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ABSTRACT

Deep Discount Group Pass Programs as Instruments for Increasing Transit Revenue and Ridership

by

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Transit properties in the USA have historically experienced loss of market share and low levels of farebox recovery. They resorted to service expansion to maximize subsidies. Experience suggests that: (a) fare increases have not had the desired effect; (b) fare reductions can boost ridership but can also reduce revenue and increase subsidies. The challenge lies with the adoption of such strategies as deep discount group pass programs that can produce more marginal revenue than cost. Deep discount transit pass programs provide groups of people with unlimited-ride transit passes in exchange for a contractual payment for or on behalf of pass users by an employer or other organizing body.

Although successes of deep discount group pass programs are documented, there is substantial skepticism toward their wide-scale deployment because transit management perceives them as “special treatments” or “favors” to participants. Management fears such perception could raise questions about equity because they fail to see the fundamental difference in the fare structure of the “group pass” from individual ticket purchases. Group passes operate in a manner analogous to insurance programs.

The deep discount program cases studied consistently revealed either higher revenues per boarding than the system-wide average or higher total revenues from target markets with the program than without it. Employment-based programs yielded the highest net revenues to operators.

Although agencies recognize the factors for price determination, research reveals that no systematic methodology exists and pass prices are largely determined by watching what others have done. This dissertation has developed a methodology to aid operators in determining deeply discounted but favorable pass prices. The methodology considers: revenue lost from existing riders at prevailing fares; level of patronage in the primary location of transit use; any additional costs necessitated by the program; attractiveness of program terms to participants; and a policy goal of increasing operating revenue. The methodology permits the investigation of alternative objective functions and thus can serve as a common tool for transit agencies, employers and other constituents who may choose to maximize or minimize either the price of the pass or the number of participants subject to sets of constraints.

DEDICATION

To my children, Taylor Awo and Collin Kofi, who bravely and patiently endured my absence

And

In loving memory of my parents, Agatha Akorshiwor and Gabriel Kormla, who did not live to witness the eventful day.

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1. INTRODUCTION

1.1 PREAMBLE

Transit ridership in the U.S.A. declined precipitously over the last half century necessitating steep subsidies to keep it operational. Despite transit's poor financial performance, society has compelling reasons to maintain public transportation. However subsidies have escalated and may not be sustainable. There is also an ethical obligation to use public subsidies to increase efficiency. Thus it becomes necessary to find innovative ways to finance transit operations. One form of innovative financing is the "deep discount group pass" (DDGP). The DDGP is similar to the monthly transit pass in common use around the nation. Its differences from the regular monthly pass include the fact that the DDGP always allows unlimited use, it is sometimes issued for longer periods of time, it often covers all members of a group and it charges very low fares per use relative to other forms of transit fare media.

This study postulates that the deep discount group pass may be an instrument for increasing operating revenues and hence system efficiency. Everything else being equal, the more revenue that is raised, the less society might need to subsidize operations.

The aim of this study is to find a way to increase operating revenues and thus transit system efficiency. However, the proposed method, the deep discount group pass, can also increase ridership. Thus is the origin of the title of the research. It is estimated that only about 27% of seat-miles on transit vehicles are in use nationwide (Brown, Hess and Shoup, 1999). There are major variations in occupancy between metropolitan areas and by time of day. Most of the operating cost is incurred in moving vehicles up and down the service routes. In many circumstances, increase in ridership would mainly fill up available capacity. If ridership increases in the cases where capacity is under utilized, one would expect it to result in minimal marginal cost, if any. If so, it would increase system efficiency.

1.2 RESEARCH PURPOSE

This dissertation is a policy study into the modus operandi and effectiveness of deep discount transit pass programs. Broadly, this research is interested in finding out (a) how the programs work; (b) changes in travel behavior of those to whom the pass becomes available; (c) impacts on and implications for parking; and (d) the costs and benefits to providers and recipients of the programs. In addition, this study has sought to develop a methodology for setting pass prices.

1.3 CONTRIBUTION TO SURFACE TRANSPORTATION POLICY

The main contributions of this dissertation to surface transportation policy are twofold:

1. First this research has identified one transportation problem that is widespread in the nation and decided to investigate one possible solution. While the primary motivation is to find a way to increase operating revenues and thus transit system efficiency, the proposed method, the deep discount group pass, can also increase ridership.

2. Second, this research has developed a methodological tool for setting prices for deep discount group passes that would ensure no net loss in revenue to transit agencies. The key lies in deeply discounted yet favorable pass prices.

1.4 ORGANIZATION OF THE DISSERTATION

The remainder of this dissertation is organized as follows:

- Chapter 2 describes the background and motivation for the research. It also includes definitions of key terms used in this dissertation.

- Chapter 3 is a review of previous studies that include both program reviews and general transit agency case overviews. Transit industry case reviews looked at the historical dynamics of fares vs. ridership levels in the Los Angeles and New York transit systems and at historical trends in net revenues vs. subsidies in the Boston and Chicago transit systems. Deep discount case studies included reviews of past programs at Connecticut, Ottawa, and Columbus as well as modern day programs covered by the case studies of this research. The literature review differentiated between <u>general discount fare</u> programs and true <u>deep discount group pass</u> programs. The latter is the subject of this dissertation.

- Chapters 4, 5 and 6 set the theoretical framework for the study. This intellectual overview is an extension of the literature review and covers theories and issues related to the subject of pricing in transit. The discussion in Chapter 4 therefore covers such topics as: the case for and limitations of marginal cost pricing in transit; the case for and limitations of Ramsey pricing in transit; marginal cost vs.

price discrimination in transit; traditional methods of cost recovery in transit; why transit operates at a loss; and the concept of opportunity cost in relation to deep discount programs. In Chapter 5, the review draws analogies between deep discount pass programs and existing concepts on insurance and risk pooling, which explain how the programs can result in increased revenue. Chapter 6 explains through the economic concepts of elasticity, income and substitution effects how the programs can result in increased ridership.

- Chapters 7, 8 and 9 cover areas of original research contributions that involved review and analyses of operating and survey data to glean lessons from three major case studies that represent the key types of deep discount programs in existence. Chapter 7 covers the assortment of programs systematically introduced by the Denver Regional Transportation District (RTD) over a period of about a decade, beginning in 1991. The RTD programs fall into four categories: the *employment-based ECO Pass*, the *Neighborhood ECO Pass,* the campus-based *College Pass*, and the *TeenPass* that is sold through middle and high schools. Chapter 8 is a case study of the University of California Student Class Pass program offered by the Alameda-Contra Costa (AC) Transit District. Campus-based programs are by far the largest and most rapidly expanding group of deep discount programs around the nation. Chapter 9 is the case study of the City of Berkeley Employee Eco Pass program also offered by AC Transit. The City of Berkeley program uses the magnetic dip fare card, a novelty with such programs that offers opportunities for rich travel data on program participants.

- Chapter 10 is an evaluation of policy implications that documents the effects of deep discount pass programs in terms of pertinent policy questions on: the terms and conditions of the programs; effect on mode choice; direct operating and maintenance cost implications; net revenue effects; effect on parking; effect on the environment; opinions, perceptions and equity concerns; and benefits to providers and recipients. Ultimately, the various policy questions translate into effects on the use of transit and the automobile. This in turn has implications for parking and for the costs and benefits to service providers and recipients.

- Chapter 11 presents the proposed pricing methodology. The objective of the methodology is to safeguard at least and preferably increase revenue receipts following implementation of the program. The safeguard is ensuring that the new revenue received from a qualified group is higher than the sum of the revenue lost from existing transit riders in the group and the additional operating costs associated with program implementation.

- Chapter 12 presents the conclusions of the dissertation and suggests directions for future research to complement this work.

- The key references used in this dissertation follow the last chapter. They are organized into four groups covering: (a) evaluations of deep discount programs; (b) the evolution and reviews of transit in the USA; (c) pricing; and (d) choice modeling. Inevitably, some references appear in more than one group.

- Finally, there is a comprehensive section of appendices that present data and details of analyses. The materials are identified for specific chapters and cover: the literature review, Chapter 3; the areas of original research contributions that include the case studies, Chapters 7, 8 and 9; as well as the evaluations, Chapter 10; and the proposed methodology, Chapter 11.

2. BACKGROUND & MOTIVATION

2.1 DEFINITION OF DEEP DISCOUNT PROGRAMS

Deep Discount Transit Pass Programs provide a group of people with unlimited ride transit passes in exchange for some contractual payment for or on behalf of pass users by an employer, other governing body or other organizing body. The deep discount transit "group pass" program is one of various forms of unlimited-use transit pass programs in operation around the country. They are termed "*unlimited-use*" because transit patrons do not have to make on-the-spot payments every time the service is used within the period defined for the specific program. A transit patron can pay $3.50 for a "day-pass" in the Baltimore metropolitan area to gain unlimited use on that day of bus, light rail and Metro rail transit services operated by the Maryland Transit Administration. For a rider expecting to make more than two one-way trips a day, this pass is a bargain when compared to the one-way transit fare of $1.60 as of mid 2003. There are weekly and monthly versions of such tickets that allow unlimited use over the respective periods. The weekly pass costs $16.50. A rider who uses transit five days a week saves $1 (or 5%) over the daily pass rate. At $64.00, the regular monthly pass offers the four-week-a-month user an additional $2 savings (or 3%) over the weekly pass and a total of $6 (or 8.5%) over the daily pass. Beside the regular urban area transit services, similar discounts exist for Express and Commuter services. The common term for these unlimited-use, periodic tickets is the "*pass*" from the fact that they allow the user to pass a conductor or turnstile on entry into most transit vehicles without per-use fee or fare.

The deep discount "*group pass*" is similar to the monthly pass with the following modifications:

- The period of permitted, unlimited use typically is longer than one month.
- The pass is often provided to all members of a group rather than individuals, hence the term "group".
- The cost of the pass per user is very low relative to per-ride fares and daily or monthly passes, hence the expression, "*deep discount*".

2.2 TYPES OF DEEP DISCOUNT PASS PROGRAMS

There are various versions of deep discount pass programs. They may be categorized into four broad groups as follows:

1. *University campus-based programs* ~ These always include students and sometimes also include faculty and staff. The pioneers and most widely documented examples include the U-PASS at the University of Washington, Seattle and the UPASS at the University of Wisconsin, Milwaukee. The ClassPass program at U.C. Berkeley and BruinGO at U.C. Los Angeles were recently introduced in California.
2. *Employment-based programs* ~ These exist in more than a dozen metropolitan areas. One of the oldest and most widely documented is the ECO Pass program in Denver, Colorado. In California, the Santa Clara Valley Transportation Authority (VTA) offers this type of program to Silicon Valley commuters and AC Transit offers it to employees of the City of Berkeley.

3. *Residential-based programs* ~ These are offshoots of the employment-based programs. One of the oldest is the Neighborhood ECO Pass program in Denver, Colorado. In California, the VTA offers this type of program to residents of Santa Clara County.

4. *Student pass programs* ~ These are variants of the campus-based programs. They typically cover middle and high school students. They are offered in Denver, Colorado as the TeenPass and to eligible students in New York City as the Student Metrocard.

2.3 PROBLEM STATEMENT

It is well known that transit patronage declined dramatically in the United States over the last 5 decades. At its peak in the 1940s, transit registered an annual ridership of 24 billion passengers. Currently transit use has fallen to an annual ridership of fewer than 9 billion passengers. Transit ridership is therefore relatively low, catering predominantly to either those captive of it or such selected trips as work trips during the peak in highly congested urban corridors. Thus demand for transit tends to be inelastic. Most transit use occurs in urbanized areas where it is most feasible to provide the service. Its use is highest in the densest, most urbanized areas where the services are most readily available.

With declining ridership, transit service became highly subsidized. In 1974, operating subsidies were added to the various federal assistance programs for transit with a 50% matching ratio from the combination of farebox, state and local sources (Wachs, 1989). Total subsidy at the national level ranged nominally from $1.4 billion in 1975 to a peak of \$10 billion in 1992 (APTA, 2000). In constant 1983 dollars, the range is from \$2.6 billion in 1975 to almost a three-fold peak of \$7.1 billion in 1992. In order to stem the tide of escalating subsidies, federal assistance has been restrained over the years resulting in its contribution to operating assistance declining nominally from a peak of \$1 billion in the early 1980s to approximately \$ 0.7 billion by 1998. In constant 1983 dollars, the decline is from a peak of \$1.2 billion in the early 1980s to nearly a third of approximately \$ 0.43 billion by 1998. Since 1992, the federal share of operating assistance has been 10% or less with the remainder from state and local sources including farebox recovery.

At the national level, fare revenue accounted for 36% (1983) to 53% (1975) of total operating costs. Historically, fare increases have typically led to declines in ridership in favor of the private automobile. Sometimes a vicious cycle ensues when fare increases lead to declines in patronage that lead to service cutbacks that lead to further declines in patronage that necessitate further fare increases or service cutbacks.

Community Issues ~ In recent years, the focus of community planning has been changing. Issues of key importance include concerns about environmental pollution, livability and sustainability. Such concerns lead to proposals for increased use of shared transportation and lessening dependence on the automobile.

Transit dependency ~ There are people who cannot drive and for whom some form of public transportation must be provided. These include the very young, the very old, and the disabled. There is also a significant segment of the populace classified as “poor” who cannot afford personal means of transportation, but whose mobility needs have to be met. In California, for instance, the 2000 Census reveals that one out of three households that earn an annual income of $10,000 or less did not have a vehicle available for work travel. Similarly, one out of five households that earn an annual income of $25,000 or less did not have a vehicle available. By comparison, less than one out of twenty households that earn an annual income greater than $25,000 did not have a vehicle available.[1] Public transit is often the only choice for many in this category.

Circumstances ~ There are many circumstances when the need exists for high capacity transportation. These include travel along congested urban corridors and travel into the CBD especially at periods of peak travel demand. Public transit is the right option to serve these types of needs.

These reasons include why governments have tried to maintain transit service with subsidies. However subsidies have escalated and may not be sustainable. In Boston, for instance, the shortfall between passenger revenue and transit agency costs increased nominally from $21 million in 1965 to $575 million in 1991.[2] In constant 1983 dollars, the increase is from $67 million in 1965 to $422 million in 1991, that is, 6 times in 26 years. In his 1996 study of the phenomenon, Gomez-Ibanez noted "there has been little political will or incentive to date to adopt measures that might help to control the deficit without greatly reducing ridership". He concluded that without deficit control measures "cities like Boston may soon find they cannot afford to maintain transit ridership". This is why it becomes necessary to find innovative ways to finance transit operations.

The successes of various deep discount pass programs are extolled in reports and articles. However there is substantial skepticism on the part of the management of transit agencies toward their adoption and wide-scale deployment. Discussions with operators revealed the following:

- Management is not generally convinced of the efficacy of the program. Rather it is considered a “special treatment” or “favor” to a segment of the population. They fear the perception of special treatment could raise questions about equity. An operator would make such an argument by comparing the $5 a month charge per person per month for the City of Berkeley ECO Pass with the regular monthly pass rate of $50 each. By such comparison, AC Transit offers the ECO Pass to the City of Berkeley at 10% of the regular rate or 90% discount. Similarly, Santa Clara VTA offers the pass at 20% of the regular monthly rate to Silicon Valley commuters. Comparisons with regular fares are interpreted as discounts that are easily misconstrued as special treatments because the argument fails to see the fundamental difference in the fare structure of the “group pass” from individual ticket purchases. The group pass covers a large number of people and is paid for the whole year in advance whether the service is going to be used or not. In this regard it operates similar to an insurance scheme, which can charge a relatively low premium as membership in the pool grows large and yet be profitable. Take the City of Berkeley case for example. Surveys revealed that 6.2% of all employees commuted to work by AC Transit before the ECO Pass program; (6.2% of 1938 employees is approximately 120 people). As detailed later in Chapter 9, if infrequent riders purchased an average number of rides while regular riders purchased the monthly pass, the estimated lost revenue would be approximately \$2,410 a month. In comparison, the City pays the equivalent of (1330 * \$5) or \$6,650 per month for all months of the year. This would translate to net revenue of \$4,240 a month, approximately 175% increase over previous fare revenue. For offering the program therefore, AC Transit would realize a net annual increase in revenue of approximately \$50,880 from that market. This illustrates the potential of the program to increase operating revenue for transit agencies. If the programs necessitate additional operating costs, these added costs would need to be considered in setting the prices for the passes.

- Discussions also revealed that the methods of determining the prices of passes are not very systematic. Prices are determined by combinations of the following:
    - Watching what others have done under similar settings
    - Considering the level of transit service available at the destination location
    - Recognizing the cost components of implementing the programs, which include operation, maintenance, marketing and administration.

It appears the key ingredients of determining the appropriate price are recognized. However the literature and discussions reveal that no formal methodology is established for price determination. That is why this study has sought to establish a methodology for determining the prices for deep discount group passes that would safeguard against net loss in revenue to transit agencies.

2.4 THE CONCEPT OF EQUITY

With deep concern by transit management about issues of equity, it is appropriate to do a brief review of the concept of equity in relation to deep discount programs. Equity is defined as "fairness in the distribution of goods and services (among the people in an economy)". [3] In the context of transit fares, equity may be defined as how just pricing is among various constituents of riders. There are three common criteria for judging equity as follows:

1. *The benefit criterion* asserts that people should pay for services in proportion to the benefits they receive from them. Going strictly by this, transit riders would pay for individual rides according to a benefit such as time savings enjoyed relative to the next best alternative means of travel available to the riders. This is virtually impossible to measure for individual riders.

2. *The cost criterion* asserts that people should be charged for the use of the transit services in proportion to the cost they impose on the transit system. This is complex to determine for individual riders, but may be captured through time of day and location-based pricing. If a deep discount pass reflects costs implied in its implementation, then it satisfies this equity concept of "cost imposed".

3. *The ability to pay criterion* asserts that people are charged for the use of transit in proportion to their wealth. While this may be partially achieved by charging lower fares to such groups as the youth, the elderly and the handicapped, there is no guarantee that the actual rider in the group is economically disadvantaged.

Equity is sometimes viewed from the perspectives of (a) the *equality of outcome*; and (b) the *equality of opportunity*. The deep discount pass has the potential to provide equality of opportunity either because it is available to all members of a target group or it is available to many groups via the work place or residential location. If the program is offered, it is then left to potential participants to organize and take advantage of the opportunity it offers. Wide scale deployment of deep discount programs in a transit service area can therefore provide equality of opportunity.

3. HISTORICAL DYNAMICS OF TRANSIT IN THE USA

3.1 TRANSIT PRODUCTIVITY AND AGENCY RESPONSES

A very low level of productivity characterizes transit service in the USA. For instance Brown, Hess and Shoup calculated at the gross national level that passengers occupied no more than 27% of available seats on urban transit buses in 1998.[4] On average therefore, there are approximately 11 passengers on board the average 40-seater bus for every revenue mile of bus service. Thus there is excess capacity to be utilized. This fact alone would largely explain why at the national level transit operating ratios fell below 50% and has hovered around 40% since 1980.[5]

Historically, transit agencies have resorted to two types of responses when faced with loss of ridership:

1. *Service improvement* – this is typically an attempt to make transit more attractive, but has proven to be expensive without yielding commensurate returns. For instance, to improve service, some transit agencies constructed new rail systems that operate on exclusive rights-of-way. However Don Pickrell's comparison of actual and forecasted figures for eight urban rail transit projects in the USA revealed that seven cost much more than expected by 17% to 150% and seven achieved less than half the forecasted ridership. [6]
2. *Fare reduction* – this is also intended to make transit more attractive per popular economic theory. As explained in the next section, it is typically inexpensive to

implement and has proven to be popular with riders. There is, however, the concern that fare reductions can lead to lower revenues and higher subsidies

As outlined in the next section on case overviews, studies have shown that the latter of the two responses might be the better policy to pursue. It is worth noting, however, that goals differ from project to project so that what is considered "better" may depend on more specific goals.

