for applying the cost doubling in peak periods only (Cambridge Systematics, Inc., and Mark Bradley, 1997).

Later in the study process the effect on mode shares during the PM peak one hour, measured on the basis of person-miles of travel (PMT) within defined intra-regional travel sheds, was estimated for using peak period pricing to fund Regional Transportation Plan improvements as compared to conventional funding (no road pricing). The peak period pricing was projected to reduce peak SOV PMT (including trucks and external traffic) by one percent (71.7 to 71.0 percent SOV share). The corresponding transit and HOV PMT increases were 1.5 percent (12.9 to 13.1 percent transit share) and 3 percent (15.4 to 15.9 percent HOV share), respectively. Given focusing of the pricing on providing new capacity in problem areas, PM peak hour speeds on new lanes were estimated to be almost 40 percent higher with the peak period pricing, and reductions in hours driven in congestion were estimated at 5.4 percent (Metro and Oregon DOT, 2000).

Impacts on Land Use

The design of a value pricing system and the use of its revenues may each influence the extent to which changes in land use, development and urban form occur in response (Deakin, 1994). Congestion or value pricing that produces travel time decreases could lead to more dispersed new development, or allow better access to currently congested centralized developments, or both (U.S. Environmental Protection Agency, 1998). The manner in which revenues from pricing strategies are applied could alter the magnitude and distribution of these effects (Deakin, 1994). For example, using pricing revenues to fund superior transit options could serve to focus development around activity nodes.

Pricing may affect short term travel patterns and thus land rents through trip maker decisions such as whether or not to make trips, and what destinations to travel to. It may also affect land use in the long term through home and employment location decisions.

When and to what degree highway improvements in general induce trips, shift modes, and alter destination choices is still a matter of much discussion, but it is certain that there is a connection (Deakin, 1994). The relationship is made more complex in the case of value pricing, in that the deterrent of the toll should operate counter to the inducement of less congested travel.

Along San Diego's I-15 corridor, researchers found that housing decisions for residents were being positively influenced by the existence of the I-15 pricing project, but that it is a secondary factor in the location choice decision. The top three factors in residence choice were still the quality of the neighborhood, proximity to good schools, and the cost of the residence (Supernak et al., 2001a). Whether pricing in the corridor with its higher cost serves as a deterrent to sprawl that is stronger or weaker than the inducement of faster travel times remains to be seen. In any case, it would seem logical that to some degree pricing would at least dampen impacts that would otherwise occur with added capacity.

Impacts on Air Quality

Several papers and models developed before actual projects were implemented in the United States focused on expected emissions reductions as justification for pursuing road value pricing projects. For example, congestion pricing has been included in Transportation System Management alternatives in regional transportation studies. This section examines the mechanisms through which value pricing can affect air quality and then looks at one recent set of estimated impacts plus the experience of two major value pricing projects. The experience appears to be neutral or positive.

Underlying Mechanisms

Congestion, particularly stop and go traffic, significantly increases vehicle emissions. As an example, one California Air Resources Board report estimates that a 10-mile trip, using an average 1987 automobile, results in three times more hydrocarbon emissions at an average speed of 20 mph than at 55 mph (Poole, 1992). The optimal operating speed is closer to 40 mph. In addition to vehicle operating speed, vehicle emission rates are a function of vehicle fleet parameters (age, emission control technology, and fuel types) and other operating characteristics such as the acceleration profile. Total emissions are also dependent on VMT (Guensler and Sperling, 1994).

Roadway pricing strategies would not be expected to have an impact on the types of vehicles used by households and, therefore, regional vehicle fleet distribution (U.S. Environmental Protection Agency, 1998). Pricing's main impacts on vehicle emissions would be expected through effects on vehicle operating speeds, speed variations and VMT. As traffic congestion is reduced and operating conditions move closer to free flow, emission rates per mile of travel would be expected to decrease (Guensler and Sperling, 1994).

In the case of pricing a single facility, it becomes more difficult to predict the overall impact on air quality. While it is likely that improvements in emissions on the priced facility would result through the mechanisms outlined above, it is unclear how VMT, and thus total emissions, would be impacted. Estimates of emission reductions from pricing individual facilities are highly dependent on the availability of alternative routes and on how much traffic would shift to such routes (Wachs, 1994).

Reduced emissions could result if facility value pricing reduces trip making or causes mode shifts into higher occupancy modes. Reduced emissions could also result if pricing simply causes motorists to shift the time of their trips, thereby lowering emissions as a result of higher average operating speeds. Increased emissions might result if value pricing has the effect of shifting motorists to longer alternative routes bypassing priced facilities (Guensler and Sperling, 1994). However, if such longer diversions take motorists away from air quality "hot spots" and "hot periods" they could still result in improvements at the worst locations and times (Wilbur Smith Associates, 1994). It is clear that the net impact is difficult to forecast except through detailed analysis of a variety of scenarios.