3.2 CASE OVERVIEWS OF AGENCY RESPONSES

Studies of transit operations in major cities in the USA reveal the following:

Boston ~ Gomez-Ibanez (1996) studied the experience with transit agency responses in Boston and concluded "fare reductions are a significantly less costly method of retaining ridership than service expansions".[7] He modeled alternative deficit and ridership projections for 2010 using a "more complex version" of formulas first developed by Don H. Pickrell (1985) in his study of why industry-wide transit operating deficits increased during the 1970s. Termed the deficit accounting model, it was estimated with 1970-1990 data and used to project ridership and deficits for 2010 under a variety of policy scenarios. Results for scenarios related to fare reduction and service expansion are compared in Table 3-1.

The following are noteworthy:

- Fare reduction would result in slightly more ridership (170 million trips) in 2010 than service expansion (166 million).
- Fare reduction resulted in \$313 million lower nominal deficit than service expansion.
- In 1990 dollars, fare reductions would add 9% to the deficit while service expansions would add 41%.
- In 1990 dollars, fare reductions would add \$2.60 per ride retained to the deficit while service expansions would add \$10.68 per ride retained.

Thus his conclusions that fare reductions are a significantly less costly method of retaining ridership than service expansions. He noted, however, that both fare reduction and service expansion are less likely to be effective in retaining ridership in the future than they were in the past.

Table 3-1: Comparative 2010 Projections of Transit Agency Responses: Case Study of The Massachusetts Bay Transportation Authority (MBTA), Boston

	Ridership		**Nominal Deficit**		**Real (1990) Deficit**		
	Millions	*Change from 1990*	*Millions (\$ 2010)*	*Change from 1990*	*Millions (\$ 1990)*	*Change from 1990*	*Increase per ride retained*
Base 1990	177	--	440	--	440	--	--
Fare reduction @ -2.7% per year	170	-4%	1,047	+138%	478	**+9%**	\$2.60
Service expansion @ +1.6% per year	166	-6%	1,360	+209%	621	**+41%**	\$10.68

Source: Gomez-Ibanez (1996), Table 7, p45

Chicago ~ Savage and Schupp posited in a study of transit service in Chicago "it is more advantageous to use subsidy monies to reduce fares than improve service levels".[8] Similar to Boston, the financial performance of the Chicago Transit Authority (CTA) deteriorated nominally from an $84 million operating surplus in 1948 to a $458 million operating deficit in 1997 (Savage, 2002). In constant 1983 dollars, the deterioration is from a $349 million operating surplus in 1948 to a $285 million operating deficit in 1997. Savage and Schupp agreed with the widely held economic notion that the advent of subsidies gave transit agencies the latitude to choose between many combinations of prices and levels of service in satisfying their budgets. The preferred combination could aim at maximizing social welfare in terms of the number of passengers carried or the amount of service provided. The authors concluded from their empirical analysis of half a century of transit operations in Chicago that the agency opted to maximize level of service as opposed to the number of passengers carried. They asserted from their economic analysis therefore "the public would be better off if service levels are reduced and the money saved channeled into lower fares".

New York City ~ It is reported that New York City lowered transit fares in the late 1990s, which led to a surge in ridership (Hirsch, Jordan, Hickey and Cravo, 1999). Besides half-priced elderly and handicapped fares, New York City was a relatively recent entrant to the practice of discount pricing of transit services, having maintained flat fares with limited transfer opportunities for almost a century. Between mid 1997 and the beginning of 1999, New York's transit operators successively adopted fare incentives that produced "greater-than-expected ridership increases". Operators are New York City Transit

(NYCT) of subway and bus and seven franchised carriers of the New York City Department of Transportation (NYCDOT), which provide additional bus services. Following a 3-year period of installing automated fare collection technology system-wide, the following fare incentives were introduced within a period of one year:

a) Free intermodal transfers offered varied levels of attractiveness. A typical commuter from outside Manhattan, for instance, who paid two flat fares one-way to work downtown, now enjoys a 50% discount on the same trip by paying one fare.

b) The MetroCard bonus program offered a 10% discount on fare cards of $15 or more, the equivalent of one free trip for ten trips purchased.

c) Express Bus fare reduction by 25% from $4 to $3

d) Unlimited-ride regular MetroCards for $4 per day, $17 for 7 days (at 13 trips to break-even) and $63 for 30 days (at 47 trips to break-even) as well as 30-day Express Bus pass for $120 (at 40 trips to break-even).

e) Student MetroCards that allow 3 trips and 3 transfers per day replaced the flash cards previously used by eligible students.

Comparing the first half of 1997 (the "before" situation) with the first half of 1999 (the "after" situation), the following are noteworthy:

- Weekly non-student ridership rose by 12% on the subway and 40% on buses during a period when New York City employment grew by 5%. Table 3-2 summarizes the annual rates of change in ridership with the introduction of various fare discounts. The convenience of the MetroCard, a "pass", over exact fare payment contributes to the initial rates of increase of 8% on weekdays and 9% on weekends, but the series of discounts offered through the fare incentives constitute most of the large ridership increases of 20% on weekdays and 24% on weekends.

Table 3-2: Annual Rates of Change in New York City Non-Student Transit Ridership

Period of Comparison		Fare Incentive	Percent Change		
From	**To**		**Employment**	**Weekday Ridership**	**Weekend Ridership**
Mar 1996	Jun 1997		1.8%	0.9%	1.8%
Jul 1996	Dec 1997		2.5%	7.8%	9.0%
Jan 1997	Jun 1998	Free transfer with bonus	2.6%	10.2%	10.6%
Jul 1997	Dec 1998	Unlimited ride and bonus	2.2%	9.3%	13.8%
Jan 1998	Jun 1999	Unlimited ride	2.2%	9.2%	12.1%
Jan 1997	Jun 1999	**All fare incentives**	**4.9%**	**20.3%**	**24.0%**

Source: Hirsch et al, 1999, Table 1, p151

- Customers using unlimited-ride MetroCards increased their trip-making disproportionately on weekends. This makes a good case for discounted travel during off-peak when there may be excess capacity.

- The 7-day MetroCard was more popular than the 30-day card by a ratio of 3 to 1 despite the lower unit cost of the latter. Surveys revealed that many customers either consider the lower fare card a less risky investment in case of theft or loss or did not have the cash outlay for the other. Due to the convenience of the "pass", MetroCard share of fare media in June 1997 was 23%. With the addition of fare discounts, the total share of all types of MetroCards rose to 75% in June 1999. See Table 3-3.

Table 3-3: Market Shares of Fare Media

Fare Media	June 1997	June 1999
Single ride fare	77%	25%
Regular MetroCard	23%	14%
Bonus MetroCard	--	30%
30-day Pass	--	7%
7-day Pass	--	22%
1-day Pass	--	2%
Total	100%	100%

Source: Hirsch et al, 1999, Figure 11, p156

These successes occurred at a cost to the transit operators. In order to accommodate the increases in ridership, annual subway seat-miles increased by 10% from the 1996 level of 293 million with a $300 million capital investment. Annual bus vehicle-miles increased by 11% above the 1996 level of 88 million with the addition of 631 peak buses to the 1996 base of 3,078.

It is interesting to note that the average adult fare decreased 21% from $1.35 in June 1997 to $1.08 in June 1999 with the discounts while ridership increased by 20% on weekdays and 24% on weekends. It is arguable that by their actions transit operators in New York attempted to maximize social welfare in terms of the number of passengers carried. The average weekday ridership exceeded 4 million unlinked subway trips, 2 million bus trips and half a million student trips for an estimated total of 5 million linked weekday trips.

Los Angeles ~ Thomas Rubin reported that there was a period when bus fares were lowered in Los Angeles. The reduced fares led to increased ridership and higher total revenue.[9] Table 3-4 summarizes trends in bus fares and ridership in Los Angeles County, California in slightly over a decade. In the mid 1970s, the cash fare for a bus ride was lowered from $0.30 to $0.25. During the ensuing period of two years, ridership increased sufficiently to make up for the lower fare charged per passenger so that total revenue increased (Rubin, 2000). The fare reduction is analogous to discounting, which resulted in increased total revenue.

Table 3-4: Trends in Bus Fares vs. Ridership in Los Angeles County

Fiscal Year	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**
Fare ($)	0.30	0.25	0.25	0.35	0.40	0.45	0.55	0.65	0.85	0.50	0.50	0.5
Bus Ridership (millions)	218	310	282	316	345	366	397	389	354	416	466	497
Change from previous year	--	92	-28	34	29	21	31	-8	-35	62	50	31
% Change	--	42%	-9%	12%	9%	6%	8%	-2%	-9%	18%	12%	7%
Fare Impact[1]		++	++	*	*	*	*	↓	↓	#	#	#

[1]**Notes -- The Impact of Fares on Revenues and Ridership:**
++ ~ Additional revenues from increased ridership more than compensated for lower unit fares
* ~ Ridership continued to increase even as fares were steadily increased
↓ ~ Decline in ridership following further fare increases
~ Dramatic increase in ridership following the introduction of deep discount fares

Source: Thomas Rubin, 2000; pp 7-15 & Figure 9

As buses became overcrowded, service was expanded with attendant increase in operating costs. In the late 1970s, a series of upward adjustments were made annually to the fares. Ridership continued to increase despite the fare increases because Los Angeles County was experiencing a major shift in its demographic composition with rapid increases in the population of minorities who tended to patronize transit service. However ridership began to decrease in the early 1980s as fare increases continued. These fare increases may be viewed as deviations away from discounting and they eventually led to decline in ridership.

Yet another period of discounting, large enough to be considered a deep discount, was introduced in conjunction with the passage of 'Proposition A', which gained 54% of voter approval in the November 1980 elections. The Los Angeles County Transportation Commission Ordinance 16 (Proposition A) imposed a ½ cent sales tax in the county to be dedicated to transit. The proposition included the provision that bus fares would be reduced and held at $0.50 per ride and at $20 for the monthly pass during the first three years of sales tax collection. Up to 35% of the tax receipts were to be used to fund the discount fare program. By the end of the third year following the deep discount fares (1985), ridership that was previously declining had increased by 40% or 143 million annual boardings. This was termed the "greatest increase in transit utilization over a comparable, non-wartime period in the United States" (Rubin, 2000). The increase in bus ridership was the equivalence of the fifth largest bus operations or the tenth largest transit system in the United States in 1985. Funding of the deep discount program required slightly less than 20% of the 'Proposition A' sales tax receipts.

When the three-year period elapsed and fares were increased, ridership began to decline. The Los Angeles experience with the cycle of fare discounts and fare increases with attendant changes in ridership partially illustrates the fact that fare discounts can attract ridership without increasing subsidy. It also supports the case for a careful administration of a deep discount program.

3.3 ELASTICITIES AND IMPACTS

In 1980 the Urban Mass Transportation Administration (now Federal Transit Administration) conducted a comprehensive study of transit fare and service elasticities.[10] The report noted that there are “significant differences in fare elasticities . . . for different periods of the day or week or type of service, service locations, trip lengths, trip purposes and ages of the transit riding population”. Table 3-5 compares a sample of the fare elasticities reported in the study. As shown, average off-peak fare elasticity is approximately twice average peak fare elasticity. Similarly, fare elasticities for school and shopping trips are at least twice the fare elasticity for work trips.

The report posited that fare policies that take into account these differences could be designed to increase transit revenue with minimum disruption to patronage. The report suggested that fares could be increased during peak hours but reduced during the midday to result in a net revenue increase at no loss in total ridership. This would occur because the higher fares charged during peak periods would result in loss of fewer passengers than would be gained by proportionally lower fares charged in the off-peak.

Table 3-5: Comparison of Selected Fare Elasticities

Type of Fare Elasticity	Components	Average Elasticity	Standard Deviation
Time of Day			
	Peak Period	-0.17	± 0.09
	Off-Peak Period	-0.40	± 0.26
Trip Purpose			
	Work	-0.10	± 0.04
	School	-0.19	± 0.44
	Shopping	-0.23	± 0.06

Source: Mayworm et al (1980), p xi

In his review and synthesis of transit pricing a decade later, Cervero (1990) made the following observations, among others:

- "Prepayment schemes have met with success in the U.S. and Europe". It is worth noting that a deep discount pass is a form of "prepayment" scheme.

- Some of the more noteworthy fare policy successes in North America have been discount programs. These include the following:

1. <u>In Connecticut, Bridgeport's combined pass-fare program</u> (1981) – The "Fare-Cutter Pass" was introduced to reduce the revenue losses associated with unlimited use passes at the time. The $15 a month pass was valid at all times along with a $0.25 extra fare. Officials estimated that the program reduced pass-related revenue

losses by 50% during the first year (Oram, 1983). Overall the program increased revenue yields while maintaining bargain rates for frequent users.

2. In Pennsylvania, Allentown's deep discounts -- Pre-paid, 10-ride strip tickets and tokens were offered for $5 a pack at a 50 percent discount over the adult cash fare of $0.75 each ($7.50 for ten). After six months, the transit agency recorded a 10% increase in farebox revenues, a 5% increase in ridership and a 14% decrease in deficit per rider compared to the same month a year earlier. (Oram, 1989). Prepaid rides rose from 37% to 67% of all trips with the largest ridership gains among infrequent users.

3. In Canada, Ottawa's major fare reduction and differentiation – Up to 1987, transit fares were indexed to the rate of inflation and increased commensurately once or twice a year in order to meet a 75% cost recovery target. In 1987 officials lowered the adult cash fare by 37.5% from $1.20 to $0.75 ($ Canadian), but introduced peak period surcharges and zonal fares and raised downtown parking rates. Within a year, revenue receipts increased by 5%, ridership remained steady while the share of off-peak trips by transit rose from 52% to 62% compared to the same period a year earlier. (Bonsall, 1988)

4. In Ohio, Columbus's substantial midday discount – In 1981 Off-peak (9:30 a.m. to 3:00 p.m.) and weekend fares were lowered by almost 60% from $0.60 to $0.25 while services within 2 square miles of downtown were fare-free. Within the first

month, ridership to downtown increased by 200% while midday ridership more than doubled. (Cervero, 1985). From 1981 to 1985, system-wide ridership rose 14% while midday ridership increased from 36% to 48% of total daily patronage. Although passenger revenues fell, officials asserted that this was more than offset by the increase in sales tax revenues dedicated to transit. The transit system's cost recovery ratio increased by 7% within the first four years of the program.

Essentially therefore, experience suggests that fare reduction is certainly a way to boost ridership. However, if not selectively implemented, it can also reduce revenue and necessitate increase in subsidy. The challenge lies with implementing fare reductions without reducing revenue. That is what a well-crafted deep discount program is hypothesized to achieve.

3.4 SELECTED DEEP DISCOUNT GROUP PASS PROGRAMS

The literature includes quite a few publications dated from the 1980s on the subject of deep discount passes. The attraction of these various forms of discounted fare instruments is that no public subsidy is required to cover the additional rides if they use existing capacity. The added fare revenue instead would help reduce the need for public subsidy.[11] However, if additional capacity is needed, the program will induce both additional investment in capital and associated increase in operating costs. This is why a well-crafted program has to be directed at appropriate target groups. Such groups include those whose travel needs occur most often outside periods of peak travel demand. The studies are overviewed in the following sections.

3.4.1 General Deep Discount Fares

Richard Oram conducted some of the earliest studies in which he specifically discussed "Deep Discount fares" that referred to reduced fares for single-rides, token packs and monthly passes. Oram (1988) discusses deep discount fare strategies that relate to the purchase of multi-ride tickets or tokens. Oram (1994) includes a review of experience in 17 US cities that are again reduced fares but not the modern trend of unlimited ride group passes. From these studies, Oram was able to identify the long list of "Benefits of Deep Discount Fares" shown in Table 3-6 (Oram, 1988, 1990). Many of these benefits are echoed today for the newer group-pass programs.

Oram (1994) concluded from his series of studies: "deep discounting has shown that it is possible to raise transit ridership and revenues simultaneously with a combination of higher cash fares and deeply discounted tickets or tokens."

Daniel Fleishman's (ca. 1993) "Recent Experience with Deep Discounting" draws on previous work by Oram. It also looks at the traditional discounting of fares rather than group passes. He traced historical trends from the early 1980s to the early 1990s in ridership versus revenues for four major transit systems: the CTA in Chicago, SEPTA in Pennsylvania, RTD in Denver and Metro in Madison. He concluded that deep discounting of fares "resulted in positive ridership and revenue impacts indicating that it offers potential to meet revenue targets while avoiding the ridership loss that invariably accompanies a general fare increase".

Table 3-6: Summary of Benefits of Deep Discount Fares

Transit Operators •provides a comprehensive/strategic framework for marketing-driven improvements •increases transit productivity •offers escape from "higher fares-less riding" cycle •can raise revenues without ridership loss •builds ridership •can boost per capita trip rates •encourages more usage by low-frequency market •increases rider commitment, reduces turnover and builds rider retention •stimulates increased attention on market research •builds appreciation of marketing's impacts •provides resources to finance expanded marketing efforts •promotes use of the most effective marketing methods •can be used as a target marketing incentive •provides a consumer-based pricing strategy •can enable less emphasis on cost-based pricing •can be integrated with peak/off-peak fare differentials to improve their operational and political acceptability and expand their impact •eases fare collection •can reduce fare evasion •can allow a reduced reliance on monthly transit passes	•can enable a prepayment program to be revenue neutral •can have the largest impacts on off-peak ridership •creates favorable public and press relations •can increase private sector support of transit promotion •develops a membership/identity mentality among riders • improves transit's overall image *Transit Users* •results in reduced fares for those choosing to prepay •raises revenues without raising fares for those sensitive to them •with revenues maximized, the average fare can be less •with revenues maximized, fare increases are less frequent •facilitates an enhanced consumer focus overall •makes payment of fares more convenient •can allow fare structures to be simplified *General Public* •can reduce general subsidy requirements of transit •improves transit productivity •expands transit use (reduces congestion, pollution, etc.) •can increase private sector support of transit promotion Source: Oram, 1988, 1990

3.4.2 Campus-Based Programs

Of the three categories of deep discount programs, the campus-based programs appear from the literature to be the most widely "evaluated". Two references are national in outlook and are identified as follows:

Brown, Hess and Shoup (1999) present a survey of "Unlimited Access" programs in 31 Universities around the nation. The authors assert: a majority of the truly "deep discount programs" operate in partnership with universities around the country. By the year 2000, there were approximately 45 and by 2002 more than 60 such programs in universities around the nation. They found from their survey that during the first year of implementation, increases in student transit ridership ranged between 70% and 200% while the average cost to the universities was $32 per student per year.[12] Table 3-7 is a summary of growth in transit ridership at selected universities due to the deep discount program. Additional details about the 31 universities surveyed are summarized in Appendix 3-1.

The effects of the programs on the financial performance of transit agencies varied from one location to another, but are not dramatic one way or the other. In most cases, the annual rate of increase in operating cost per ride decreased after inception of the program. This resulted in a general reduction in operating subsidy per ride. Details are included in Appendix 3-2.

Table 3-7: Increases in Transit Ridership in First Year of Deep Discount Programs

University	Year Began	Annual Student Transit Ridership			Fare Elasticity
		Before	After	Change	
Cal State Univ., Sacramento	1992	315,000	537,700	**+ 71%**	-0.26
Univ. California, Davis	1990	587,000	1,054,000	**+79%**	-0.28
Univ. Wisconsin, Madison	1996	812,000	1,653,000	**+104%**	-0.34
Univ. Illinois, Urbana-Champaign	1989	1,058,000	3,102,000	**+193%**	-0.49
Univ. Colorado, Boulder	1990	300,000	900,000	**+200%**	-0.50

Source: Brown, Hess and Shoup, 1999, Table 3

Under the emerging programs, a university negotiates with the local transit agency to pay an annual lump sum based on the frequency of "expected" ridership by program participants. Participants always include students and in some programs also include faculty and staff. Participants use their university identification cards as passes to board the transit vehicles. Most often all members of a participating body are included. In some cases, as at the University of Washington, Seattle, members could opt out of the program. Table 3-8 summarizes the types of coverage options in existence.

Table 3-8: Deep Discount Program Options at Universities

	Partial Coverage		Universal Coverage
	Opt In	**Opt Out**	**Cannot Opt Out**
Example Institution	*University of California, Irvine*	*University of Washington, Seattle*	*University of Colorado, Boulder*
How program works	The university buys bus passes from the Orange County Transit Authority for $33.50 per month and sells the passes to	Students, faculty, and staff are automatically enrolled but can opt out and not pay the fee. Students pay $28 per quarter and faculty and	Students are automatically enrolled and cannot opt out. Students pay a mandatory transit fee of $19.52 per semester.
Percent who	1% of students	74% of students,	100% of students
University's cost per	$246 per year	$130 per year	$41 per year

Source: Brown, Hess and Shoup, 1999, Table 5

TCRP Synthesis Report #39 (2001) by James Miller is a synthesis of transit practice entitled "Transportation on College and University Campuses". The synthesis discusses the range of transit services provided including unlimited access programs and identifies sources of revenue. The synthesis has determined that typically "all systems start with students as the first group of eligible riders". This is mainly because student travel times are predominantly in the off-peak and student demand is not anticipated to overwhelm the existing transit service. After the transit system has made operational and financial adjustments to increases in ridership, other groups such as faculty and staff are added to the program. In certain cases, where increases in student ridership are feared to overwhelm the transit system, as at Penn State University and Indiana University, the unlimited access program is initially restricted to designated routes. The study concludes: “unlimited access systems appear to be the greatest success for campus transit systems”.

The literature reveals evaluations of three individual university programs. These three studies report similar success stories and may be viewed as representative of the success that could be expected when a campus-based deep discount program is well administered. The individual studies are outlined as follows:

Williams and Petrait (1993) discussed the U-PASS program at the University of Washington, Seattle in the report, “A Model Transportation Management Program That Works”. The U-PASS program has been in existence since 1991 and is considered a model of success (Williams and Petrait). Its impacts are well documented from biennial telephone surveys that have been administered since 1992 to ask a sample of faculty, staff and students about their travel behaviors and attitudes. The program allows these three groups of affiliates of the university (faculty, staff and students) to ride on “Metro” and “County” buses at a fraction of the cost of a regular bus pass. Students pay $20 per quarter while faculty and staff pay $27. Studies revealed the following:

- It enabled the reduction of parking facilities. The 12,000 current campus parking spaces are fewer than existed in 1983 despite the addition of 8,000 more people to the campus community since then.
- It helped to avoid building 3,600 new parking spaces that saved $100 million in construction costs.

- It caused a significant shift in mode choice from drive-alone to transit and vanpools. The increase in transit patronage is expectedly higher among students than faculty and staff. Table 3-9 summarizes the shifts observed in mode choice.

- In response to ridership gains, Metro added 60,000 annual hours of new bus service, the equivalent of 10 more buses operating for approximately 18 hours a day.

Table 3-9: Change in Mode Choice One Year after Initiation of U-PASS Program

	Students		**Faculty & Staff**	
	Before	**After**	**Before**	**After**
Auto Drive Alone	25%	14%	49%	40%
Transit	21%	35%	21%	28%
*All Others (*carpool/vanpool, bicycle, walk, "other"*)*	54%	51%	30%	32%

Source: Williams and Petrait

Meyer and Beimborn (1996) and also in TRR 1618 (1990) prepared "An Evaluation of an Innovative Transit Pass Program: The UPASS" at the University of Wisconsin, Milwaukee (UWM). The study examined the effects of the program on transit ridership, traffic congestion, parking and other transportation related issues and also assessed its transferability to other areas. The program was initiated in 1994 for students and is judged to be highly successful. The highlights of the evaluation are the following:

1. The UPASS program influenced modal shifts as follows:

- The share of students who drove to UWM declined from 54% prior to UPASS to a rate between 38% and 41% after the implementation of UPASS.

- The share of students who rode Milwaukee County Transit System (MCTS) doubled from 12% prior to UPASS to a rate between 25% and 26% after the implementation of UPASS.
- Transit mode share for work trips by survey respondents showed nearly a doubling over pre-UPASS semesters from a rate of 8% to approximately 15%.
- Surveys indicate a 17% to 18% increase in transit ridership for other trip purposes compared to pre-UPASS ridership.

2. The UPASS program reduced vehicle trips to the university, which resulted in reductions in emissions and fuel consumption and translated to dollar savings to students during the 1994-95 academic year as follows:

- 221,055 fewer vehicle trips
- 5,084,265 fewer VMT for trips to UWM
- 242,108 gallons of fuel savings
- $295,372 savings in fuel costs
- 20% reduction in emissions for trips to UWM and approximately 0.1% for the entire Southeastern Wisconsin region.

3. Students perceived improvements in the parking situation at the university since the implementation of the UPASS program as follows:

- 19% of students indicated parking on-campus was easier
- 16% indicated parking off-campus was easier
- 24% of students who drove prior to the implementation of UPASS and who continued to drive indicated they found it easier to locate parking near campus.

Brown, Hess and Shoup (2002) present an evaluation of the BruinGO Program at UCLA. The study examined: (a) the effects of the program on commuting by faculty, staff and students; (b) fare elasticities; (c) parking demand; (d) non-commute trips; and (e) costs and benefits. The program, begun in Fall 2000, is reported by the authors to incur a cost of about $1.27 per eligible rider per month and a benefit-cost ratio of 4 to 1. By Fall 2002, the program resulted in the following[13]:

- 56% increase in bus ridership for commuting to campus;
- 20% decrease in drive-alone commuting;
- Over 1000 solo drivers gave up their parking spaces

3.4.3 Employment-Based Programs

The literature reveals few evaluations of the employment-based programs. Several transit agencies have extended the deep discount program to groups outside the university under the term “ECO Pass”. Examples include the Denver Regional Transportation District in Colorado, Metro in Seattle, Washington and the Santa Clara Valley Transportation Authority (VTA) in California. Similar programs were in existence in more than a dozen metropolitan areas around the country by the late 1990s and are listed in Appendix 3-4.

Denver – Since inception of the ECO Pass program in 1991, both ridership and revenues of the RTD have increased steadily. Chapter 7 presents a detailed case of the Denver ECO Pass program. In the six-county Denver metropolitan area, the level of participation in 1998 included 1,123 companies and a total of 44,536 employees. Fay Lewis reports estimates in TransAct that the average employee who used the ECO Pass in 1996 would have eliminated the following[14]:

- 300 single occupancy vehicle trips
- 5,000 miles of driving
- 200 gallons of gasoline
- 200 pounds of pollutants.

Seattle -- From the success of the U-PASS program, Metro extended the idea of "putting a transit pass in everyone's hands at a greatly reduced price" to employers. Today the FLEXPASS program serves 130 employers and 74,000 commuters in addition to participants of the U-PASS program. The widespread distribution of the program encourages both occasional and regular transit riders to the mode.[15]

Santa Clara County – Replicating the key feature of the Denver ECO Pass program, employers in Santa Clara County, California are required to purchase the pass for all employees whether they use the service or not. Thus the VTA is able to offer discounted monthly group passes at less than 20% of the price for the conventional monthly pass. Even though only 40% of employees for whom passes are purchased actually use them, the rate of discount per actual user is approximately 50% of the price for the conventional monthly pass. A survey of commuters to the Silicon Valley indicates that the program resulted in the following[16]:

- Reduction in the drive-alone share from 76% to 60%,
- Increase in transit mode share from 11% to 27% and

- Reduction in parking demand by approximately 19%.

City of Berkeley -- The City has approximately 1940 employees, of whom 1330 are qualified and covered by the program even if they do not use transit. Full time employees of the City of Berkeley are issued unlimited ride AC Transit passes in exchange for a contractual payment per employee per year by the city government. The large volume allows the passes to be sold at the relatively low unit cost of $60 a year or $5 per month. Thus the ECO pass is offered at approximately 10% of a basic adult monthly pass. Chapter 9 contains the case write-up on the City of Berkeley ECO Pass program.

3.4.4 Residential Location -Based Deep Discount Programs

Success of the campus and employment based programs led to the introduction of the residential ECO Pass programs. The literature search does not reveal evaluations of the residential-based programs. The Denver RTD and Santa Clara VTA offer the most notable of the programs.[17]

Denver RTD – The Neighborhood ECO Pass is a deep discount annual transit pass purchased by a neighborhood organization for all members of participating households. RTD charges an annual fee per housing unit. The price reflects the number of eligible housing units, amount of transit availability and usage. The minimum amount required to initiate a Neighborhood ECO Pass contract is the greater of the computed cost for 100 residential units or $5,000. The Neighborhood Eco Pass program offers substantial savings when compared to the per person price of a monthly pass. Chapter 7 presents a detailed case of the programs including the Neighborhood ECO Pass program.

Santa Clara County VTA -- The VTA offers the Residential ECO Pass to residential communities of 25 units or more that are defined geographically as apartment or condominium complexes, or by neighborhood or community associations. All members of the community of age 5 or above must participate. Participants have unlimited access to light rail, bus and paratransit services in addition to free “emergency ride home” via taxi.[18]

The assortment of ECO Pass programs offered by the Denver RTD and the Santa Clara VTA exemplifies the general concept of a wide scale deployment of the deep discount program that is the motivation for this study.

3.5 SUMMARY

Review of the historical dynamics of fares, revenues and ridership confirms that price discounts have been able to both increase total revenue receipts and attract ridership. Cases reviewed include major transit operations in New York, Los Angeles, Chicago and Boston. Studies of these systems produce results that point to the conclusion that it is preferable to maximize social welfare through the number of persons carried with reduced fares than to maximize the level of transit service provided.

The literature review differentiated between general discount fare programs and true deep discount group pass programs. The group pass is the subject of this dissertation. There are various versions of deep discount pass programs that may be categorized into four broad groups as follows:

1. *University campus-based programs,* which always include students and sometimes also include faculty and staff. The pioneers and most widely documented examples include the U-PASS at the University of Washington, Seattle (1991) and the UPASS at the University of Wisconsin, Milwaukee (1994). The ClassPass program at U.C. Berkeley (1999) and BruinGO at U.C. Los Angeles (2000) were introduced in California relatively recently. Chapter 8 presents a detailed case study of the U.C. Berkeley program.
2. *Employment-based programs* exist in more than a dozen metropolitan areas. One of the oldest and most widely documented is the ECO Pass program in Denver, Colorado (1991). In California, the Santa Clara Valley Transportation Authority (VTA) offers this type of program to Silicon Valley commuters and AC Transit offers it to employees of the City of Berkeley (2002). Chapter 7 presents a detailed case study of the Denver programs while Chapter 9 presents a detailed case study of the City of Berkeley program.
3. *Residential-based programs* are offshoots of the employment-based programs. One of the oldest is the Neighborhood ECO Pass program in Denver, Colorado (1995). In California, the VTA offers this type of program to residents of Santa Clara County.

4. *Student pass programs,* which are variants of the campus-based programs, typically cover middle and high school students. They are offered in Denver and New York City.

The next three chapters are extensions of the literature review. They cover the intellectual and theoretical analyses of pricing and the effects of deep discount group pass programs relative to revenues and ridership.

4. TRANSIT AND PRICING

4.1 THE CASE FOR MARGINAL COST PRICING

Economists would argue that transit, like other economic goods, should be priced at marginal cost if subsidies are to be reduced or eliminated. However, transit is not simply an economic good. It is also a social good stemming from the reasons society has for maintaining it in spite of its poor financial performance. The following discussion explains the economist's concept of marginal cost pricing and its applicability to public transit.

4.1.1 Definition

Marginal cost is defined as "the increase in total cost that occurs from producing one more unit of output or service". (Gomez-Ibanez, 1999).[19] Charging transit riders the marginal cost ensures that they will demand an extra unit of service only when the value to them is at least as great as the cost of providing it. An efficient allocation method should seek to maximize net "social" benefit (NSB). And NSB may be defined as the difference between riders' willingness to pay for services and the costs of providing the services.

4.1.2 Formulation

Gomez-Ibanez formulated the concept of net social benefit and marginal cost analytically as follows:

Let

NSB = net social benefit

P(X) = inverse demand curve of transit riders

Q = quantity of unit service demanded

UC = average cost to a rider of using a unit of transit service

CC = average amortized cost of providing a unit of system capacity

L = the number of units of capacity

Then net social benefit is:

$$NSB = \int_{[0,Q]} P(X)\, dX - Q*UC(Q/L) - L*CC(L) \qquad (4\text{-}1)$$

Taking the first derivative of Equation 4-1 with respect to Q, *quantity of unit service demanded*, and setting it equal to zero derives the optimal price under first-order conditions. (Second order conditions for optimality require that the second derivative is negative.) The result provides marginal cost that has the two components of (a) average user cost and (b) the change in average cost of serving an additional service demand as follows:

$$P = UC + Q*(\partial UC/\partial Q) \Rightarrow MC \qquad (4\text{-}2)$$

Similarly, taking the first derivative of Equation 4-1 with respect to L, *the number of units of capacity*, and setting it equal to zero derives the optimal level of investment as follows:

$$CC + L^*(dCC/dL) = - Q^*(\partial UC/\partial L) \tag{4-3}$$

Equation 4-3 translates to the following:

a. On the left-hand side, the marginal cost of adding an additional unit of capacity;

b. On the right-hand side, the saving in user costs from the additional unit.

This suggests that a transit agency should expand capacity to the point where the marginal cost of providing extra capacity equals the marginal savings it brings to the users of its services.

However, whether pricing transit service at marginal cost is financially efficient or not depends on whether its operations exhibit economies or diseconomies of scale. If average costs of transit services are not affected by volume of demand, then the "change-in-average-cost" component of Equation 4-2 is zero and marginal cost equals average cost. If operations exhibit economies of scale due to large fixed costs, then marginal cost is lower than average cost (and the "change-in-average-cost" component is negative). Thus pricing at marginal cost will not generate sufficient revenue for the transit agency to be financially self-sufficient. In the unlikely event that the agency exhibits diseconomies of scale, then the "change-in-average-cost" component is positive and the agency will generate surpluses from an allocation procedure based on marginal cost.

4.1.3 Limitations of Marginal Cost Pricing

The discussion so far has indicated some limitations to a blanket advocacy of marginal cost pricing. Certain peculiar characteristics of transportation systems make the application of marginal cost pricing a complex endeavor. (Gomez-Ibanez, 1999)[20] These are outlined as follows:

- Joint use in which not only a commuter train operator, but intercity passenger and freight carriers might share the same track. While joint use enables the spreading of cost over a wide clientele, it makes the allocation of costs among the different types of users difficult.
- A transit agency is the type of organization whose operations require high levels of capital investment and tend to exhibit economies of scale. As discussed, marginal costs are thus less than average costs and marginal cost pricing will produce less than adequate revenue.

It is worth noting that with a wide range of users, there may be groups that would try to justify low fees and cross-subsidies in their own self-interest by overstating the complexity in allocating costs based on marginal costs. This could lead to the adoption of non-marginal cost pricing schemes. However, alternatives to pure marginal cost pricing revealed the following:

- Attempts to apply level payment schemes that deviate from marginal cost pricing sometimes lead to a system of cross-subsidies whereby some users pay more than marginal cost while others pay less thereby raising issues of equity.

- Others involve complex pricing schemes that are designed to raise more revenue than marginal cost pricing can while seeking to leave usage levels the same. Key among such schemes is Ramsey pricing, which is for practical purposes modified marginal cost pricing. Ramsey pricing is therefore examined next for its applicability to transit.

4.2 THE CASE FOR RAMSEY PRICING

4.2.1 Antecedents

In their 1970 survey of inverse elasticity pricing methods, Baumol and Bradford proposed: “generally, prices which deviate in a systematic manner from marginal costs will be required for an optimal allocation of resources, even in the absence of externalities”.[21] They posited that “social welfare will be served most effectively not by setting prices equal or even proportionate to marginal costs, but by causing unequal deviations in which items with elastic demands are priced at levels close to their marginal costs” while “prices of items whose demands are inelastic diverge from their marginal costs by relatively wider margins”.[22] They concluded, “the percentage deviation of price of any taxed commodity from marginal cost should be inversely proportional to its own price elasticity of demand”.[23] These statements are essentially the tenets of Ramsey Pricing.

Baumol and Bradford summed up that “it follows for the economy as a whole that unless marginal cost pricing happens to provide returns sufficient to meet the social revenue requirement, a quasi-optimal allocation calls for systematic deviations of prices from marginal costs". They conclude: "in a world in which marginal cost pricing without excise or income taxes is not feasible, the systematic deviations between prices and marginal costs may truly be optimal because they constitute the best we can do within the limitations imposed by normal economic circumstances".[24] With these, they affirmatively supported the idea of Ramsey pricing that was formally laid down much earlier in 1927.[25]

4.2.2 The Idea of Ramsey Pricing

The idea of Ramsey Pricing is to charge the largest markups over marginal cost to those consumers who are least sensitive to price, that is, those who have the least price elastic demand. The objective is to minimize the reduction in consumption that would result from charging higher prices. This type of pricing is termed "inverse elasticity pricing". This idea of pricing is conceptually very appealing and is often attempted in transportation. In public transit, however, those who have the least price elastic demand are very likely to include the transit dependent, many of who may be the poor. Charging them the largest markups over marginal cost could raise equity issues.

4.2.3 Formulation

There are two formulations for Ramsey Pricing. If there are no cross-elasticities of demand between the various transit services, Ramsey's formula to minimize distortions is the following:

$$(P_i - MC_i) / P_i = k / E_i \qquad (4\text{-}4)$$

where

P_i = price charged for service i

MC_i = marginal cost of producing service i

k = a constant determined by the amount to be raised to meet a budget target

E_i = price elasticity of demand for service i.

In Equation 4-4, the left-hand term shows that the percentage of markup over marginal cost for each user is inversely proportional to the user's demand elasticity, E_i as conceptually explained.

If there are cross-elasticities of demand between various transit services, the formula becomes:

$$(P_i - MC_i) / P_i = (k / E_i) - \Sigma_{(j \text{ not } i)} \{[(P_j - MC_j) / P_j]* E_{ij} *[(P_i Q_i) / (P_j Q_j)]\} \quad (4\text{-}5)$$

where

E_{ij} = cross-elasticity of demand for j with respect to the price charged service user i

Equation 4-5 requires not only information about own-price elasticities but also estimates of cross-price elasticities.

4.2.4 Limitations of Ramsey Pricing

The application of Ramsey Pricing to transit services will carry with it its widely acknowledged limitations that include the following:

- It is often difficult to estimate the elasticities of demand for different groups of users

- The scheme often sows the seeds of its own demise as it gives those charged high mark-ups the incentive to find alternative services or sources. If those who are transit dependent are charged high markups, they are likely to find it worthwhile to own and travel by the private automobile. Thus this method of pricing can trigger some curtailment of patronage in the long run even among the transit dependent.
- Changes in the demand elasticities of users resulting from the above would necessitate the calculation of a new set of Ramsey prices.
- As the number of users with inelastic demand declines, it will make it harder to charge much above the marginal cost without reducing demand.

A case application to the U.S. post Office illustrates the limitations of Ramsey Pricing. William Tye (1983) found in this case that the Ramsey pricing formula was "very sensitive to the direct- and cross-price elasticities assumed and that these elasticities were seldom known with great precision". When estimated, "the standard errors of the estimated elasticities were often very high, so that very different mark-ups over marginal cost among mail classes were based on statistically insignificant differences in the estimated elasticities".[26]

From the foregoing discussion, it is apparent that using Ramsey pricing is by and large using marginal cost pricing, but with markups. The issue therefore is not the choice between marginal cost pricing and Ramsey pricing. It is a question of whether marginal cost pricing and its variants, Ramsey pricing and other inverse elasticity pricing methods, are appropriate applications in public transit.