Studies on I-35W in the Twin Cities region showed that traffic diversions to local streets were likely to occur under priced scenarios, even with incentives for mode shifting. Air quality on the local streets would then be adversely affected as a function of traffic volume, travel speed and intersection delays (Wilbur Smith Associates, 1994). Researchers have pointed out that in order to improve air quality, value pricing policies need to be designed not only to increase average speeds on congested routes, but also to avoid creating congestion on arterial unpriced routes (Guensler and Sperling, 1994).

Modeled Impact Estimates

Table 14-11 sets forth impacts of congestion pricing as estimated for four major urban areas in California. These forecasts illustrate the relationship of large congestion delay reductions being associated with small overall reductions in peak traffic volumes (Victoria Transport Policy Institute, 2002b). They predict congestion delay reductions roughly 10 times the extent of the estimated VMT reductions, fuel consumption reductions about 3 times VMT reductions, and key pollutant reductions approximately 2-1/2 times VMT reductions.

Table 14-11 Estimated Year 2010 Impacts of Road Pricing on California Urban Regions

Region	Average Fee	VMT	Trips	Delay	Fuel Consumed	ROG Emissions
S.F. Bay Area	13¢	-2.8%	-2.7%	-27.0%	-8.3%	-6.9%
Sacramento	8¢	-1.5	-1.4	-16.5	-4.8	-3.9
San Diego	9¢	-1.7	-1.6	-18.5	-5.4	-4.2
South Coast	19¢	-3.3	-3.1	-32.0	-9.6	-8.1

Notes: Average Fee = average congestion fee per mile in 1996 dollars applied to vehicle travel on congested roads. VMT = change in total vehicle mileage. Delay = change in congestion delay. Fuel = change in fuel consumption. ROG = reduction in a criteria air pollutant.

Source: Harvey, G. and Deakin, E., "The STEP Analysis Package: Description and Application Examples." Appendix B, in *Technical Methods for Analyzing Pricing Measures to Reduce Transportation Emissions*. U.S. Environmental Protection Agency (1998) as presented in Victoria Transport Policy Institute (2002b).

Analyses Based on Project Experience

In the Orange County, California, SR 91 corridor, researchers calibrated an aggregate emissions model capable of estimating the emission impacts of the SR 91X Express Lanes. It was then used to project that if dual HOV lanes had been constructed instead, overall emissions would have been approximately the same. Similarly, it was estimated that additional general use lanes would have induced a 7 percent increase in VMT and resulted in emissions from 6 percent less to 4 percent higher than the existing conditions. A no build analysis scenario suggested that if nothing had been done, VMT would be 8 percent less and that emissions would be 18 percent less than the existing situation in which two priced lanes had been added in each direction (Sullivan, 2000).

In the case of the I-15 corridor, a comparison was made with the relatively nearby I-8 control corridor to arrive at findings of emissions impacts. From 1997 to 1999, the average relative increases in morning peak period emission levels along the I-8 corridor were three times larger than the average relative increases along the I-15 corridor. During the evening peak period the I-8 emissions were five times greater. Since no other factors other than the FasTrak program were identified that could have been responsible for the mitigated emission levels on the I-15 corridor, researchers concluded that the program likely moderated emission levels during the period (Supernak et al., 2001a). Unfortunately, the findings are not quite as conclusive as if it had been possible to select a comparison corridor with reversible HOV lanes, an original characteristic of the I-15 corridor, along with more equivalent geographic orientation.

In neither case was any measurement of region-wide air quality impacts taken, nor would there be any reasonable expectation of a significant effect on a large scale. Clearly, the long-term effects of the projects on air quality depend on a number of factors, including the effects on land use and use of alternative modes (Federal Highway Administration, 2000a). However, it is useful to note that in each case the immediate air quality impacts were apparently neutral or positive when compared with other build scenarios.

Impacts on Revenue

The revenue generation of road pricing projects depends on the scope and scale of the project including the geographic coverage, population of vehicles affected, operating hours, fee schedules, and technology adopted. In addition, the equity implications of pricing projects depend in significant measure on the use of revenues generated by the project. Recent operating projects as well as feasibility studies here and overseas indicate that road pricing can generate substantial revenues, enabling collateral or mitigating actions to be funded (Federal Highway Administration, 1998a, 1998c and 2000a). In assessing net revenue potential, however, it is essential to distinguish between projects involving existing facilities and projects where the pricing is expected to fund new construction, to take into account project policy ramifications, and to recognize the crucial importance of the existence of and interplay between alternative toll-free routes and levels of congestion.

Revenue Aspects of Pricing Existing Facilities

Pricing project financial demands, although significant, will under almost any circumstances be inherently less when it is existing facilities being priced. Implementing pricing technology can have substantial costs, and operating expenses are not insignificant, but construction costs of new highway capacity are not part of the financial equation. Even so, examples exist of both revenue positive and revenue negative results.

U.S. applications of pricing existing facilities fall into both categories. Among revenue positive examples, income of approximately $1.2 million per year from San Diego's I-15 corridor HOT lane pricing allows the project to be "fully self sufficient" including support of a new express bus service. In Houston, revenues from QuickRide are "defraying the cost of operating the express lane service" (Federal Highway Administration, 2000a).