4.3 COST RECOVERY IN TRANSIT

4.3.1 Marginal Cost Pricing versus Price Discrimination[27]

Marginal cost pricing and its variants imply two principal methods of economic pricing. The discussion so far does not support either method for use in transit. Prest (1969) makes a brief comparison of the two methods for clarity.

A system of *marginal cost pricing* equates benefits with costs at the margin. It is implied that if price, defined as marginal benefit, exceeds marginal cost, there will be an incentive to expand output until any difference is eliminated.

A system of *price discrimination* approximates in the limit to one of charging according to total benefit. It is implied that total revenue is equal to the whole area under the demand curve and consumers are deprived of all consumers' surpluses. Under price discrimination, it may be sensible to price transit usage below marginal cost if a higher fare means a reduction in usage and hence a smaller incremental return to the operation.

4.3.2 The Problem with Marginal Cost Pricing in Transit

A problem arises when marginal cost (MC) pricing is used in transit because the prices do not generate sufficient revenue to cover costs. This occurs when average total cost is greater than marginal cost because of any of the following:

1. *Decreasing costs and economies of scale* ~ MC pricing implies that fares are fixed on the basis of marginal operating costs and that fixed costs are ignored.
2. *Discontinuities in variable costs* ~ an extra passenger may be responsible for zero additional cost, if he could find an empty seat on the transit vehicle, or for the provision of an extra vehicle or an extra run. Thus strict adherence to the principle can lead to tremendous volatility in prices with sudden changes in demand or major discontinuities in variable costs.
3. *Consistency across sectors* ~ the proposition holds for a sector if all other sectors of the economy operate on similar principles. It is well known and argued, for instance, that use of the automobile, the primary competition to transit, is excessive because it is not priced at marginal cost. Using marginal cost pricing in transit will thus not be consistent even within the transportation sector.
4. *Externalities* ~ MC pricing also assumes that the externalities and the consequences of resorting to general government revenues to finance deficits can be ignored.

4.3.3 Why Transit Runs at A Loss

As previously discussed, society has reasons to maintain transit service. In addition to these reasons, there has been the consistent tendency to over-estimate demand and over-invest in transit capacity. There is also the peak demand that must be catered for. Both of these latter factors result in the procurement of larger capital equipment, design of larger operations and employment of more personnel than needed. Thus society is forced to fall back on government subsidies to keep operations running.

4.3.4 Subsidies in Transit

Subsidies are generally introduced for several reasons. Dalrymple (1975) identified those outlined as follows:[28]

- To stimulate development or consumption of some desired activity or service
- To stimulate development of a particular area
- To redress deficiencies in income distribution
- To reduce risks of speculative activity such as research and development
- To encourage activity that yields external economies. The transit sector, for instance, is purported to help in the revival of urban centers and to generate economic spin off on local economies.

However criticisms and concerns have been expressed that subsidies result in the following:

- Lead to unanticipated distortions elsewhere in the economy
- Require counter-subsidies to offset distortions created
- Become burdensome administratively
- Inhibit incentives to efficiency
- Give unwarranted market protection
- Become difficult to terminate.

Thus it is argued as undesirable to fall on government subsidy as a financial solution to the shortfall in transit revenue because of the following:

1. Subsidy from public funds can only come from the generation of more public revenue, more borrowing or less spending elsewhere so that the consequences of any of these courses of action may be substantially worse than the loss of benefits to consumers through paying fares higher than marginal variable cost.
2. On the grounds of income distribution, there is a stronger case for meeting the deficit out of pockets of transit consumers rather than from those who would pay the higher taxes or receive less from government spending.
3. Once started, subsidies breed expectations of further subsidies and so become conducive to inefficiency in management. Organized labor pitches demands for wage increases at much higher levels if it thinks the public purse can provide more.

4.3.5 Traditional Methods of Cost Recovery in Transit

For these reasons, therefore, it is argued as preferable to make the consumers of the service pay for the deficits. Three methods are traditionally employed to make consumers absorb deficits as follows:

1. *Discriminatory pricing* ~ this is traditionally used in railway ratemaking and in the pricing of airfares. It is in many ways similar in concept to such modified marginal cost pricing schemes as Ramsey pricing.
2. *Two-part tariff* ~ whereby each consumer pays a fixed or quasi-fixed sum as well as according to the amount consumed. For instances many transit agencies charge zone fares that vary by length of trip over and above a basic fare. This method has the drawback that it is likely to keep out some consumers and so reduce

consumption below what it would be if based purely on marginal cost. It will thus in turn reduce the usage of capacity below the optimum level.

3. *Long range marginal cost pricing* ~ will ensure that capital as well as variable costs are considered, but deficits may not necessarily be eliminated while it can result in reduction in usage below the optimum level.

While all these methods are invariably applied in transit fare pricing, there are no unique principles for choosing between them. Besides, all these methods may be weak instruments when benefits are not concentrated on a discernible body of consumers. Thus there is no clear or easy answer to the dilemma posed by the need to maintain service versus the desire to reduce or eliminate subsidies. One answer is to devise ways of increasing revenue without driving away patronage. This is what a well-crafted deep discount program would attempt to accomplish.

This research proposes that transit services are offered in multiple product configurations in the attempt both to appeal to users and to elicit the most revenues. Product configurations are to include the following:

- *Single-fare* rides for the occasional and convenience user as widely in existence
- *Periodic pass* (daily, weekly, monthly) rides for habitual, yet individual users as already in existence
- *Deep discount group passes* for easily targeted groups akin to group health insurance plans. This is also in existence, but not widely deployed despite the potential it offers as a relatively "profitable" source of revenue.

The analogy of the deep discount group pass to a group insurance plan is the subject of the next chapter.

4.4 OPPORTUNITY COST AND DEEP DISCOUNT PROGRAMS

The decisions of travelers to drive or to take an alternative mode and to seek parking or not to be bothered with parking all imply alternative allocations of the resources available to them. The concept of cost is fundamental to the comparison of alternatives. The concept of costs could refer to those incurred by society or by individuals or agencies. Thus three different definitions may arise in the evaluation of costs and benefits (Friedman, 2002) of deep discount programs as follows:

Social opportunity cost is defined as the value forgone in using resources in one activity by not using them in the next best alternative activity. The concept treats a whole community as if it were one large family so that all things forgone are counted as part of the social cost. The concept is most relevant in efficiency considerations.

Private opportunity cost is defined as the payment necessary to keep a resource in its current use. It is similar to social cost, but may be different if the prices of resources do not reflect their full social costs. It represents the value in its next best alternative use from the point of view of the individual who employs the resource. The concept is important because individual decision makers are thought to act on their perceptions of costs, that is, their private opportunity costs.

Accounting cost is the bookkeeper's view and reflects what is recorded on financial statements and budgets of agencies. For instance the cost to construct one parking space is an accounting cost. The social opportunity cost may be larger and represents alternatives forgone such as use of the space for buildings, environmental pollution associated with use of the space, etc.

The concept of opportunity cost may be illustrated in the context of the deep discount analysis as follows. Suppose an agency, such as a University, has the choice to allocate resources (say a transportation budget) to the provision of either transit passes or parking for its employees. The opportunity cost of providing parking, for instance, is the transit pass forgone. More realistically the concern would lie with the minimum number of parking spaces that could be forgone if use of transit passes were to increase by one unit. This is even better stated as how many parking spaces the university might not need to spend construction funds on because of the availability of transit passes to its affiliates. Consistent with the compensation principle in economics, "a change in allocation is relatively efficient if its social benefits exceed its social costs"[29]. Thus if the provision of passes results in higher societal benefits than the parking forgone, then the decision to provide passes is an efficient one.

As individuals choose between travel-with-transit-pass and drive-to-park in order to maximize their individual utilities, the composite of choices would maximize social benefits less social costs or equivalently net social benefits. This is so because individual decisions on choice to travel or not to travel with the deep discount pass may be viewed as consumption decisions that maximize consumer surplus. Likewise transit agency decisions on the terms of deep discount programs may be viewed as production decisions to maximize producer surplus. The sum of the consumer and producer surpluses is the net social benefit. The concept of a “surplus” thus equates to net benefit because it represents the difference between benefits and costs.

In the assessment of cost impacts, two distinctions are necessary. One is the assessment whether society is made relatively more efficient by the pass program. The other is the assessment of the program’s effects from the perspectives of such constituencies as participants in the deep discount program, university administrations, other governing bodies and service providers. The latter assessment can help determine potential support for the program by these constituents or in evaluating the equity of the deep discount program.

4.5 SUMMARY

Review of the intellectual literature on pricing reveals that both marginal cost pricing and modified marginal cost pricing schemes like Ramsey Pricing are conceptually appealing in general, but have limitations when applied to public transit. The foremost reason for the mismatch is the fact that transit operations fall among the types of organizations that require high levels of capital investment and tend to exhibit economies of scale. Such organizations typically have marginal costs that are less than average cost so that marginal cost pricing produces less than adequate revenue. Traditional pricing methods such as price discrimination, two-part tariffs and long range marginal cost pricing may be weak instruments for pricing when benefits are not concentrated on a discernible body of consumers. Thus there is no clear or easy answer to the dilemma posed by the need to maintain service while reducing or eliminating subsidies. The deep discount group pass program may be a device for increasing revenue without driving away patronage. How the group pass can achieve this is the crux of the discussion in the next two chapters.

5. ANALOGIES TO INSURANCE AND RISK SPREADING[30]

5.1 INTRODUCTION

This research proposes that *deep discount group passes* are offered to easily targeted groups similar to the way group health insurance or property insurance plans are administered. This analogy explains the paradox of how offering deep discounts can result in net increases in total revenue. The analogy is outlined in the form of comparative tables first in terms of risk spreading and then in terms of insurance.

5.2 RISK SPREADING

5.2.1 The Concept of Risk Spreading

Risk spreading occurs when different individuals share the returns from one risky situation.[31] In transit, the risk may be viewed as the indebtedness associated with provision of services and the returns may be viewed as the available transit services.[32] The analogy of deep discount programs in transit operations to risk spreading is sketched in Table 5-1.

Table 5-1: Comparison in Terms of Risk Spreading

A Firm	A Transit Agency
A firm diversifies ownership through the stock market by issuing common stock.	A transit agency diversifies responsibility for generating fare revenue by selling the responsibility in the form of passes.
By this move, a single firm can allow many individuals to bear only a small portion of the total risk of operating the firm.	The transit agency thus allows many individuals to bear only a small portion of the responsibility.

5.2.2 Illustration of Risk Spreading

The advantage of risk spreading is that the sum of the costs of risk faced by each individual is significantly lower than if there were a single risk-taker. This is so because the risk cost is approximately proportional to the variance. And risk spreading reduces the variance more than proportionately and thus reduces the risk cost. For example, $1/10^{th}$ reduction in expected value results in $1/100^{th}$ of the original variance. This is illustrated by Friedman (2002) as follows:

Let us suppose one large investment owned by one person were divided into ten equal, smaller investments among ten individual investors. The expected value of the investment would remain the same whether it is a single or ten smaller investments. However the variance that each investor would experience will change significantly as follows:

Let,

X_i represent the i^{th} outcome of the one large investment; π_i its probability; and

$X_i/10$ represents how much each of the ten investors would receive in state i.

Then,

$$\mathrm{Var}(X/10) = \Sigma\pi_i[E(X_i/10) - X_i/10]^2$$

And factoring out 1/10

$$= (1/10)^2\ \Sigma\pi_i[E(X_i) - X_i]^2$$

$$= (1/100)\ \mathrm{Var}(X)$$

The illustration reveals that when the risk is spread, each individual investor receives 1/10 of the expected value, but only 1/100 of the original variance, which is far less than the proportionate reduction of 1/10. A lower variance implies a lower level of uncertainty or risk. Because the cost of risk is approximately proportional to the variance, the cost of risk of each smaller investment is substantially less than 1/10 that of the original one-owner investment.

5.2.3 Risk Spreading and Diminishing Marginal Utility

The risk spreading may also be viewed in terms of diminishing marginal utility of wealth. The concept states that as an individual acquires more units of wealth, the total utility received increases, but the extra or marginal utility decreases. Viewed the opposite way in terms of risk, a larger gamble represents not only a larger total but also a larger marginal risk cost. Just as the expected utility gain from a second winning is less than that from the first, so also is the expected utility lost from a second unit of loss exceeds that of the first unit of loss. The marginal risk cost increases therefore as the stakes increase. Thus when two or more similar individuals share the risk from one risky event, each has a lower risk cost than one individual facing the risk alone. This is one of the basic rationales behind insurance programs, stock shares and futures contracts.

5.3 INSURANCE

5.3.1 The Concept of Insurance

Pooling is the concept behind insurance. Risk pooling occurs when a group of individuals, each facing a risk that is independent of the risks faced by the others, agree to share any losses (or gains) among themselves.[33] Insurance therefore represents a large pool of people who agree to divide any losses among themselves. The analogy of deep discount programs in transit operations to insurance is outlined in Table 5-2.

Table 5-2: Comparison in Terms of Insurance

Insurance Company	**Transit Agency**
An insurance company that insures properties against theft does not care whose property is stolen. Its concern is that the total premiums it collects will (at least) cover the total cost of replacing the property that is stolen.[34]	It does not matter to the transit agency which members of a group use the service it provides. It is concerned that the total group revenue covers the "total cost" of providing the service.
An insurance company is an intermediary, which organizes the pools and incurs transaction costs.	Transit agency is a facilitator, which promotes the pool through deep discount pass programs and incurs transaction costs.
As the number of people in the pool gets larger, the risk cost and often the transaction costs become smaller and the premium approaches the fair level.	As the number of participants increases, the unit service and transaction costs become smaller and the price per participant (or per pass) reduces.

5.3.2 Hypothetical Example

This illustration of the basics of insurance is adapted from Friedman (2002) as follows:

Let us assume the following:

$5,000 = Value of property to be insured per household

0.2 = the probability that any household's property will be stolen

To provide full coverage insurance at the fair entry price, the premium must equal the expected loss.

Let:

$$E(V) = \Sigma_N \Pi_i X_i \qquad (5\text{-}1)$$

Where

$E(V)$ = expected loss

Π_i = probability of occurrence

X_i = payoff or value of property

N = possible states ('i = 1: stolen' or 'i = 2: not stolen')

And Equation 5-1 interprets as:

"The sum of (probability a property is stolen times the value of property stolen) + (probability a property is not stolen times the value of the un-stolen property)."

This calculates as:

$$\begin{aligned} E(V) &= 0.2(5000) + 0.8(0) \\ &= 1000 \end{aligned}$$

The expected loss fair premium from the hypothetical example therefore is \$1,000 per household. By the law of large numbers, it is virtually certain that the insurance company will total claims from 20% of the insured households, which equals the premium collected.

By shifting the risk to the insurance company where it is pooled, the risk cost is reduced for all insured. Without the insurance, each household would have to set aside $5,000 to replace the property if stolen.

5.4 SUMMARY

The analogy to insurance and risk pooling explains how deep discount programs can increase revenues to transit operators. By selling group passes, the transit agency diversifies the responsibility for generating fare revenues with participating groups. As the number of participants in the pool increases, the unit service and transaction costs become smaller and the price per pass reduces. Lower pass prices translate to higher levels of discount relative to regular pass prices. The next chapter explores how the deep discount group pass affects ridership.

6. A GENERALIZED FRAMEWORK FOR FARE DISCOUNTS

6.1 INTRODUCTION

Given the analogy of deep discount group pass programs to insurance and risk-pooling schemes, an important policy question that may arise is how the participation of groups in the programs might affect the demand for transit. Like an insurance scheme, because deep discount programs lower the out-of-pocket costs to participants, some increase in demand is to be expected. A follow-up question is how large the increase would be. The degree of change would depend on the fare elasticity of demand for transit. The elasticity of demand with respect to out-of-pocket cost therefore explains how offering deep discount programs can result in increased transit ridership.

6.2 ELASTICITY OF DEMAND

6.2.1 Definition[35]

Economists define the *elasticity of demand with respect to price* as the relative responsiveness in the quantity of a commodity purchased per unit of time to a change in its price. In public transit, fare elasticity is a measure of the responsiveness in the quantity of rides purchased to a change in the fare. In mathematical terms, $e_{X,Y}$, the elasticity of one variable, X (say ridership), with respect to another variable, Y (say fare), is the percentage change that occurs in X in response to a 1 percent change in Y. It is expressed in terms of macro change and termed "arc elasticity" as:

$$e_{X,Y}, \quad = \quad \frac{\Delta X/X}{\Delta Y/Y} \quad = \quad \frac{\Delta X}{\Delta Y} \cdot \frac{Y}{X} \tag{6-1}$$

And in terms of partial derivatives and termed "point elasticity" as follows:

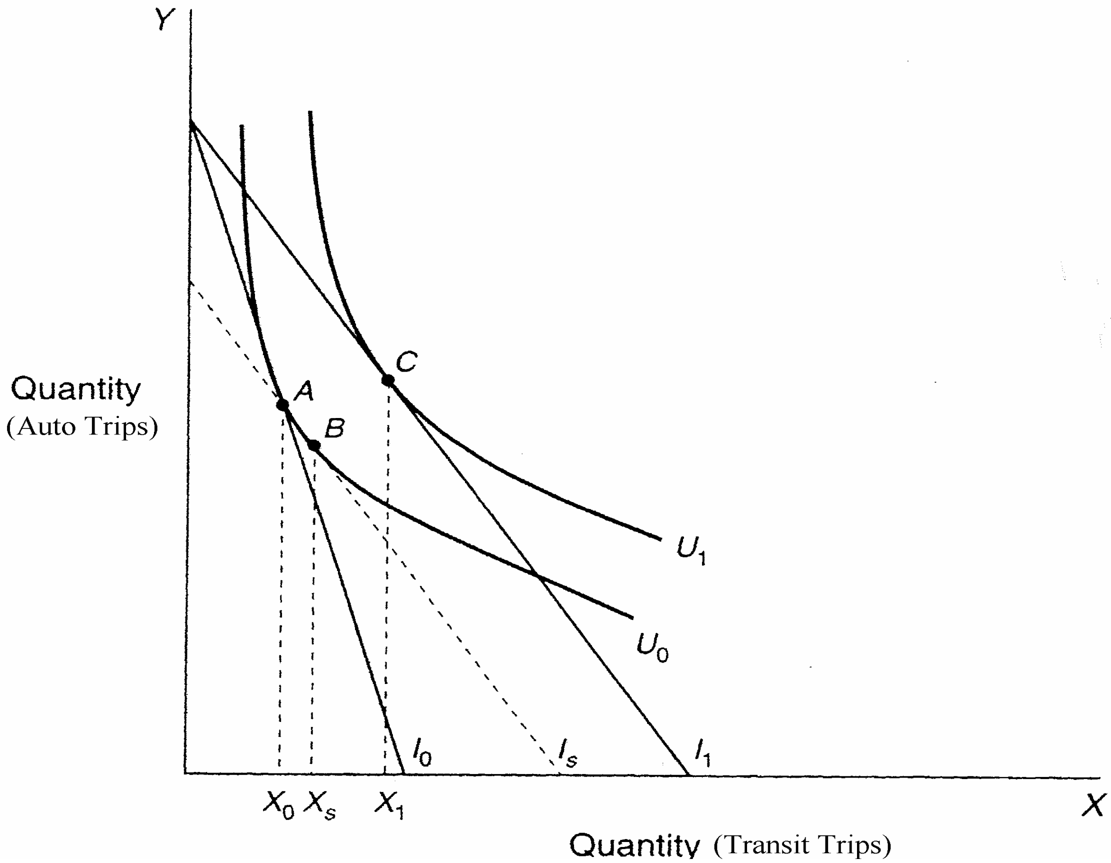
$$e_{X,Y}, \quad = \quad \frac{\partial X/X}{\partial Y/Y} \quad = \quad \frac{\partial X}{\partial Y} \cdot \frac{Y}{X} \tag{6-2}$$

6.2.2 The Components of Response to Fare Reduction

The response to a change in fare or out-of-pocket cost is decomposable into two parts: an *income effect* and a *substitution effect*. The response is illustrated in Figure 6-1, which assumes that a traveler chooses between two modes of transportation, transit and auto. Initially, the traveler maximizes utility at point A where his indifference curve, U_o, meets his budget constraint, I_o, by consuming X_o quantity of transit. When the deep discount pass program causes his out-of-pocket cost to fall, the individual's indifference curve will shift outward to become U_I, while the budget constraint rotates outward to form the new budget constraint denoted I_I. Now the traveler maximizes utility at point C where his new indifference curve, U_I, meets his new budget constraint, I_I, by consuming X_I quantity of transit. This is, however, a two-step adjustment process as follows:

1. First, consumption will expand from X_o to X_s in response to the new price assuming the individual was compelled to remain on the initial indifference curve. Termed the *substitution effect*, or pure price effect or compensated price effect, it is determined by finding the budget constraint, I_s, with the same slope as I_I reflecting the reduced price. The difference in the two new budget constraints, $(I_I – I_s)$ is the compensation required to keep utility at the initial level.

Figure 6-1: Income and Substitution Effects of Out-of-pocket Cost Reduction for Transit Travel Due to Deep Discount Pass Programs



Adapted from Friedman (2002), Figure 4-4, p89.

2. Second, the income effect occurs whereby the change in the quantity of rides caused exclusively by the change in budget brings the individual from the initial to the new utility level while holding fare constant. Consumption will expand from X_s to X_I maximizing utility at point C where the new indifference curve, U_I, is tangent to the new budget constraint, I_I.

6.2.3 Analytics of Income and Substitution Effects

The utility-maximizing choice of an individual depends on the prices of goods (P_i) or transport mode including X, the transit mode, and the budget level (I). In response to changes in any of the parameters, say fare or income, the individual will change demand for the good, say transit rides. The responses are reflected in a *demand function* that may be generalized as follows:

$$X = D_x(P_1, P_2, \ldots, P_x, \ldots, P_n, I) \tag{6-3}$$

Income Elasticity

Taking the partial derivative of the demand equation with respect to income will provide a measure of the response to a unit increase in income. The income elasticity is defined therefore as:

$$e_{X,I}, = \frac{\partial X/X}{\partial I/I} = \frac{\partial X}{\partial I} \cdot \frac{I}{X} \tag{6-4}$$

Where $e_{X,Y}$, denotes the elasticity of one variable, X (say ridership), with respect to another variable, I (say Income),

Price Elasticity

Similarly, taking the partial derivative of the demand equation with respect to price (expressed as $\partial X/\partial P_x$) will provide a measure of the response to a unit increase in price. The price elasticity is defined therefore as:

$$e_{X,P_x}, = \frac{\partial X/X}{\partial P_x/P_x} = \frac{\partial X}{\partial P_x} \cdot \frac{P_x}{X} \tag{6-5}$$

Total Effect and the Slutsky Equation[36]

The Slutsky equation describes the decomposition of the total effect of a price change to its component income and substitution effects as follows:

$$\frac{\partial X}{\partial P_x} = \left.\frac{\partial X}{\partial P_x}\right|_{U=U0} - X\frac{\partial X}{\partial I} \qquad (6\text{-}6)$$

Where

(a) The first term on the right is the *substitution effect* in which utility level is held constant at its initial level of U_o.

(b) The second term on the right is the *income effect* which is proportional in size to the individual's initial consumption level of good X, transit.

The Slutsky equation may be rewritten in terms of price and income elasticities by multiplying both sides by P_x/X and the last term by I/I as follows:

$$\frac{\partial X}{\partial P_x} \cdot \frac{P_x}{X} = \left.\frac{\partial X}{\partial P_x}\right|_{U=U0} \frac{P_x}{X} - X\frac{\partial X}{\partial I}\frac{P_x}{X}\frac{I}{I} \qquad (6\text{-}7)$$

(a) The left side term is now the same as the price elasticity, $e_{X,Px}$, (Equation 6-5);

(b) The first term on the right side is the substitution elasticity, $e^{s}_{X,Px}$

(c) Rearranging the second term on the right side produces the income elasticity, $e_{X,I}$, (Equation 6-4) and the proportion of income spent on good X, -(P_x X) / I.

Equation 6-7 may be written more concisely therefore in terms of price and income elasticities as:

$$e_{X,Px}, \quad = \quad e^{s}_{X,Px} \ -(P_x X)/I \quad e_{X,I} \qquad (6\text{-}8)$$

6.3 EMPIRICAL ELASTICITIES IN TRANSIT

Table 6-1 presents some empirical estimates of the fare elasticities of demand for transit in general and for selected deep discount group pass programs. The following are noteworthy:

- In general, all elasticities are larger than -1 and range between -0.26 and -0.6 indicating that the demand for transit service is quite inelastic. However, the figures suggest that the demand may expand as a result of reduction in the effective fares whether directly in per ride fares or indirectly in out-of-pocket cost through deep discount programs.

These observations carry certain policy implications. The elasticities do not justify the concern that implementation of deep discount programs could overwhelm existing operations. This is especially so vis-à-vis the fact that approximately 27% of existing transit capacity is used overall in urban areas (Brown, Hess and Shoup, 1999).

Table 6-1: Comparative Fare Elasticities[1]

Transit in General		
By Time of Day[2]	Peak	-0.17
	Off-Peak	-0.40
By Trip Purpose[2]	Work	-0.10
	School	-0.19
	Shopping	-0.23
By Mode[3]	Rail	-0.26
	Bus	-0.46
College Campus-Based Student Deep Discount Programs[4]		
California State University, Sacramento		-0.26
University of California, Davis		-0.28
University of Wisconsin, Madison		-0.34
University of Illinois, Urbana-Champaign		-0.49
University of Colorado, Boulder		-0.50
University of California, Berkeley[5]		-0.60
Employment-Based Deep Discount Programs[5]		
City of Berkeley Employees – AC transit		-0.33
Silicon Valley Employees – Santa Clara VTA		-0.60
College Campus-Based Mixed-Affiliate Deep Discount Programs[5]		
University of Washington, Seattle – Students		-0.28
University of Washington, Seattle – Faculty and Staff		-0.17

[1] Mid-point arc elasticities

[2] Mayworm et al, 1980, p xi[37]

[3] Savage, 2002, Table 1[38]

[4] Shoup et al, 1999, Table 3[39]

[5] Author's estimate[40]

- The responsiveness to fare changes may differ significantly by time of day, trip purpose, transit mode, and type of fare instrument. The largest responses are likely to occur during off-peak periods (when excess capacity is most likely to be available) and for the bus travel mode, which is more ubiquitous than the rail modes.

  This implies that groups need to be carefully selected to maximize benefits from the use of existing transit capacity. Participants who need to travel more during the off-peak than peak periods are therefore prime candidates for deep discount programs.

- In general, deep discount programs exhibit higher fare elasticities than the industry as a whole. This implies that it may be more beneficial to direct efforts at promoting deep discount programs than general fare reductions.

6.4 GENERALIZED IMPLICATIONS OF ELASTICITIES

6.4.1 Geometric Interpretations of Responses to Fare Changes

Figure 6-2 depicts hypothetical plots of demand elasticities with respect to deep discount fares. The following are noteworthy:

- If elasticity is zero as in “Curve A”, change in ridership due to the institution of the deep discount pass program is also zero. This means there is no benefit to the agency nor employer (or payer) except for the existing transit riders within the group who would enjoy lower fares.

- If elasticity is very low as in “Curve B”, a large reduction in out-of-pocket cost due to the deep discount pass will trigger a less than proportionate increase in riders. The payer (employer or group) may end up paying more per ride than the transit agency previously recovered from that market segment. The operator will therefore make a net gain in revenue.

- If elasticity is high as in “Curve C”, then a reduction in out-of-pocket cost due to the deep discount pass program will trigger a larger than proportionate increase in riders. In this case, the payer (employer or group) is likely to pay less per ride than the transit agency previously recovered. The operator could therefore incur a net revenue loss per ride. However, the agency could still make a gain in total net revenue if the product of pass price and quantity of participants is higher than the revenue generated from previous transit riders in the group. This situation thus still remains advantageous to the transit agency where there is existing capacity to be filled by the new riders.

- If, as is quite possible, the elasticity curve is non-linear as in “Curve D” of Figure 6-3, then either of the last two situations discussed could result depending on the origin and destination points of the changes in price. As shown, results related to either elastic or inelastic conditions could occur. For this reason, it is necessary to know the shape of the elasticity curve and the loci of prices and quantities if a reliable projection is to be made.

Figure 6-2: Hypothetical Demand Curves of Different Elasticities

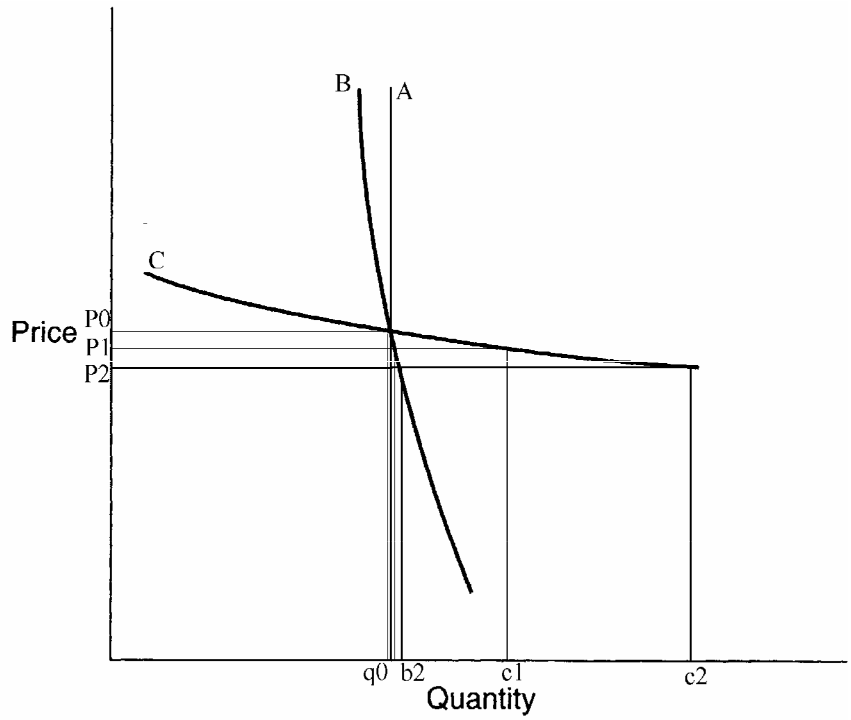
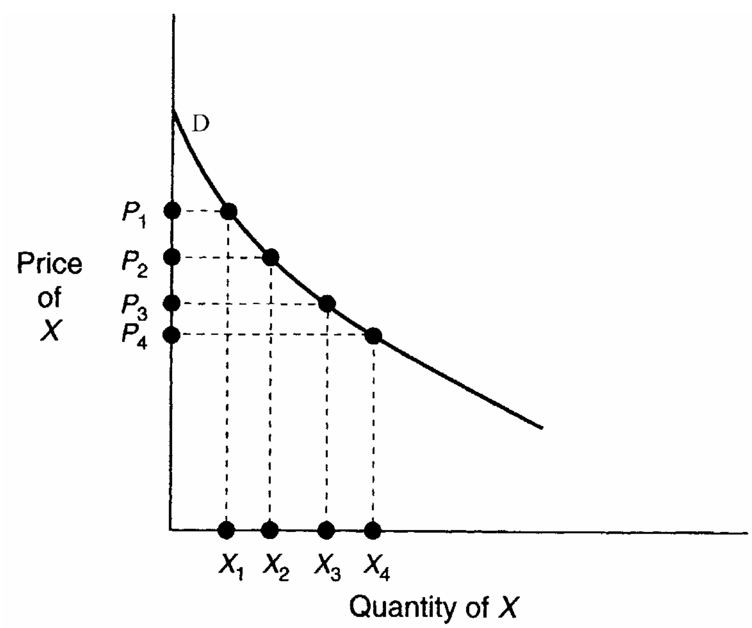


Figure 6-3: Hypothetical Non-Linear Demand Curve



6.4.2 Analytics of Price vs. Patronage Implications

Let us define variables as follows:

P_g = equivalent monthly unit price of the deep discount pass sold to a group

P_s = standard monthly pass price

N_g = number of persons passes are purchased for in a group

R_b = number of transit riders from the group before implementation of the pass program

R_a = number of transit riders in the group following implementation of the pass program

I_o, I_c = revenue from passes sold to the group before and after pass implementation respectively

Then current revenue from pass holders is the cost of pass to purchasers represented as:

$$I_c = P_g * N_g = \Sigma_{Ng} P_g \qquad (6\text{-}9)$$

And previous transit revenue is now lost revenue under the pass program represented as:

$$I_o = P_s * R_b = \Sigma_{Rb} P_s \qquad (6\text{-}10)$$

Implications

If $I_c > R_a * P_s$ ceteris paribus, then the payer (employer, group, or association) loses

If $I_c < R_a * P_s$ ceteris paribus, then the transit agency loses

If $I_c = R_a * P_s$ ceteris paribus, then no party makes a gain from the program.

Estimation

It may be necessary to make future projections during planning and negotiations leading to the institution of a deep discount group pass program. Empirical elasticities may be used under ceteris paribus assumptions if the projected conditions are similar to those under which the empirical estimates were derived.

1. Future Riders (R_a)

$$R_a = f(e_{X,Px}, R_b) = R_b\,(1 + |e_{X,Px}|) \quad \text{for } 0.26 \le |e_{X,Px}| \le 0.60 \qquad (6\text{-}11)$$

2. Unused Passes (N_g - R_a)

$$(1 - |e_{X,Px}|\max) \le (N_g - R_a) \le (1 - |e_{X,Px}|\min) \qquad (6\text{-}12)$$

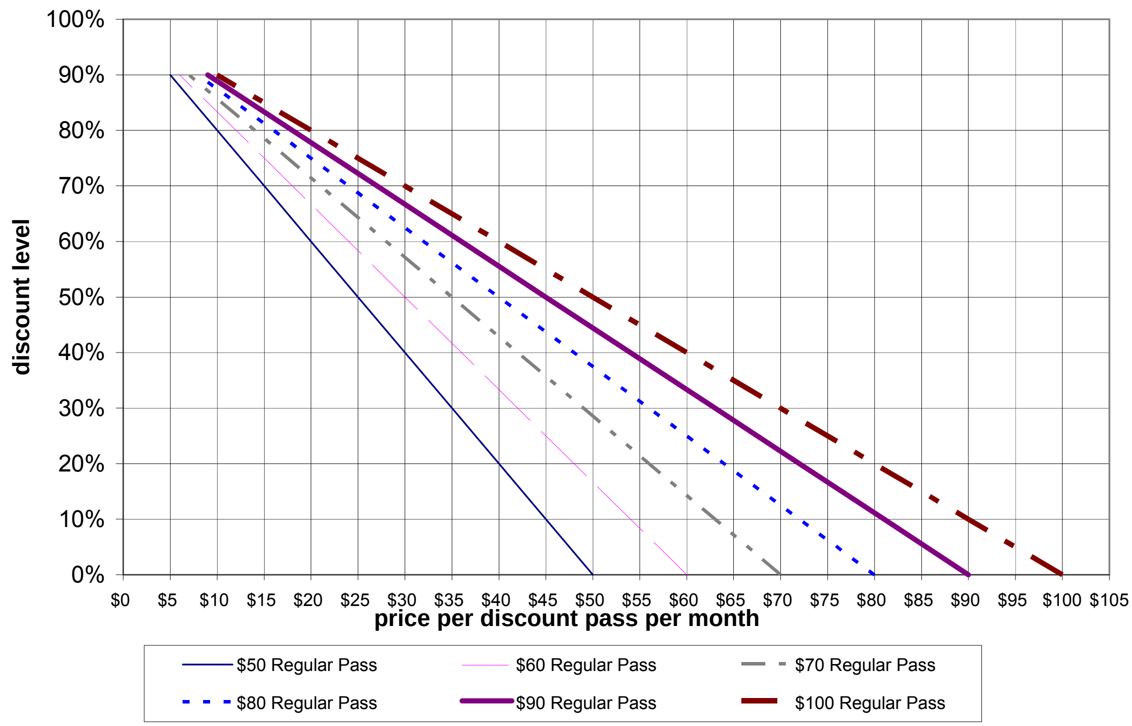
$$(1 - 0.60) \le (N_g - R_a) \le (1 - 0.26)$$

6.5 ATTRACTIVENESS OF DEEP DISCOUNT PRICING

6.5.1 General Attractiveness

The attractiveness of deep discount pricing is the fact that pass prices tend to be very close in magnitude even if the base or regular fares were wide apart to begin with. Figure 6-4 illustrates this point. For a variety of regular periodic passes that are priced from $50 to $100 each, a deep discount price of $10 across the board will translate to deep discount levels of 80% to 90%. Viewed from a different perspective, a 90% discount across the board will result in deep discount fares that range between $5 and $10, all of which are extremely low relative to the regular fares. This fact could minimize contentions from stakeholder groups about the equity of prices among various deep discount programs.

Figure 6-4: Discount Level by Unit Pass Price by Regular Pass Fare



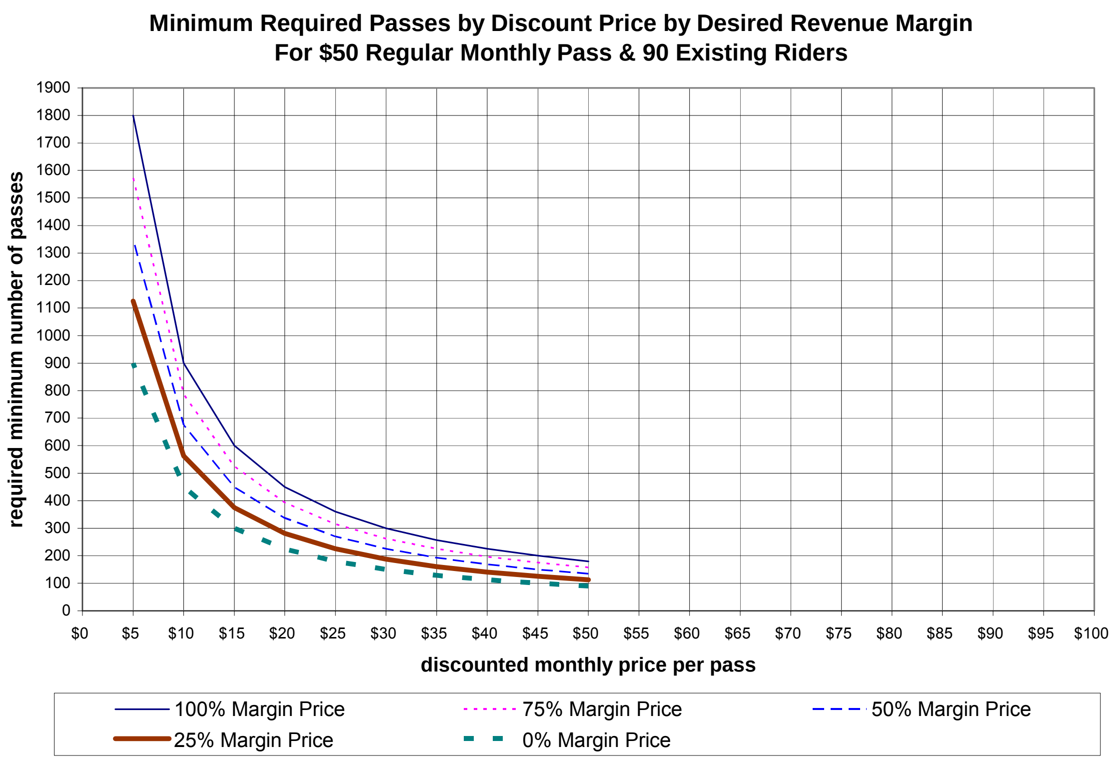
6.5.2 Hypothetical Examples

Figures 6-5, 6-6 and 6-7 illustrate, for hypothetical cases, the minimum required number of passes that need to be sold in order to achieve desired revenue margins over existing receipts at various levels of deep discount prices. The charts illustrate that deep discount pricing is most attractive when populations of target groups are large. Minimal pass prices can yield significant margins on revenue if the target groups are sufficiently large. They also illustrate that the required minimum number of passes for a given group increases in proportion to the number of existing riders for given pass prices. This is also demonstrable analytically with the equation for calculating the required number of passes (**N_g**) as a function of the standard monthly pass price (**P_s**), the deep discount pass price

(**P_g**), the desired margin over existing revenue (**T_m**) and the number of existing transit users (**R_b**) within the group.

$$N_g = (P_s / P_g) * (1 + T_m) * R_b \quad (6\text{-}13)$$

Figure 6-5: Deep Discount Price by Required Number of Passes (Case I)



The charts illustrate that a transit agency could offer very high discounts (at say 90% of standard pass prices) to target groups with large memberships and still make net gains on revenue. For example, supposing an employer purchased 1,330 passes for employees at the equivalent rate of $5 per month and previously, 90 employees used transit at the regular pass price of $50 per month. Figure 6-5 shows that the transit agency can earn more than a 50% margin over previous revenue for offering the program to the group.