In existing revenue-negative examples involving pre-existing facilities, it has been by design that the negative revenue has occurred. The shoulder-of-the-peak price discount project on the Lee County bridge crossings in Florida does not generate positive cash flow. The Garden State Parkway discounts are revenue negative also. In both cases the negative revenue impact on pre-existing toll collections was expected, since no other tolls were raised when the discounts were put into place. In contrast, the Tappan Zee truck toll project is revenue positive since the discount was packaged with an increase in the peak toll, and demand was relatively inelastic.

Revenue Aspects of Pricing New Construction

Expecting pricing to cover all or part of highway construction costs, in the case of new construction, puts project financial demands into a wholly different arena. Prospective bondholders rely on expert projections of traffic, revenues and costs for assurance that their investment will be protected. In the case of conventional toll bridges, tunnels and intercity roads, 20th Century investors in U.S. projects usually but not always found them to be good investments.

Pricing a highway facility to be built in an urban environment involves a whole new level of complexity, relative to most intercity roads and crossings of geographic barriers, because of the multiplicity of alternative travel routes and options available to the motorist. Sometimes the availability of untolled alternatives is by design, as in the case of placement of the California's SR 91X express toll lanes in the middle of an untolled freeway.

Orange County, California's SR 91X and Toronto's 407ETR projects are North American examples of corridor pricing applications where revenues do fully cover operating expenses and debt service costs. On SR-91X, pricing revenues are part of the financial package that made construction and operation of the new road capacity possible (Federal Highway Administration, 2000a). These projects are in mega-metropolises, however, with few or highly congested alternative express highway routes. Net revenues from the SR 91X facility have benefited from a unique combination of intense corridor congestion, few alternative routes through a geographic barrier, and easily developed underutilized right-of-way, that make the situation not comparable to most urban applications.

There are urban toll roads in the United States, with conventional pricing, where revenues have contributed importantly to the construction financing packages. There is no reason to believe the same cannot be the case with variable pricing. In Portland, Oregon, a mid-sized city with medium congestion, extensive study of applying peak period pricing incentives has led to a finding that some 30 to 40 percent of highway construction capital costs could be covered during the lifecycle of the improvements. This particular study looked almost exclusively at options where unpriced alternative routes would remain available (Metro and Oregon DOT, 2000).

ADDITIONAL RESOURCES

Transportation Research Board (TRB) *Special Report 242*, "Curbing Gridlock," prepared by TRB and the Commission on Behavioral and Social Sciences and Education, focuses on congestion pricing. Although its 1994 issuance predates most of the actual value pricing demonstration projects in the United States, the report provides a broad range of perspectives on the subject, and discusses topics from the policy basis for congestion pricing to impact estimates from travel models. Volume 2 contains 18 commissioned papers (for example, Bhatt, 1994). FHWA's *Value Pricing Notes* is a periodic publication of the Value Pricing Pilot Program that gives regular updates on demonstration projects (for example, Federal Highway Administration, 2000b).

The State and Local Policy Program of the Hubert H. Humphrey Institute of Public Affairs at the University of Minnesota provides outreach activities for the FHWA value pricing program, and maintains a website on the subject. The MC-ICAM (Implementation of Marginal Cost Pricing in Transport – Integrated Conceptual and Applied Model Analysis) research funded by the European Commission is producing a series of relevant research efforts (for example, Castellani et al., 2002). Portland's Traffic Relief Options Study and companion documents illustrate a particularly comprehensive analysis of urban road pricing and its likely impacts, costs and benefits (Metro and Oregon DOT, 2000). Finally, there are the extensive studies of the California SR 91 and I-15 projects. The project reports contain exhaustive coverage of traffic, travel demand and related findings (Sullivan, 1998 and 2000; Supernak et al., 2001b and companion reports).

CASE STUDIES

Singapore Electronic Road Pricing

Situation. Singapore, an Asian island city-state with a total population of nearly four million, has long used pricing to control congestion in its central area. The Singapore Area License Scheme (ALS) was originally put into place in 1975 when the population was closer to two million and there was about one car for every 16 persons. As covered earlier under "Response by Type of Strategy" — "Response to Areawide Value Pricing" — "Singapore's Area Licensing Scheme," the windshield-license-based ALS was very effective in reducing traffic, and over the years was enhanced and modified. In 1998, the paper-based system was converted into the fully automated Electronic Road Pricing (ERP) system. As of 2000, there is about one car for every nine persons, but the pricing system still effectively mitigates congestion.

Singapore's Land Transport Authority intends the ERP system to be a traffic management tool rather than a revenue generator. Tolls are reviewed every three months to ensure the program objectives are being met. Traffic flows on selected routes are reviewed quarterly and may be adjusted up or down depending upon degree of congestion. As long as speeds do not drop below a 20 to 30 km/h range, pricing is not increased.