The same example with 90 existing riders requires that 900 deep discount passes are sold to earn a 100% margin on existing revenue with a deep discount pass price of $10 (Figure 6-5). Comparatively, if there were 880 existing riders, 8,800 passes would have to be sold to earn a 100% margin on existing revenue with a deep discount pass price of $10 (Figure 6-6). However if the standard pass fare were double at $100, the example with 90 existing riders requires that twice as many or 1,800 deep discount passes are sold to earn a 100% margin on existing revenue with a deep discount pass price of $10 (Figure 6-7).

Figure 6-6: Deep Discount Price by Required Number of Passes (Case II)

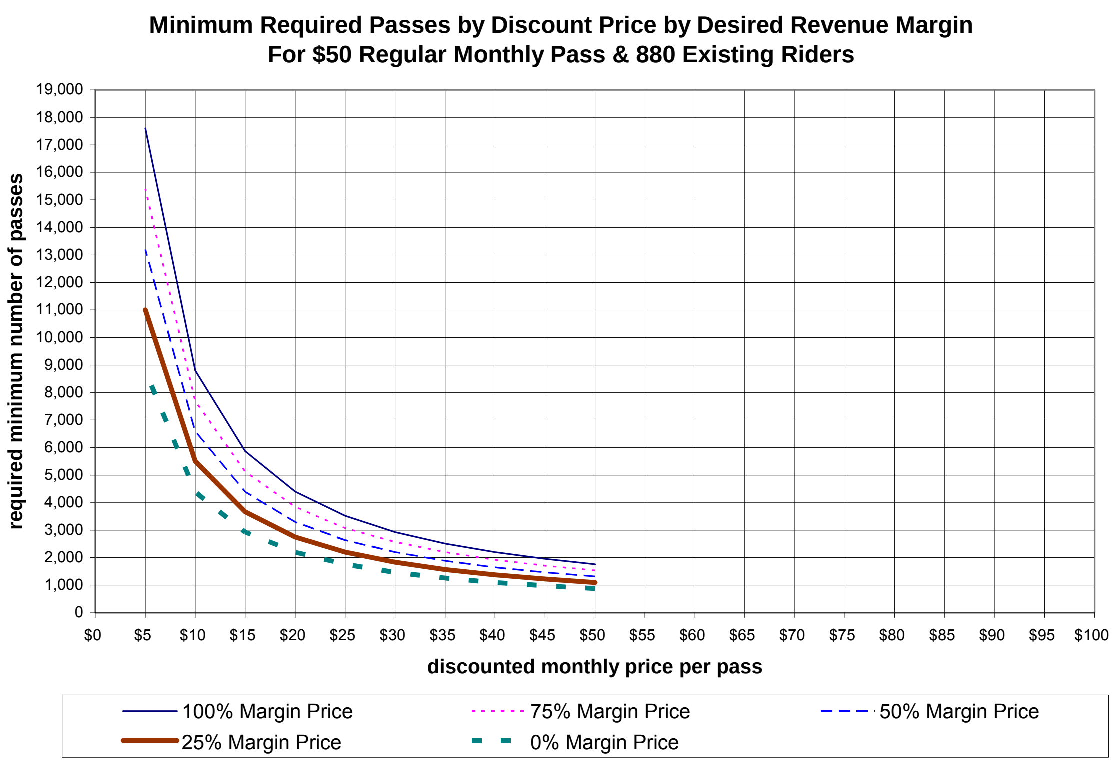
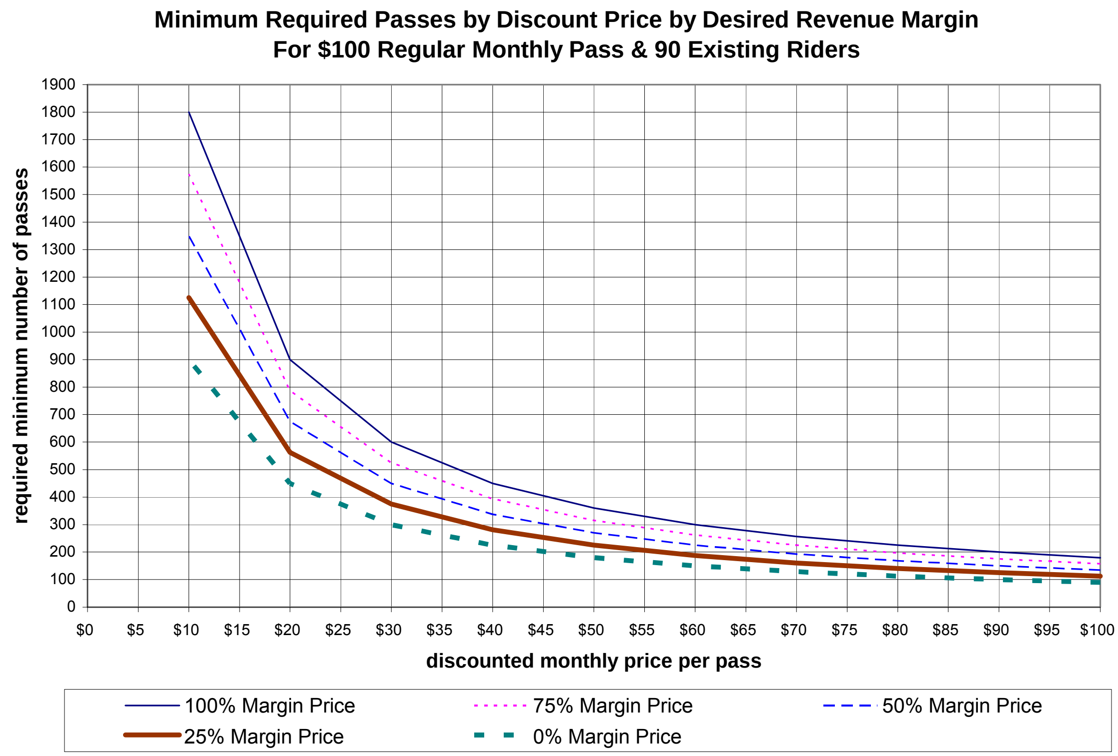


Figure 6-7: Deep Discount Price by Required Number of Passes (Case III)



6.6 SUMMARY

With deep discount passes, program participants respond to the resultant reduction in out-of-pocket cost of riding transit by increasing the number of rides taken. This is consistent with the utility-maximizing choice behavior of individuals. This consumer response is decomposable into two parts: an income effect and a substitution effect. This decomposition of the total effect of the change in out-of-pocket cost (the surrogate for price) is explained by the Slutsky Equation in terms of price elasticity, income elasticity, and substitution elasticity.

Comparisons of empirical elasticities reveal that deep discount programs exhibit generally higher fare elasticities than those in the transit industry as a whole. This implies that it may be more beneficial to direct efforts at promoting deep discount programs than general fare reductions. The responsiveness to fare changes may differ significantly by time of day, trip purpose, transit mode, and type of fare instrument. This implies that groups need to be carefully selected to maximize benefits from the use of existing transit capacity. Participants who need to travel more during the off-peak than peak periods are therefore prime candidates for deep discount programs.

The attractiveness of deep discount pricing lies in the fact that pass prices tend to be very close in magnitude even if the base or regular fares were wide apart to begin with. For instance, 90% discounts on $50 and $100 fares produce $5 and $10 respectively, which are quite similar in magnitude. This fact could contribute to minimizing contentions from stakeholder groups about the equity of prices among various deep discount programs.

The next three chapters present detailed case study examples of the various types of deep discount group pass programs. The case studies provide first-hand information on how the programs work, changes in travel behavior of program participants in response to changes in out-of-pocket costs, and the effects on transit agency operations in terms of ridership and revenues.

7. THE DENVER RTD ECO PASS PROGRAMS

7.1 INTRODUCTION

The Regional Transportation District (RTD) of Denver has instituted one of the oldest, employment-based, deep discount transit pass programs in the country. The design of the program provides a model that other transit providers seem to emulate. The term, ECO is originally an acronym for “employee commute options”. As the program is extended from employment-based to residential-based passes, the term tends more and more to connote both “economical” and “ecological”.

7.2 TYPES OF PROGRAMS

RTD offers four types of deep discount programs in addition to regular periodic passes. The first is the *employment-based ECO Pass*. Its success led to the institution of the residential-based deep discount pass termed, the *Neighborhood ECO Pass*. Another is the campus-based *College Pass* program. A variant of the latter is the *TeenPass* that is sold through middle and high schools. RTD offers three other types of “discounted” passes that are not considered true deep discount fare instruments according to the definition in this document and are therefore not included in the analysis. They include the following:[41]

- *ValuPass:* The ValuPass is available for any monthly pass category. A rider who pays for ten months in advance can get two months free.
- *Just For Youth:* This pass is available for the youth age 18 and under. It sells for $10.00 per month, but is only available for the months of June, July and August.

- *GradPass*: Each year, RTD offers the GradPass, a free summer bus/train pass, to all graduating 8th graders.

The City of Boulder located approximately 20 miles to the northwest of Denver offers all these programs and many other experimental programs. The Boulder program is overviewed in Appendix 7-1.

7.3 GOALS AND OBJECTIVES

The primary goal of the ECO Pass was to increase transit ridership. Its secondary goals aimed at improving the quality of life in the region through reductions in traffic congestion, air pollution, vehicle miles traveled and the impact of the automobile on the environment.

The objective of the program was to promote transit as an alternative to driving alone through the provision of a low-cost fringe benefit to workers. Its targeted subjects are expanded to include neighborhood residents and students.

7.4 HOW THE PROGRAMS WORK

7.4.1 The Employment-based ECO Pass[42]

Universality ~ The Eco Pass is an annual transit pass. A participating employer purchases the transit pass for all full time employees in the organization.

Unlimited Ride ~ The pass is in the form of a photo ID card that permits pass holders to make an unlimited number of rides on all RTD services (excluding special services) 7 days a week for an entire year. Holders can ride:

- Local, Express or Regional buses
- SkyRide bus service to Denver International Airport
- Light Rail
- Call-n-Ride

Guaranteed Ride Home ~ All Eco Pass cardholders are eligible to use the Guaranteed Ride Home Program from *RideArrangers*. This peace-of-mind program gives pass holders a **FREE** taxi ride home in the event of an emergency, illness or unexpected schedule change that requires them to work late. They may use the Guaranteed Ride Home Program on any day they ride the bus or use another form of alternative transportation to get to work.

Innovative Financing ~ The program adopts an insurance concept for financing the ECO Pass. That is why an employer purchases passes for all employees, regardless of the level of individual use or whether every employee would use the program or not. The large volumes allow the passes to be sold at relatively low unit costs. Thus the pass is issued at deep discounts when compared to the regular monthly pass.

Pricing ~ However, not all passes are priced equally because the pricing is designed to cover costs of providing service that include operational, maintenance and administrative expenses of the transit agency and program marketing as well as administrative assistance to participating employers. The price of the ECO Pass per employee is therefore based on employment location as follows:

- Availability of bus service at that location – the need for service extensions would result in a higher unit price
- Number of employees at the location – the fewer the number of employees the higher the unit price
- The level of peak-hour service trips near the location -- the higher the level of peak-period travel in the locality (such as a CBD), the higher the unit price.

As an example, the price of an ECO Pass per employee is considerably higher in downtown Denver, where there is a concentration of services and peak period travel and where parking is expensive, than in the suburbs, where there are fewer services and peak period travel and plenty of free parking. The RTD attempts to capture these factors in the rate chart presented in Table 7-1.

Participation ~ Table 7-2 shows an upward trend in the purchase of the ECO Pass over its existence. The number of participating companies was 47 at program inception, but grew twenty-four-fold within 5 years peaking at 1,178 and appeared to have tapered off thereafter. The number of eligible employees grew over the entire decade from 3,900 in 1991 to 77,500 in 2001 after which there are indications to suggest a tapering off. Additional details are included in Appendix 7-2.

Table 7-1: Denver RTD Pricing Chart (Effective 01/01/2003)

RTD 2003 Eco Pass Pricing							
SLA	Contract Minimum Per Year		Per Employee/Per Year				
	Employees	Amount	1-24	25-249	250-999	1,000-1,999	2,000+
A	1-10 11-20 21+	$420 $840 $1,260	$44	$39	$34	$29	$27
B	1-10 11-20 21+	$900 $1,800 $2,700	$95	$85	$78	$73	$69
C	1-10 11-20 21+	$1,260 $2,520 $3,780	$242	$225	$213	$208	$197
D	1-10 11-20 21+	$1,260 $2,520 $3,780	$247	$236	$219	$213	$202

Table Notes:

1. Source: http://www.rtd-denver.com/FaresAndPasses/Passes/Eco_Pass/pricing.html
2. The contract amount is either the number of employees times the cost per employee or the contract minimum, whichever is greater.
3. The Service Level Area (SLA) designation helps determine the price of the Eco Pass. The SLA is determined by the amount of bus service available to the office location and other factors. There are four SLA categories:
   A. Outer suburban and major employment centers outside CBD*
   B. Downtown Boulder CBD* and fringe Denver CBD*
   C. Downtown Denver CBD*
   D. Denver International Airport (DIA) and home businesses
   **CBD = Central Business District*

Table 7-2: Trends in ECO Pass Participation

	Participating Companies	Employee Pass Holders
1991 – Program Inception	47	3,912
1996 – Half a Decade Later	1,178	32,976
2002 – Recent	1,059	76,577

The trends in participation are explained by the fact that large firms added to or replaced small firms over the years as additional firms adopted the ECO Pass as a "benefit" to employees. In 2002, for instance, Table 7-3 shows that firms that have 100 or more employees constituted 11% of participating companies but accounted for 73% of employee participants. At the other end of the spectrum, firms that have less than 25 employees constituted 63% of participating companies but accounted for 8% of employee participants.

Table 7-3: Distribution of Company Size by Eligible Employees (2002)

Company Size	Companies Enrolled	% of Companies Enrolled	Eligible Employees	% of Eligible Employees
100 +	120	11%	56,260	73%
< 100	940	89%	20,320	27%
< 25	670	63%	6,430	8%

The perception and acceptance of the ECO Pass as an "employee benefit" is reflected in the fact that 74% of all participating companies provide some level of subsidy. Among firms that subsidize the Pass, 88% cover the full cost while only 12% cover a portion. Table 7-4 and Appendix 7-2 contain additional details.

Table 7-4: Degree of Subsidization of the Employee ECO Pass (2002)

All Companies Enrolled			Companies Providing Subsidy	
Subsidy Level	**% of All Companies Enrolled**		**Subsidy Level**	**% of Companies Providing Subsidy**
All Levels	74%		**Full**	88%
None	26%		**Partial**	12%
Total	100%		**Total**	100%

7.4.2 The Neighborhood ECO Pass[43]

Description ~ This is a deep discount annual transit pass purchased by a neighborhood organization for all members of participating households. Once a community organization concludes their Neighborhood Eco Pass agreement with RTD, eligible residents are issued individual photo ID passes that entitle residents to one year of unlimited travel on all RTD Local, Express, Regional, call-n-Ride, and Light Rail routes, plus unlimited skyRide service to Denver International Airport. When residents ride the bus, they simply show their Neighborhood Eco Pass ID to the driver and take a seat.

The Neighborhood Eco Pass is touted as an "environmental alternative to single occupancy vehicles, a cost-saving convenience for residents and a great way to enhance community relations". Similar to the employment-based program, the Neighborhood Pass exudes the features of universal coverage of members of an identified group, unlimited ride, and innovative financing with deep discount pricing.

Requirements ~ The standardized requirements to qualify for the program include the following:

1. Only neighborhoods located within the RTD District are eligible.
2. The neighborhood is required to be represented by a registered neighborhood organization or association, or by a city or county government entity for the purpose of entering into an agreement with RTD.
3. All housing units within a participating residential neighborhood are included in the total price of the program.
4. The neighborhood organization appoints someone to act as liaison between RTD and the neighborhood residents. This individual is responsible for: (a) providing RTD with the requested household information; and, (b) collecting the funds to meet the terms of the agreement.
5. The neighborhood organization provides a map outlining the neighborhood's boundaries, plus other neighborhood information requested by RTD.

Pricing ~ RTD charges an annual fee per housing unit. The price reflects the number of eligible housing units, amount of transit availability and usage. The minimum amount required to initiate a Neighborhood Eco Pass contract is the greater of the computed cost for 100 residential units or $5,000. The Neighborhood Eco Pass program offers substantial savings when compared to the per person price of a regular monthly pass.

7.4.3 The Colorado University (CU) College Pass[44]

As early as 1991, the University of Colorado (CU) students voted to adopt a bus pass program that has been a resounding success and still exists today. In 1998, the Faculty and Staff ECO Pass began initially as a pilot program. The following indicate its effectiveness:

- In six years, the number of students riding the bus jumped fivefold from 300,000 trips to 1,500,000 trips annually.
- A modal choice survey revealed that 42% of these trips would have been by car.
- The biannual travel behavior survey released in January 1999 indicates that student bus ridership to campus has risen by a factor of about 550% from 1990 to 1998.
- The Student Bus Pass program won the EPA's “Way-to-GO” award for its achievements in reducing pollution by encouraging alternative transportation and providing economical options for greater student mobility. EPA estimates that the bus program reduces driving by 3.2 to 6.5 million miles per year consequently preventing 1,700 to 3,000 metric tons of greenhouse gas emissions from entering the atmosphere.[45]

The tremendous student ridership increase encouraged the implementation of two new transit services, which have proven to be great assets to the city of Boulder and the goals of its Transportation Master Plan.

- The HOP is a smaller shuttle type bus that runs on high frequencies connecting the downtown, the university and the major commercial shopping areas in a circular route. It was initially funded by federal grant money but more recently with support from the student bus pass fee.
- The SKIP is an express bus that travels the north/south span of the city, running by the university at high frequencies.

CU students demonstrated their overwhelming support of the bus pass program in 1997 by approving a referendum by an extraordinary 16 to 1 margin that raised their student fees by $5 a semester to $19.42 in order to extend transit benefits and services as follows:

- In addition to free local bus service, students consequently gained free unlimited access on regional trips that cost $3.25 for metro area cities and up to $8 for the DIA airport.
- They also enjoy heavily discounted weekend bus service to major Colorado ski areas.
- Finally, the extra fee helps pay for the HOP and the SKIP bus routes.

The cooperative relationship forged between students, the administration, employees, the city and the RTD demonstrates that everyone can win if they can come together on common goals.

7.5 RIDERSHIP TRENDS

7.5.1 Historical Trends

The investigation of the effect of the ECO Pass on ridership began with a review of historical annual boarding data over approximately two decades: a decade before and a decade after the inception of the ECO Pass program. Table 7-5 is a summary comparison of system-wide boardings with those by three major deep discount groups. They include: (a) the top seven employment-based participating companies, (b) Colorado University, Boulder and (c) Auraria Higher Education Center. Appendix 7-3 shows additional details. The data reveal the following:

- Annual system-wide boardings more than doubled from 25 million (1981) to more than 56 million (1991) over the decade preceding the introduction of the ECO Pass. However, the change from year to year fluctuated quite noticeably including negative growth in three of the years.
- In the decade following the inception of the ECO Pass program, system-wide boardings grew consistently from year to year and peaked at 82 million (2001) with much less fluctuation in the annual rates than the previous decade.
- Over the second half of the decade following inception of the ECO Pass program, system-wide boardings increased by 17% while ECO Pass boardings grew three times as fast by 52%. Within this period, the increase in ECO Pass boardings of the three major participating groups accounted for a third of the annual system-wide increase. In those years, the contribution of the ECO Pass to ridership growth is unquestionable.

Table 7-5: Trends in System-wide vs. ECO Pass Ridership

	System-wide Boardings	"Three Majors[1]" ECO Pass Boardings	% of System-wide Boardings
1991 – Program Inception	56,687,001	83,652	0.15%
1996 – Half a Decade Later	70,217,783	6,452,209	9.19%
2002 – Recent	81,322,365	9,826,303	12.08%

[1] The three major deep discount programs of the RTD include the following:

(a) Top seven employment-based participating companies

(b) Colorado University (CU), Boulder

(c) Auraria Higher Education Center (CU-Denver, Metro State and Community College of Denver

It is worth noting that there are a few other ECO Pass participating groups not accounted for in the data. These include the remainder of the employment-based and all of the residential-based and non-college student-based groups. With the addition of these other groups, even more of the annual increase in system-wide boardings would be attributed to the deep discount group pass programs. Regardless of the actual level of contribution of the ECO Pass to ridership, the historical comparison of boardings supports the hypothesis that deep discount group passes may be instruments for increasing transit ridership.

7.5.2 Pre & Post Ridership Surveys

A number of "before and after" surveys could shed light on how many ECO Pass participants were previous regular fare riders. This information is necessary to make the determination whether the net revenues that accrue to the transit agency due to the deep discount programs are positive or negative. Results of the surveys related to the various programs are outlined in the following sections.

Business Eco Pass ~ In 1997, the RTD conducted a survey of Eco Pass participating companies in Downtown Denver with the following findings:

- Before the Eco Pass, these companies posted 37% RTD ridership overall. According to the responses, 37% rode at least once a week to commute to work.
- After the Eco Pass, they posted a 58% ridership overall.
- These translate to more than half as much increase overall in the number of employee transit riders following introduction of the employee ECO Pass programs.

The RTD is currently conducting pre- and post surveys with all new Eco Pass companies, but has not conducted enough surveys to have valid data on business ECO Passes outside of downtown. The results presented here are therefore valid only for Downtown Denver and may be different for other areas in the RTD District. Even in the downtown area, ridership levels varied by company size with a tendency for larger changes to occur with smaller companies. This is shown in Table 7-6.

Table 7-6: Percent Employee Ridership Before and After Inception of Business Eco Pass

Company Size (employees)	Pre-Ridership	Post-Ridership	Changes	
			% Point	% of Pre
1-24	48%	74%	26%	54%
25-249	27%	53%	26%	96%
250+	42%	58%	16%	38%
Overall	37%	58%	21%	57%

CU Boulder College Pass ~ In 1991, a survey was conducted to determine ridership prior to the start of this College Pass program with the following results:

- 6% of students living off-campus said they rode RTD to school on the day of the survey
- 46% rode RTD at least once the previous semester.

In 2000, CU conducted an after survey with the following results:

- 67% of students said they rode RTD at least once during the past four weeks.
- 59% said they ride RTD at least once during a typical week.

While the "before and after" results are not directly comparable, one can infer that there was no less than the increase from 46% (within a semester "before") to 67% (within four weeks "after"). At most, the increase would be from 6% (on the survey day "before") to 67% (in four weeks "after").

Auraria Campus College Pass ~ In 1993, a survey was conducted to determine ridership prior to the start of this College Pass program with the following result:

- 21% of the students said they rode RTD to school at least once a week.

In 2000, the RTD conducted an after survey with the following result:

- 49% of the students said they rode RTD to school at least once a week.

While the "before and after" results are directly comparable, the response rate for this survey was very poor. The results therefore have a large margin of error.

TeenPass ~ When the TeenPass first started, it was a pilot program at just a few Denver city high schools.

- 33% of students at participating high schools said they typically used RTD to get to school at least once a week the year before the TeenPass program started.
- 29% said they used RTD at least once a week to get to school after the TeenPass program started.

While the "before and after" results are directly comparable, the base populations of the surveys are not the same. The results are therefore inconclusive.

GradPass ~ In 2000, the first year the GradPass was offered, the RTD did a pre and post ridership survey with the following results:

- Before they received their GradPass, 53% of GradPass applicants said they had not ridden RTD. The before ridership of various frequencies therefore stood at 47%.

- After the end of the summer, 96% of GradPass holders said they had used their GradPass at least once during the three months it was valid.
- 54% said they typically used it three days a week or more.

It may be inferred that the composite of varying levels of ridership approximately doubled from 47% to 96% following issuance of the GradPass.

Neighborhood Eco Pass ~ The RTD does not have any survey data on the Neighborhood Eco Pass at this time.

7.5.3 Peak vs. Off-Peak Ridership

A major limitation with the RTD ridership data on the ECO Pass is that it is not recorded by time of day. The RTD expects to rectify this deficiency in the future when program participants are issued with Smart Cards. Due to this limitation, the following are not determined:

- The percentage of ECO Pass boardings that are in peak and off-peak periods.
- Whether the increases in ridership cause more peak crowding than existed before introduction of the various programs.

7.5.4 Ridership Effect on Supply of Service

Boarding by the three major ECO Pass groups accounted for 12% or less of annual system-wide ridership. The data therefore does not support the notion that the program could overwhelm the existing supply of services necessitating capital expansion. One of the areas of potential concern is CBD travel. A 1997 survey of ECO Pass participants in downtown Denver revealed the following:[46]

- 58% of employee Pass holders who worked downtown used it;
- It is estimated that ECO Pass riders accounted for 13% of all downtown employees.

Similarly, it is estimated from a 2001 survey that 44% of employee Pass holders who worked at the airport used it.[47] These levels of Pass use are consistent with survey findings about Silicon Valley commuters in California among whom 40% of pass holders actually use it.[48]

7.6 REVENUE TRENDS

Revenue trend data are available for 7 continuous years out of ten in the 1990s. The data are compiled from the following two sources:

1. System-wide fare revenue data come from the National Transit Database (NTD) of the Federal Transit Administration.
2. ECO Pass revenue data come from the RTD and are available for the key seven employment-based participating groups and the other deep discount programs.

7.6.1 Total Annual Revenue

Table 7-7 is a summary comparison of system-wide revenues with those from the deep discount programs. Appendices 7-4a and 7-4b show additional details in current and constant dollars respectively. The data reveal the following:

- System-wide fare revenue increased consistently in both nominal and constant (1983) dollars each year between 1993 and 2000. During this period, the ECO Pass program has not merely been in existence, it has been expanded. And revenue from the ECO Pass program also increased consistently from year to year in both nominal and constant (1983) dollars.
- From 1995 onwards, annual ECO Pass sales began to account for more than all the annual growth in system-wide fare revenues in either current or constant dollars.
- For the years that data are available, the annual sales revenue from the deep discount programs accounted for between 10% and 90% of the year-to-year increase in system-wide revenues.

Table 7-7: Trends in System-wide vs. ECO Pass Revenue (in Nominal Dollars)

	System-wide		**Deep Discount Programs**	
	Revenue	**Revenue Per Boarding**	**Sales Revenue**	**Revenue Per Boarding**[1]
1994	$26,508,526	$0.43	$3,009,235	$1.09[2]
1997	$36,746,800	$0.51	$5,611,869	$0.77
2000	$45,474,675	$0.58	$8,872,327	$1.07

[1] Revenue per boarding for combined three major programs

[2] Data for 1993

7.6.2 Average Revenue per Boarding

Data reveal that every deep discount program offered by the RTD yields more revenue per boarding than the system-wide average. Additional details are included in Appendix 7-4c. The following are noteworthy:

- Together, the three major ECO Pass programs yielded almost two times as much as the system-wide average by the year 2002. Generally, the employment-based program appears to yield the highest revenue per boarding among the various deep discount programs.
- In constant 1983 dollars, revenue per boarding increased generally in the 1990s both system-wide and across various deep discount programs.

7.6.3 Administrative Cost

The administrative cost associated with implementing the employment-based ECO Pass program ranged between 1% and 7% of total sales receipts each year. Details are included in Appendix 7-3b. By comparison, the proportion of total operating expenditure on materials and supplies at the national level hovered around 9% and 10% each year within the 1990s. During the same period, the proportion of expenditure on general administration ranged between 14% and 22%. The cost of administering the ECO Pass, therefore, did not appear to be excessive and indeed appeared to be less than what was typical with comparative objects of expenditure.

The data analyzed are indicative that a carefully selected combination of deep discount programs (employment-based, neighborhood-based, and student-based) has the potential to contribute significantly to a transit operator's total revenue. The historical data suggests that the employment-based deep ECO pass could serve as the backbone of the deep discount programs offered by a transit agency.

7.7 STATISTICAL ANALYSIS OF RTD OPERATIONAL DATA

7.7.1 Objectives

A fundamental issue to be determined in analyzing the historical data on the RTD is whether changes in any operating variable do cause changes in others or whether changes in individual variables are endogenously determined. Ultimately, two determinations are to be made with reference to deep discount programs. They are the following:

(a) The effect of deep discount programs on revenue.

(b) The effect of deep discount programs on ridership.

There are five operational variables whose effects on each other are therefore of primary concern. They are identified in Table 7-8.

Table 7-8: Operational Variables and Units of Measurement

Operational Variable	Unit of Measurement
1. System-wide Ridership	Annual boardings
2. Service Supply	Annual revenue vehicle miles
3. System-wide Revenue	Constant 1983 Dollars per annum
4. Eco Pass Ridership	Annual boardings
5. Eco Pass Revenue	Constant 1983 Dollars per annum

7.7.2 The Granger Causality Test[49]

The approach to testing for causality is based on the procedure by Granger and Sims.[50] The test is based on the idea that if X causes Y, then changes in X should precede changes in Y. To satisfy this premise, the following two conditions should be met:

(a) In a regression, the independent variable, X, should contribute significantly to the explanatory power of the model predicting Y.

(b) Y should not help predict X. If the latter occurs, then it is likely that one or more other variables are indeed causing the observed changes in both X and Y.

To test for the presence of each of these two conditions, a hypothesis test is performed for a pair of variables stating that: "one does not help to predict the other". First one variable is assumed to be dependent and the other independent. Next, the roles of the variables are switched and the test repeated.

Each of the tests within the pair involves two regressions as follows:

(a) The dependent variable, Y, is regressed only against lagged values of Y. Thus $Y_t = f(Y_{t-1})$. This lagged endogenous model may be termed the "reduced model" that may be presented structurally as:

$$Y_t = \sum_{i=1}^{m} \alpha_i Y_{t-1} + \varepsilon_i \qquad (7\text{-}1)$$

(b) The dependent variable, Y, is regressed against both its lagged values and the lagged values of X. Thus $Y_t = f(Y_{t-1}, X_{t-1})$. This lagged endogenous and exogenous model may be termed the "full model" that may be presented structurally as:

$$Y_t = \sum_{i=1}^{m} \alpha_i Y_{t-1} + \sum_{i=1}^{m} \beta_i X_{t-1} + \varepsilon_i \qquad (7\text{-}2)$$

Where

Y	=	the dependent variable
X	=	the independent variable
α, β	=	parameters to be estimated
ε_i	=	a random error term
m	=	the number of lags

Finally, the sums of squared residuals from both regressions are used to calculate an F-statistic to test whether the group of coefficients, $\beta_1, \beta_2, \ldots, \beta_m$, are significantly different from zero. If they are, the hypothesis is rejected. Commensurate with the two conditions tested for, two results are essential to conclude that "X causes Y". They are:

(a) The initial hypothesis, "X does not cause Y" must be rejected.

(b) The reversed hypothesis, "Y does not cause X" must be accepted.

Permutations of the five variables of primary interest created seven pairs of causality tests, three for all system-wide and four for Eco Pass vs. system-wide relationships. The pairs of variables tested are presented in Table 7-9.

Table 7-9: Pairs of Variables Tested

Initial Hypothesis[1]	**Reversed Hypothesis**[1]
1. supply → system-wide rides	1R. system-wide rides → supply
2. system rides → system revenue	2R. system revenue → system rides
3. supply → system revenue	3R. system revenue → supply
4. Eco Pass rides → system rides	4R. system rides → Eco Pass rides
5. Eco Pass revenue → system revenue	5R. system revenue → Eco Pass revenue
6. Eco Pass rides → system revenue	6R. system revenue → Eco Pass rides
7. Eco Pass revenue → system rides	7R. system rides → Eco Pass revenue

[1] The null hypothesis of these causal statements is tested as: "X does **not** cause Y".

7.7.3 Autocorrelation Tests

Autocorrelation tends to occur with time series data such as used in this analysis. Also called serial correlation, it refers to the correlations of error terms for different observations over time. It violates the Ordinary Least Squares (OLS) assumption of independent error terms and leads to inefficient parameter estimates. When serial correlation is present, then

$$\mathrm{Cov}(\varepsilon_t, \varepsilon_{t-1}) <> 0.$$

Let[51]

$$\varepsilon_t = \rho\varepsilon_{t-1} + \gamma_t$$

So that

$$\gamma_t = \varepsilon_t - \rho\varepsilon_{t-1}$$

Where

ρ is the first-order serial correlation coefficient

γ_t is a random disturbance term that is independent and identically distributed

ε is the error term associated with individual observations

For a count of T time periods of data with t = 1, 2, ..., T, the first-order serial correlation coefficient is calculated for a time lag of one period as follows:

$$\rho = \{Cov(\varepsilon_t, \varepsilon_{t-1})\}/\{Var(\varepsilon_t)\} = \{\sum_{t=2}^{T} (\varepsilon_t * \varepsilon_{t-1})\}/\{\sum_{t=1}^{T} (\varepsilon_t)^2\} \tag{7-3}$$

And similarly for a time lag of two periods as follows:

$$\rho = \{\sum_{t=3}^{T} (\varepsilon_t * \varepsilon_{t-2})\}/\{\sum_{t=1}^{T} (\varepsilon_t)^2\}, \ldots\ldots, \text{and so on.}$$

The higher the absolute value of the coefficient, the more dominant is that lag period in the time series analysis. A plot illustrates the dominance of the coefficients of the various lag periods.

Before application of the Granger Causality Tests therefore the appropriate lag period was determined with plots of autocorrelations for residuals over lags of different numbers of years. To produce the residuals, OLS regressions were performed for the pairs of variables to be tested for causality.

The autocorrelation plots revealed overwhelmingly that a one-year lag is the most dominant. Details of the plots and OLS regressions are presented in Appendix 7-5.

7.7.4 Causality Test Results

Table 7-10 lists the various hypothesis statements tested and their results. Details of the Granger Causality Tests are included in Appendix 7-6. The following are noteworthy:

- All models tested produced certain consistent results that include the following:
    - Both reduced and full models were significant with large F-statistics and high R-squares.
    - The lagged endogenous variables were significant whereas the lagged exogenous variables were not.

  These results suggest in general that the pairs of variables tested did not significantly influence each other. Instead, changes in individual variables are endogenously determined, that is, ongoing trends tend to perpetuate themselves over time. In addition, other undetermined factors contribute to observed changes in the variables over time.

  Human, political and other not-so-measurable factors may have contributed to the changes in supply and patronage of service and in fares and consequent revenues. This implies that program success should not be judged in terms of quantifiable performance measures only, but also in terms of intangible factors.

Table 7-10: Summary of Causality Test Results

INITIAL HYPOTHESIS				REVERSED HYPOTHESIS		
Statement	**Test Result**	**F_{calc}**	**F_{crit}**	**F_{calc}**	**Test Result**	**Statement**
1. System: supply changes do not cause ridership changes	Accept	2.98	**4.41**	3.03	Accept	1R. System: ridership changes do not cause supply changes
2. System: ridership changes do not cause revenue changes	Accept	0.08	**4.41**	3.01	Accept	2R. System: revenue changes do not cause ridership changes
3. System: supply changes do not cause revenue changes	Accept	3.38	**4.41**	2.55	Accept	3R. System: revenue changes do not cause supply changes
4. Eco Pass ride changes do not cause system ride changes	Accept	0.37	**5.32**	6.16	Reject	4R. System ride changes do not cause Eco Pass ride changes
5. Eco Pass revenue changes do not cause system revenue changes	Accept	0.66	**5.32**	0.35	Accept	5R. System revenue changes do not cause Eco Pass revenue changes
6. Eco Pass ride changes do not cause system revenue changes	Accept	3.95	**5.32**	3.30	Accept	6R. System revenue changes do not cause Eco Pass ride changes
7. Eco Pass revenue changes do not cause system ride changes	Reject	9.47	**5.32**	0.79	Accept	7R. System ride changes do not cause Eco Pass revenue changes

- For the three system-wide tests, results are not conclusive. Thus the statistical tests are unable to establish causality one way or the other between pairs of such operational variables as service supply, ridership and revenue. This means other variables are causing the observed changes.

  The RTD embarked on a program of transit service expansion over the last few decades in an attempt to increase the use of shared transport in order to slow the deterioration in air quality. Thus it is not so surprising that the analyses showed that ridership did not significantly contribute to service expansion. In similar vein, ridership changes did not significantly contribute to revenue changes (in constant dollars) since fares were not typically adjusted regularly for inflation. Finally, on account of the above reasons, changes in supply have not significantly affected changes in revenue.

- The test for causality between Eco Pass and system-wide ridership suggests that system-wide ridership changes **do** cause changes in Eco Pass ridership, but not the other way around. These results are explainable by the fact that as a relatively small proportion of the whole, Eco pass rides stabilized at between 9% and 12% of system-wide boardings for more than half a decade.

  This implies that major swings in transit patronage such as occurred previously in times of either crises or economic boom will undoubtedly affect Eco Pass ridership. Transit operators need to be cognizant of this and decisively make adjustments in service supply whenever necessary to accommodate demand. Another policy implication is that more groups need to be identified for deep discount program expansion subject to capacity and cost limitations. Indeed the RTD embarked on such expansion in recent years to the neighborhood and teen Eco Pass programs for which ridership data are not available. Such data should become available when the RTD adopts the magnetic dip fare card in the future.

- The test for causality between Eco Pass and system-wide revenues is not conclusive as the test is unable to establish causality one way or the other. Although the lagged exogenous variables are not significant in the models, examination of standardized beta weights confirms that Eco Pass revenues yield nearly two times as much influence on increases in system-wide revenues as the latter yields on the former. This implies that expansion of Eco Pass programs is recommended for as long as they continue to demonstrate higher marginal revenues than the existing fare instruments.

- The tests failed to reject the hypothesis that "changes in Eco Pass rides do not cause system revenue changes". While unit revenues per boarding from deep discount programs are significantly higher than the system-wide average, the programs constitute a relatively small share of the entire operation and thus are unable to register a significant effect on system-wide revenues.

- The tests rejected the null hypothesis enabling the inference that Eco Pass revenue changes account for system-wide ridership changes although all variables are individually insignificant suggesting the lack of other explanatory variables. Beta weights reveal that Eco Pass revenue increases, which are themselves caused by expansion in the program, exert more than proportionate increase on system-wide ridership while the latter endogenously exerts a slight negative influence on itself.