Action. In 1998, Singapore launched an extensive and ambitious ERP-based value pricing system as a replacement for the paper-based ALS in the central area, and added a series of radial and peripheral highways in the metropolitan region into the pricing scheme. The ERP utilizes in-vehicle transponder units (IUs) that accept stored-value smart cards for payment.

The stored value card system was preferred over a standard billing system because it offered better privacy protection. Enforcement is handled using video cameras.

The new electronic pricing system allows motorists much more flexibility in choosing whether and when to enter the restricted zone. Monthly commitments are no longer involved and lower tolls are charged at off-peak times. Under ERP, restricted zone entry tolls apply on weekdays from 7:30 AM to 7:00 PM. They range, for private autos, from free (10:00 AM to 12:00 PM) to S $2.50 (8:30 AM to 9:00 AM at most entry points), according to a fixed schedule keyed to the time of day. Previously the ALS applied tolls of S $3.00 throughout the entire morning and evening peak periods. Pricing under ERP covers not only more routes, with different prices along expressways according to location, but also more hours for restricted zone entry, than under the ALS.

Analysis. There has been comprehensive analytical treatment of Singapore's original ALS, and the reader is referred to *NCHRP Synthesis 210* as a first stop in learning more. Coverage of traveler response to the ERP scheme is as yet more limited. A recent Discussion Paper from the World Bank's Transport Division includes some post-ERP results. The key analyses were based on before and after observations conducted in accordance with a comprehensive study design.

Results. After the new traffic patterns stabilized, measurements showed that the weekday traffic volume entering the Restricted Zone had dropped by 20 to 24 percent, from 271,000 vehicles per day in 1997, to between 206,000 and 216,000. With the lower traffic volume, average traffic speeds in the zone increased from 30-35 km/h to 40-45 km/h. These changes are relative to conditions under the previous ALS pricing scheme. Some peak spreading within the former peak periods has occurred as motorists take advantage of lower tolls on either side of the peak hour. The authorities have had to enforce a no stopping rule near the toll gantries to prevent motorists from waiting on the shoulder for scheduled toll reductions.

More... On the technical side, the system works even when vehicles pass at 120 km/h. The CashCard, which is used to store the prepaid value used for tolls, is also accepted as a means of payment at stores, government agencies, and Internet sites. The Singapore government views it as an important step in becoming a cash free society. The card can be recharged at automatic teller machines, special kiosks, and gas stations. With violations recorded by video cameras for later enforcement, the ERP violation rate is only 0.3 percent.

The ERP system costs are high, but still much less than the cost of building new capacity. The Singapore system cost S $200 million (about US $110 million on the basis of 2002 exchange rates) to implement, including equipment for up to 60 overhead gantry points and nearly 1.1 million IUs. Half of the S $200 million cost was for the fitting of IUs, provided free to vehicles that came forward at the time requested.

Sources: Dupont Teijin Films, "CashCards Take the Heat." http://www.DupontTeijinFilms.com/news/article35.html (Webpage dated 2000). • Gomez-Ibanez, J. A., and Small, K. A., "Road Pricing for Congestion Management: A Survey of International Practice." *NCHRP Synthesis 210* (1994). • Willoughby, C., *Singapore's Experience in Managing Motorization and Its Relevance to Other Countries.* Discussion Paper TWU-43. The World Bank, Washington, DC (April, 2000). • World Bank, *Study On World Transport Development.* The World Bank, Washington, DC (August, 2000). • Zen, I. T., "Hints to Successful Implementation of Electronic Road Pricing Systems — The

Singapore Experience." Hong Kong Institution of Engineers. http://www.itshongkong.com/report/erp.html (November, 1999). • Land Transport Authority, "Electronic Road Pricing — Passenger Cars (with effect from 05 August 2002)." http://traffic.smart.lta.gov.sg/erprates.htm, Singapore (Webpage accessed October 22, 2002).

I-15 Value Pricing Demonstration Project, San Diego

Situation. The two-lane exclusive HOV facility on I-15 in the northeast side of San Diego is approximately 8 miles in length. It was opened in 1988 with a two person per vehicle (2+) occupancy requirement. The lanes operate in the southbound direction from 5:45 to 9:15 AM and in the northbound direction from 3:00 to 7:00 PM, and are closed at other times. There is one entry point and one exit point. In light of unused available capacity in the HOV lanes, a value pricing demonstration was considered as one potential transportation control measure for the regional air quality plan, and emerged as one of the preferred alternatives for the I-15 corridor. The ultimate primary goals of the demonstration, as per the "Phase II Year Three Overall Report," were to maximize use of the existing express lanes, fund new I-15 corridor transit and HOV improvements, test whether allowing priced SOVs to use the HOV lanes can help freeway main line congestion, and set tolls on the basis of a market-based approach.

Actions. The I-15 Freeway HOV Pricing project was a congestion pricing demonstration funded through the ISTEA of 1991, with the FHWA as the primary funding agency. The two phase project provided a test of allowing single occupant vehicles to use the I-15 HOV lanes for a fee. Funding for express bus service in the corridor and a freeway service patrol was provided locally. Private enterprise was used for operations and marketing, and the California Highway Patrol (CHP) was paid for enforcement during the project.

ExpressPass, the Interim Operations phase of the demonstration, was in operation from December 1996 to March 1998. During this phase, a limited number of monthly permits were sold to motorists on a first-come, first-serve basis. Drivers with permits could use the HOV lanes during all operating hours without meeting the vehicle occupancy requirement. Carpools and vanpools with 2 or more persons continued to use the lanes for free. Initially, the monthly fee was set at $50, and permits sold were held to 500 in number. In February 1997, the limit was increased to 700 monthly passes, and in March the monthly fee was raised to $70. The number of available monthly permits was increased to 1,000 by the end of the Interim Operations Phase in March 1998.

The full Implementation phase, or FasTrak, started on March 30, 1998. This second phase ended December 1999, but FasTrak continues in use as of 2002. FasTrak tested variable fees with electronic toll collection for single occupant vehicle use of the HOV lanes. The fees were based on congestion levels in the general purpose lanes, and ranged from $0.50 to $4.00 under normal traffic conditions. During severe traffic, the fees could go as high as $8.00. Variable message signs are used to display the fees in effect to motorists approaching the lanes. As of July 1998, all 5,000 of the initial transponders had been distributed to 3,700 customers and a waiting list was being maintained. By December 1999, 11,091 transponders had been issued.

New bus service, called the Inland Breeze, was implemented in March 1997 as part of the demonstration. The route connected to the San Diego LRT system at the Fashion Valley Mall Transit Center. During the demonstration peak period service headways were 30 minutes and midday and off-peak service was provided every 60 minutes.

Analysis. A monitoring and evaluation program continued throughout the demonstration phases. The "Traffic Study" collected and analyzed data on traffic volumes and speeds, travel modes and times, violations of the exclusive lanes, and associated quantitative information. The "Attitudinal Panel Study," covering three different commuter groups, surveyed 1,500 persons every six months. The overall evaluation also addressed air quality, delay, business impacts, bus ridership, bus and carpool park-and-ride lot occupancy, media response, public acceptance, marketing and institutional issues. For certain analyses, the nearby I-8 corridor was selected as a control corridor. Comparisons were hampered by that corridor's lack of freeway express lanes, and differing geographic orientation and socioeconomic makeup, but it did serve a similar travel function and offered an indication of which effects were external to the demonstration project.

Results. During Phase I, the total vehicles using the HOV lane increased by approximately 27 percent. Carpools comprised a large share of this increase in vehicles. Use of the HOV lanes by ExpressPass permit holders was less than expected. Fewer than 55 percent of the permits were used on a regular basis. The remainder were used periodically or infrequently. In March 1998, the last month of Phase I operation, pass holders comprised approximately 10 percent of vehicles using the HOV lanes on any given day.

This periodic use by paying customers continued in Phase II, with the majority of FasTrak participants becoming occasional users. From April through September 1998, 53 percent of the FasTrak transponders were used one to five times a month, 18 percent were used six to ten times, 11 percent were used 11 to 15 times, and 19 percent were used 16 to 40 times. Revenues have been lower than projected, but successfully funded operating expenses and the Inland Breeze bus service. During the ExpressPass phase, monthly revenues started at $25,000 and plateaued — after five months — at about $65,000. Revenues during the FasTrak phase at first quickly stabilized at roughly $80,000 a month, and then in 1999, rose to over $100,000 per month.

More use of the Express Lanes was achieved as desired, without detriment to HOV lane level of service. Total I-15 peak period vehicular volumes increased correspondingly, while volumes and traffic conditions on the main general purpose freeway lanes held fairly steady throughout, meeting additional project objectives. These relationships may be seen in Table 14-12 for the years 1996 (before implementation) through 1999 (last demonstration year). Volumes for 1991 are also shown for a sense of trends. Overall I-15 traffic growth during the demonstration proper was about three quarters that of the I-8 control corridor.

Table 14-13 gives October and April Express Lanes volumes with category breakouts. The totals roughly correspond to the express lanes totals in Table 14-12, although the time spans effectively covered do not exactly match, and the original count sources are different. HOV volumes on the Express Lanes jumped when value pricing started, an unexpected phenomenon. Perhaps potential carpoolers better saw the value of free Express Lane travel when others paid for it, or chose carpooling when enforcement was increased. During-project average rates of change (after the initial shifts), determined by regression analysis using the more extensive original data set, were: HOV volumes during Phase I, 81 vehicle growth per month; HOV during the Phase II, 27 vehicle shrinkage per month (ending up well above the starting point). Paid SOV volumes during Phase I, 17 vehicle growth per month; Paid SOV during Phase II, 125 vehicle growth per month. The growth in total Express lane volume averaged about 125 vehicles per month throughout. No major changes in travel speed or travel time were recorded on either the Express Lanes or the general purpose main lanes.

Table 14-12 I-15 Average Peak Period, Peak Direction Vehicular Volumes by Type of Lane Before and During Value Pricing

	6 to 9 AM Peak Period SB			3 to 7 PM Peak Period NB			Total Peak Period/Direction		
Spring of Year	Main Lanes	Exp. Lanes	All Lanes	Main Lanes	Exp. Lanes	All Lanes	Main Lanes	Exp. Lanes	All Lanes
1991	30,400	3,809	34,209	33,797	4,946	38,743	64,197	8,755	72,952
1996	30,834	3,754	34,588	36,893	5,512	42,405	67,727	9,266	76,993
1997	31,561	4,600	36,161	37,397	5,840	43,237	68,958	10,440	79,398
1998	30,548	4,880	35,428	36,653	6,831	43,484	67,201	11,711	78,912
1999	30,909	5,668	36,577	36,624	7,268	43,892	67,533	12,936	80,469

Note: Express Lanes were HOV lanes through November 1996, and HOT lanes thereafter. HOT lane value pricing was initiated under the Phase I ExpressPass program (see "Actions"), transitioning to the Phase II FasTrak program in the Spring of 1997, with April as the first month of FasTrak.

Table 14-13 I-15 Express Lanes Average Daily Vehicular Volumes by Category Before and During Value Pricing

Month	Operating Phase	HOVs	SOV Violators	SOV Paid	Total
October 1996	Before Pricing	7,865	1,351	0	9,216
April 1997	I. ExpressPass	9,141	194	1,018	10,352
October 1997	I. ExpressPass	10,172	250	1,070	11,492
April 1998	II. FasTrak	9,686	881	1,460	12,027
October 1998	II. FasTrak	9,087	1,093	2,435	12,614
April 1999	II. FasTrak	9,651	444	2,900	12,995
October 1999	II. FasTrak	9,836	723	3,604	14,164

Source: Both Case Study tables — Supernak et al. (2001b).

One phenomenon not captured in the above tables, and difficult to explain satisfactorily, was a major decline observed during the demonstration proper in the HOV share of AM peak period, main lane, general purpose traffic. The missing main lane HOV vehicles were in effect replaced by SOVs. Either as a result, or perhaps reflecting an oddity of the final demonstration year count, I-15 did not see a net increase in AM peak period person throughput from the initial to the final counts during the demonstration.

Counts of the corridor park-and-ride lots, including both those with bus service and lots serving park-and-pool activity only, showed large fluctuations in utilization. Overall trends, however, first down and then up, tracked similar trends exhibited by park-and-ride lots in the I-8 control corridor. There was no indication that the value pricing project had been a significant influence on I-15 corridor park-and-ride lot usage.

In August through October 1998, a little over halfway through the demonstration, ridership on the Inland Breeze bus service was averaging between 475 and 500 passengers daily. The new bus line attracted more reverse commute ridership than commuting into San Diego.

March 1998 AM peak period counts showed 99 boardings northbound (the reverse commute direction) and 59 southbound (toward San Diego). Overall I-15 corridor bus ridership grew 9 percent between the Fall of 1996 and the Fall of 1999, compared to a 23 percent growth for the entire San Diego region.

More... An Attitudinal Panel survey covering Phase I, of 500 ExpressPass participants and 1,000 other I-15 commuters, indicated general support for the demonstration. Some 70 percent of I-15 commuters responded that the program was fair to travelers in the HOV lanes and the general purpose lanes. Approximately 95 percent of the ExpressPass respondents drove alone before they purchased a permit, while 5 percent were carpoolers. In the final Fall of 1999 panel survey, over 90 percent of FasTrak customers, over 50 percent of carpoolers, and almost 40 percent of I-15 solo drivers judged the program a success. Customers tended to be middle-aged (more women than men) and to be from two-vehicle households, and to have higher incomes, more years of work experience, more education, and higher levels of home ownership than the general population.

In September 1998, the FasTrak pricing structure was further refined by reducing per trip fees during the shoulders of the peak periods. This was done to create an incentive for users to travel outside of the peak of the peak, and thereby distribute traffic volumes more evenly throughout the peak periods. This change was responded to by FasTrak customers. The average toll paid for inbound morning trips dropped from $2.25 in the Spring of 1998 to $1.77 in the Fall of 1999. FasTrak's variable pricing was able to redistribute some of the paid component of HOV lane traffic from the middle of the peak into the shoulders. Carpoolers reported satisfaction throughout with travel conditions, and Level of Service C was indeed maintained throughout virtually all of the demonstration project.

A post-demonstration public opinion survey of users and non-users of FasTrak conducted in late 2001 revealed overwhelming support for the HOT lanes including operating policies, toll rates, the technology, use of revenues, and proposals for facility extension. These results pertained across users and non-users, and all socioeconomic groups.

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SR 91 Express Lanes, Orange County, California

Situation. The SR 91 Express Lanes (91X) are ten miles of four-lane divided toll highway built in the median of the Riverside Freeway (SR 91) in Orange County, California, in the form of barrier-separated express lanes. There are no on or off ramps on the express facility. The location, which includes passage through suburbs of Anaheim and Yorba Linda, California, is within the westerly half of the only freeway connector across the topographic barrier between heavily suburbanized Orange and Riverside Counties. This is a rapidly growing area. The affected portion of SR 91 was formerly one of the most heavily congested freeway sections in the state, with typical peak period delays of 20 to 40 minutes.

The $134 million project is one of four private, for profit investments of the type authorized by the California Legislature during the 1990s, selected for this location because of an inability to fund improvements quickly through the public sector. The lanes give motorists on the parallel freeway lanes, still significantly congested, the option to pay to use dedicated lanes that normally provide a faster trip. In addition, HOV 3+ users can use the lanes at a 50 percent discount (initially for free).

Action. The 91X Express Lanes opened December 27, 1995, and feature tolls that vary by time of day and day of week. The private operator, free to set tolls within the constraints of a maximum financial return, elected to employ a published schedule. The toll schedule has been adjusted and has become more complex over time. Since the 91X toll collection system is fully automated, it is not difficult to have the tolls changing throughout the day. The range of tolls in 1996 was from $0.25 off-peak to $2.50 during the peak. As of 2001, the tolls ranged from $1.00 off-peak to a high of $4.75 during the evening peak. In 1996, only five different toll amounts were charged. They were based on time of day and whether the trip was made Monday through Thursday, Friday, or on the weekend. In 2001 (taking an example) the Eastbound toll at 6:00 PM was different each weekday, ranging from $3.50 on Monday to $4.25 on Friday, and 16 different toll amounts were charged based on time of day and day of week.

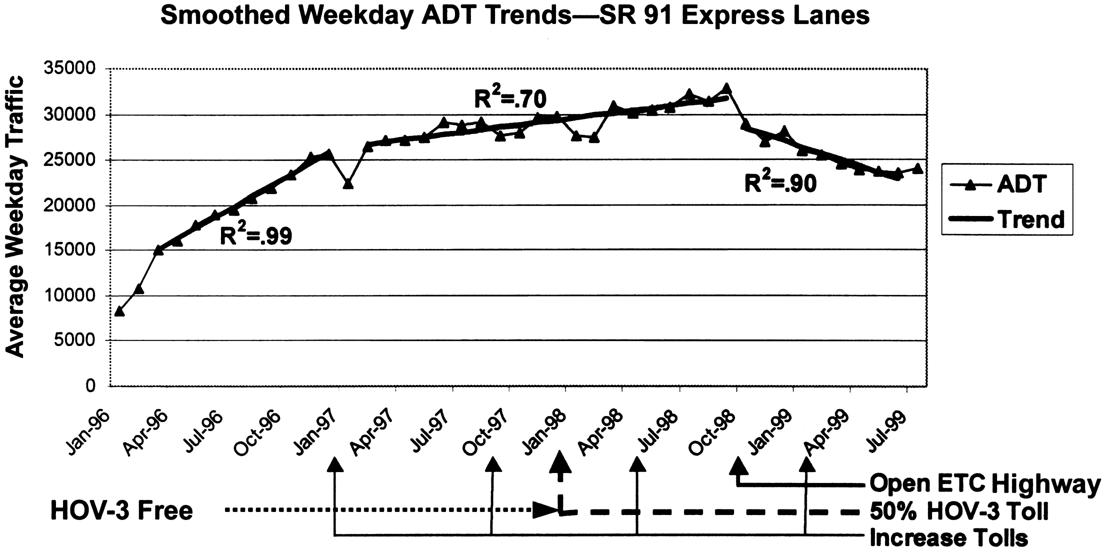
Analysis. There is an extensive data set collected as part of Federally funded evaluations of the SR 91 project. Cal Poly State University has provided the Principal Investigator for these evaluation efforts and produced two major reports which, along with several papers on the subject, describe the observed effects of the Express Lanes. Much of the data is from traffic observations including classification counts collected both before and after the Express Lanes were built, along with results of telephone and other surveys conducted between 1995 and 1999 of highway users, randomly sampled households, and panel samples. Two separate modeling efforts have provided estimates of elasticities. Note that the "corridor," for which selected findings are reported, is not a broad swath. The "corridor" as defined consists of only the SR 91 Riverside Freeway, inclusive of the 91X Express Lanes located in its median.

Results. The 91X Express Lanes provided two additional highway lanes of capacity in each direction, priced to maintain uninterrupted traffic flow. Motorists report being attracted to the toll lanes by the travel time savings, improved driving comfort, and perceptions of improved safety. The result has been improved travel conditions overall, albeit dissipating as traffic grows. The 91X tolls have been maintained at levels sufficient to preserve good levels of service during even the peak periods. For discussion of the actual and perceived travel time savings see the "Underlying Traveler Response Factors" section under "Travel Time Savings" including Figure 14-1.

In the first few months of operation, SOV traffic increased because of mode shifts among prior users of SR 91, traffic moving over to the freeway from city streets and local roads, induced demand — primarily discretionary non-work purpose travel, and continuing development growth in the area. HOV traffic also grew significantly, in part due to direct toll incentives for HOV 3+ motorists, and the opportunity to split tolls for HOV 2 commuters. The initial overall change in average vehicle occupancy (AVO) was downward because of the large number of new SOV users in the narrowly defined travel corridor. Over time the new lower AVO has not changed much, and not much traffic has returned to local roads, but the peak-period non-work travel has declined toward prior levels as congestion has gradually returned to the SR 91 free lanes. The commute trip mode shares on SR 91 (free and toll) in 1999 were 73 percent SOV, 19 percent HOV 2, 7 percent HOV 3+, and 1 percent motorcycle and other.

There were five general toll increases on the Express Lanes between the time that they opened and the Summer of 2000. The first general toll increase, which occurred in January 1997, was followed by a significant and permanent reduction in the rate of Express Lanes traffic growth. Subsequent toll increases, which were less substantial and focused on fine-tuning of the hour-by-hour toll schedule, were not followed by perceptible changes in traffic trends. Opening of an alternative route for some through Orange County, the Eastern Toll Corridor, initiated a decline in 91X traffic that lasted about 9 months. Trends from 1996 into 1999 are shown in Figure 14-2.

Figure 14-2. Traffic growth on SR 91 Express Lanes



Notes: Average weekday traffic (ADT) trend lines shown were developed with regression analysis.

"ETC" is the Eastern Toll Corridor, a nearby toll highway corridor which, for some, is an alternate route.

Source: Sullivan (2000).

It has been argued that the financial success of facilities such as the SR-91 project, where the toll lanes are paralleled by free lanes, depends on the presence of congestion on parallel facilities to induce toll lane use. Indeed, the SR-91 concession agreement includes a non-compete clause that has severely restricted the State's ability to build additional capacity in the corridor. It appears that the ultimate resolution to this and other conflicts is the purchase of the privately owned 91X facility and franchise agreement by a public entity, the Orange County Transportation Authority.

More... Use of the priced lanes has been found to be highly selective. Half of the toll lane users choose to do so once per week or less. The decision to use the lanes is largely related to travel conditions, but other factors contribute. Motorists on business or traveling to or from work are more likely to use the lanes than motorists traveling for non-work purposes. Travelers with higher incomes and education use the lanes more frequently than those with lower incomes and education. Female commuters are about a third more likely than men to make frequent use of the express lane option. The youngest and oldest travelers are less likely than others to be frequent toll facility users.

Demographic information obtained through the project evaluation surveys allows findings concerning the distribution of use across different traveler groups. In this relatively affluent area, the 1999 income distribution of 91X users was 19 percent users from households with less than $40,000 annual income, 23 percent $40,000 to $60,000, 37 percent 60,000 to $100,000 and 21 percent over $100,000. Commuters in the high income group were two-and-one-half times as likely as commuters in the "low" income group to have used the 91X toll lanes for their most recent SR 91 corridor trip in 1996, or to have used a toll facility (91X or the new Eastern Toll Road) for their most recent comparable trip in 1999. Nevertheless, roughly 20 percent of the lowest income travelers had chosen a tolled route for their most recent trip in both years.

The basic associations between income and use of the tolled lanes remained stable between 1996 and 1999, with one notable change: there was a decline from 40 to 25 percent in the percentage of trips by travelers in the $40,000 to $60,000 middle income category made on toll facilities. This suggests a particular sensitivity to the toll increases among these middle income travelers. It should be noted that commuters in the corridor overall are more affluent than the overall urban population of Southern California, and thus caution should be applied in generalizing the results to areas with different demographics.

Price elasticities have been estimated for 91X and the SR 91 corridor based on two separate methodologies and contexts. Observed traffic volume time series trend data have been used to compute elasticities of -0.4 (eastbound) to -0.5 (westbound), based on dampening of traffic growth at the time of the first toll increase. No traffic growth effects of subsequent toll increases prior to opening of the Eastern Toll Corridor highway could be discerned, implying zero elasticity. These elasticities of -0.5 to zero apply to the segment of SR 91 corridor travelers already having chosen to use the 91X toll lanes.

Assembly of SR 91 corridor traveler survey and network data has allowed calibration of travel demand models, including nested logit models of "mode" (SOV, HOV 2, HOV 3+), transponder (to have or not to have) and route choice; and of time of day, transponder and route choice. Approximated point elasticities [shrinkage-ratio-like formulation] for choice of travel via the 91X toll lanes have been derived from the models, ranging from -0.8 to -0.9 for the afternoon eastbound to -0.7 to -0.8 for the morning westbound. These values of -0.7 to -0.9 apply to all SR 91 corridor travelers irrespective of route choice at the time of the surveys, and reflect the response of a broader cross-section of travelers than the segment already having chosen to use the 91X lanes. The relatively high elasticities also reflect the availability of an adjacent freeway alternative, and a high willingness to alter route in response to cost. The same analysis found a quite low sensitivity of mode choice and time of day choice to cost, as was discussed in the "Underlying Traveler Response Factors" section under "User Cost."

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ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
U.S.DOT	United States Department of Transportation