This implies that while the Eco Pass program might draw from the existing transit riding population, it yields more than proportionate increase in revenue resulting in a net gain in fare revenue. This finding is consistent with the basic hypothesis of this study that deep discount group pass programs may be instruments for increasing transit revenue and ridership.

7.8 SUMMARY

The Denver RTD Eco Pass case study is the most extensive and one of the oldest deep discount programs in the nation, spanning more than two decades. The assortment of programs offered provides an example of the concept for wide deployment of deep discount programs that originally motivated this research. Granger Causality Tests of time series data on RTD operations did not produce conclusive results on the extent of causality between pairs of such operational variables as service supply, ridership and revenues. This is explained by the fact that the RTD embarked on a program of transit expansion to slow the deterioration in air quality and not because of the interaction of prices and ridership. Neither did the tests confirm causal relationships between Eco Pass and system-wide revenues or ridership. This is explained by the fact that Eco Pass programs constitute a relatively small proportion (between 9% and 12%) of the agency's entire operations which stood at approximately 81 million boardings in 2002.

It is interesting to note, however, that every deep discount program offered by the RTD yields more revenue than and up to two times as much per boarding as the system-wide average. The data also reveal that employment-based programs yield the highest revenue per boarding among the various deep discount offerings.

The next chapter explores university campus-based programs. These are the most rapidly expanding type of deep discount programs around the country.

8. CAMPUS-BASED PROGRAM: U.C. BERKELEY STUDENT CLASS PASS

8.1 INTRODUCTION

The majority of students at the University of California, Berkeley voted to assess themselves a fee to be applied toward the deep discount group pass program referred to as the “ClassPass”. The program was consequently initiated in the fall semester of 1999. The data presented in this overview come from two random surveys. Both surveys were weighted to the student population with weights created to reflect undergraduate versus graduate status, gender and ethnicity.

1. The paper survey “before” program initiation took place in the fall semester of 1997. There were 3,357 responses representing 11% of the student population. The margin of error is 1.69% with a 95% confidence interval.
2. The web-based survey “after” program initiation took place in the fall semester of 2000. There were 3,008 responses representing 9.6% of the student population and 51% of the sample. The margin of error is 1.79% with a 95% confidence interval.

8.2 THE PROGRAM

A key feature of the ClassPass program is its universal coverage of all students enrolled during each semester. Another feature is that it allows participants unlimited use of all services provided by AC Transit at no out-of-pocket charge. For a fare medium, a validation sticker is affixed each semester to the official picture identification cards of all students who choose to avail themselves of the services. Currently, approximately 26,000 stickers are picked up a semester out of the student population of about 32,000. To ride an AC Transit bus, a student simply flashes the validated ID card to the operator on entry. Beginning in 2003, the fall semester sticker is valid through the winter break while the spring semester sticker is valid through the summer break. Effectively therefore, the two stickers now cover twelve calendar months.

Each student was initially assessed $34.20 per semester as part of student fees billed through the student's university account to cover the ClassPass and campus perimeter shuttle services. According to the terms of agreement, the assessment is distributed as shown in Table 8-1.

Table 8-1: Distribution of ClassPass Assessment per Semester

	Year of Program	
	1st and 2nd	**3rd and 4th**
Payment to AC Transit	20.00	22.00
Allocation to Student Aid Fund (@ 33.3% of assessment)	11.40	12.40
Campus Parking and Transportation Department (for perimeter shuttle services)	2.80	2.80
Total Assessment	**34.20**	**37.20**

By way of cost sharing, AC Transit supplies the validation stickers based on enrolment while the university distributes the stickers. In order to keep costs low, AC Transit did not commit from the outset to satisfy any service improvements that the ClassPass program would necessitate. However, the agency agreed to provide the Transit Guide to students, to install route map and schedule information at key stops on the perimeter of the campus, and to hold a student forum periodically to inform and receive comments on the status of transit service affecting the campus area.

8.3 CHANGES IN CHOICE OF MODE

The surveys reveal that the choice of AC Transit as the primary mode of travel to campus jumped from 5.6% to 8.7% in the first year of ClassPass implementation; it more than doubled to 14% in the second year of the program. The data suggests that the ClassPass program may have helped reverse a downward trend in the choice of BART as the primary mode of travel. Although a significantly small share, the choice of “other transit" also increased with the introduction of the ClassPass program from 0.2% to 1.3%. Apparently, the pass and AC Transit service provide convenient access to and from BART and other transit services at no additional out-of-pocket cost to the students. This could explain the increase in use of all forms of transit. Results are summarized in Table 8-2. Additional details are included in Appendix 8-1.

Overall, the survey results reveal the following:

- Before the ClassPass, just as many students took public transportation (12.2%) as those who drove (12.5%) and both combined were half as many as those who walked (53.5%).

Table 8-2: Choice of Travel Mode Before and After Introduction of the ClassPass Program

	Before ClassPass Program		With ClassPass Program		Statistically Significant Difference[1]
	1996	**1997**	**1999**	**2000**	**1997 - 2000**
Walk	42.9%	53.5%	42.3%	51.6%	N
Auto Drive Alone	8.5%	12.5%	9.1%	11.5%	N
All Transit	9.0%	12.2%	15.4%	21.7%	**Y**
All Other Modes	39.6%	21.8%	33.2%	15.2%	--
Total	100%	100%	100%	100%	--
Transit					
AC Transit	3.9%	5.6%	8.7%	14.1%	**Y**
BART	4.9%	6.3%	5.6%	6.3%	N
Other Transit	0.2%	0.3%	1.1%	1.3%	**Y**

[1] Null hypothesis: $\%_{1997} = \%_{2000}$; alpha level = 5%; **Y** = **significant**; N = not significant

- After the ClassPass was introduced, there were twice as many transit riders (21.7%) as drivers (11.5%) and both combined increased to nearly two-thirds of those who walked (51.6%).

- Most of the shift in mode to transit came from the personal transportation modes such as walking, drive-alone, and biking.

- Public transit and campus shuttles gained in mode choice because the pass provided convenient access to both types of services.

Statistical tests of mode choice proportions before and after introduction of the ClassPass (Appendix 8-8) reveal the following:

- No statistically significant differences in the shares of walk and drive-alone modes. Although these two modes are the main losers of shares to the transit modes, the losses have not caused significant shifts away from them.
- No statistically significant difference in the share of the BART mode. This may be explained by the fact that the ClassPass provides no direct savings in out-of-pocket costs to BART users. The 2000 survey shows that 84% of student BART riders travel more than 5 miles and 64% travel more than 10 miles to campus. By comparison, 12 % of student AC Transit riders travel more than 5 miles and 5% travel more than 10 miles. Thus many of the BART riders among the students travel over much longer distances than those who travel by AC Transit. Having a pass for AC Transit, which serves a relatively smaller geographic area than BART, appears to have effected negligible change on the choice of BART for travel among the students.
- Differences in the mode shares of AC Transit and "other" transit (including campus perimeter services) were statistically significant at the 5% level. This fact speaks for the effectiveness of the deep discount program in increasing bus transit ridership.

8.4 REASONS FOR MODE CHOICE CHANGES

Before the ClassPass - The survey revealed that 22% of students had changed mode of travel in the two consecutive years before the pass was introduced. Details are included in Appendix 8-2. The top three reasons indicated for changing primary mode of travel to campus were the following:

a. Change in residential location (10.8%)
b. "Other" reasons (5.8%)
c. Change in class or work schedule (1.4%)

AC Transit and BART related issues were minimally selected as reasons for changing primary mode as follows:

a. 0.7% of respondents selected the pilot AC Transit pass program offered voluntarily at $60 per semester.
b. 0.2% of respondents also selected change in AC Transit route or service.
c. 0.1% of respondents selected discount on BART, Muni and BART-plus tickets.

After the ClassPass – The survey revealed that 38% of students had changed mode of travel between the first and second years following the introduction of the program. Besides the 11.5% of respondents who were not enrolled in the previous year, the three top reasons indicated for changing primary mode of travel to campus were the following:

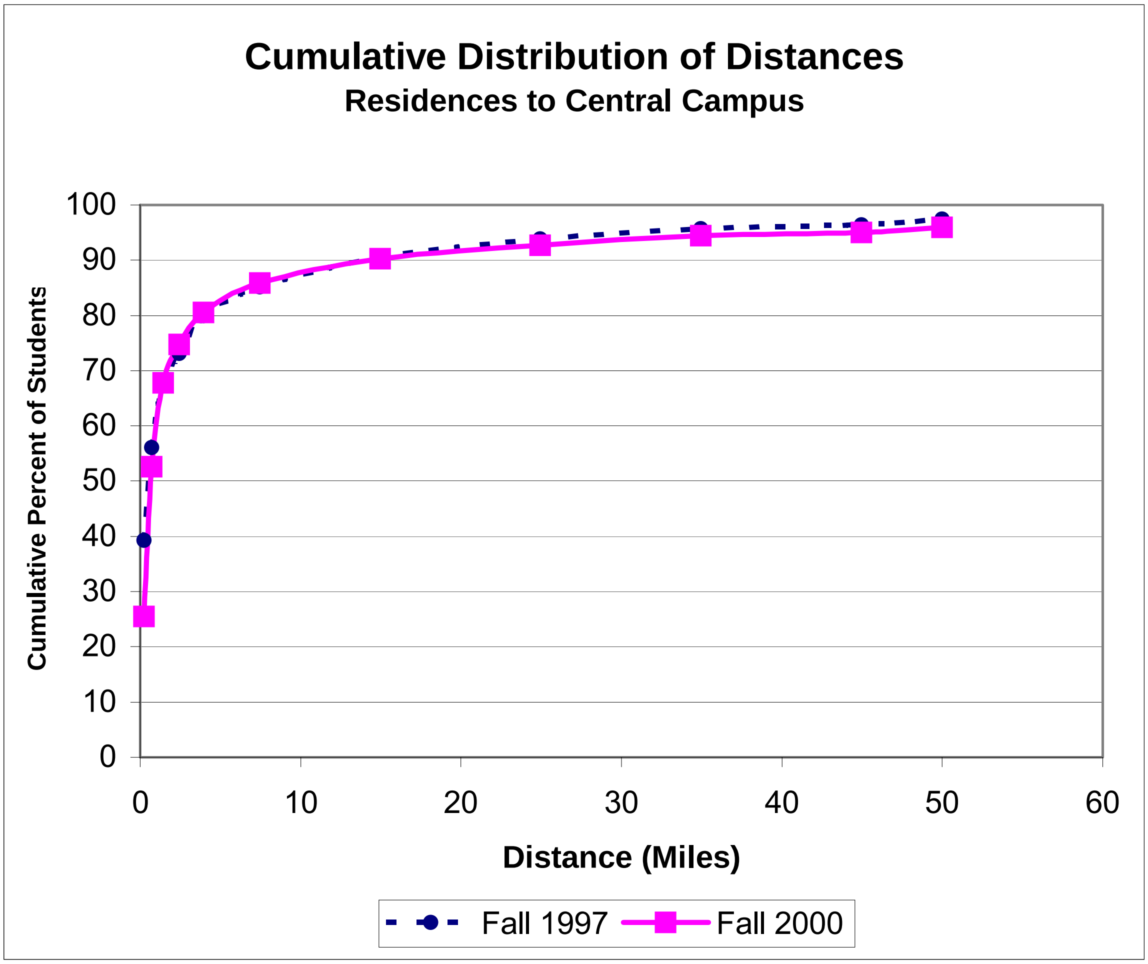
a. Change in residential location (9.9%)
b. "Other" reasons (7.9%)
c. AC Transit ClassPass (3.6%).

These findings are consistent with the increase in transit mode share noted in the previous section. While less than 4% of respondents specifically attributed their shift in mode of travel to the ClassPass, it could very well contribute to the change in residential location and the "other" reasons that together represented nearly half of those who shifted mode.

8.5 CHANGES IN RESIDENTIAL LOCATION

Travel distances between residence and central campus were analyzed to determine the types of "changes" that occurred in residential location subsequent to the introduction of the ClassPass. Figure 8-1 shows cumulative plots of reported median distances "before" and "after" program introduction. The plots lie very close to each other. It is noticeable, however, that the plot for fall 2000 lies beneath the 1997 plot for the most part. Before the ClassPass, nearly 56% of students lived within 1 mile of campus and 73% lived within 3 miles. One year following the introduction of the pass, the respective percentages changed to about 55% within 1 mile and about 75% within 3 miles. The overall average travel distance decreased by about 10% from 4.28 miles to 3.88 miles. As shown in Table 8-3, the short distances over which most students relocated are consistent with the finding that many of the increases in transit mode choice came from walkers. Additional details are included in Appendix 8-3.

Figure 8-1: Cumulative Distribution of Distances



Statistical tests of the proportions of student travel distances before and after introduction of the ClassPass (Appendix 8-8) reveal the following:

- The differences in the proportions of students who resided within the short distances (up to 1 mile) are statistically significant.
- The differences in the proportions of students who resided over distances greater than 1 mile are not statistically significant.

After just the first year, it was not conclusive, as anticipated, that the pass program increased student latitude to seek more affordable or better quality accommodations that were further away from campus, but within relatively easy access of AC Transit or to other transit modes to which AC Transit service facilitated access. However the real estate market was in a state of rapid change in the entire metropolitan area at the time and several extraneous reasons could have explained this initial lack of dispersion.

Table 8-3: Locations of Student Residences from Campus

Distance from Residence	1997	2000	% Change	Statistically Significant Difference[1] 1997 - 2000
Average distance to campus	4.28 miles	3.88 miles	-9%	--
Within 0.5 mile of campus	39.3%	25.5%	-35%	**Y**
Within 1 mile of campus	56.1%	52.6%	-6%	**Y**
Within 2 miles of campus	67.6%	67.8%	+0.3%	N
Within 5 miles of campus	80.0%	80.5%	+0.6%	N

[1] Null hypothesis: $\%_{1997} = \%_{2000}$; alpha level = 5%; **Y** = **significant**; N = not significant

3-D surface charts were prepared to illustrate the spatial distribution of mode choice changes. Figures 8-2 and 8-3 compare the distributions of travel distances between student residences and primary modes of travel before and after the introduction of the ClassPass. Additional details are included in Appendix 8-4. The following are noteworthy:

- As expected, most walkers (65%) lived within half a mile to three miles of central campus and their numbers reduced rapidly over the distance. Although the number of walkers dropped after the pass was introduced, the pattern of spatial distribution of walkers remained the same.

Figure 8-2: Student Travel Distances (Home to Campus) by Primary Mode (1997)

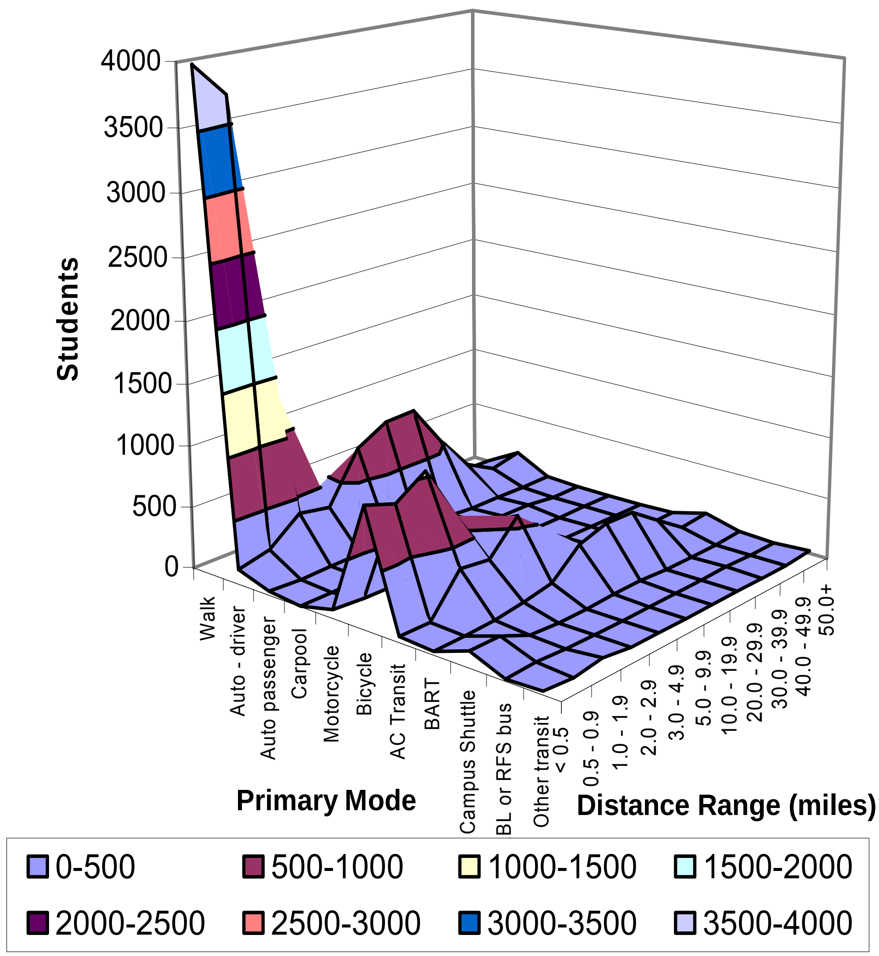
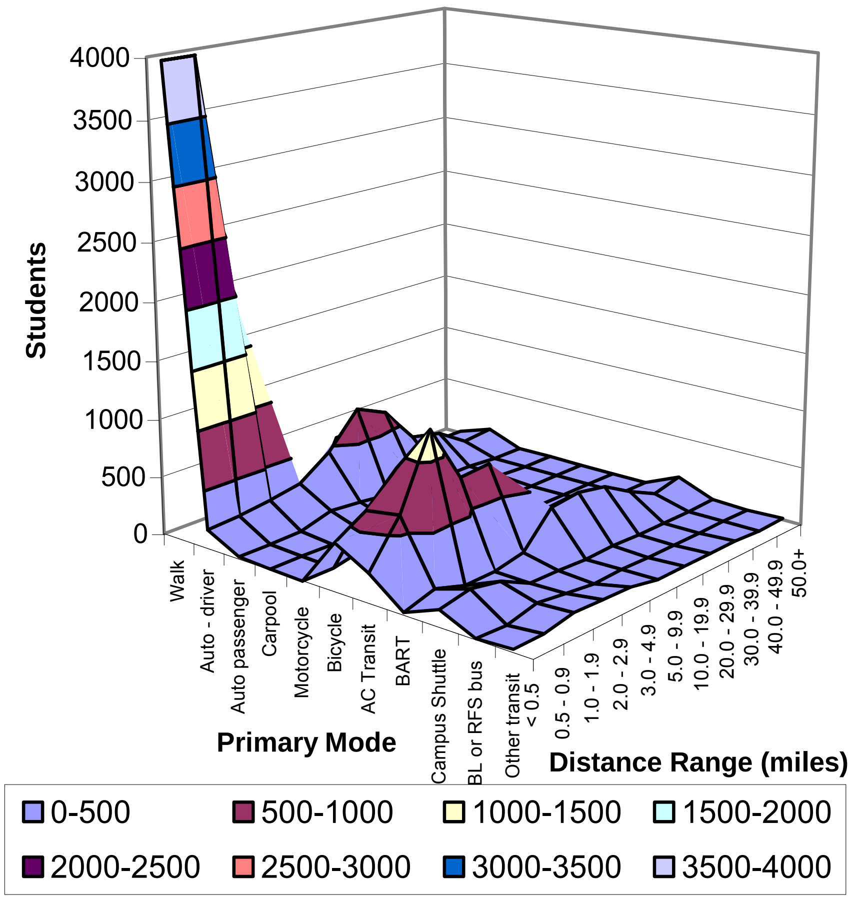


Figure 8-3: Student Travel Distances (Home to Campus) by Primary Mode (2000)



- Similarly, motorcycle and bicycle riders resided close and mainly up to 5 miles from central campus. Most of the shift away from these two modes occurred among those who resided within 2 miles of campus.

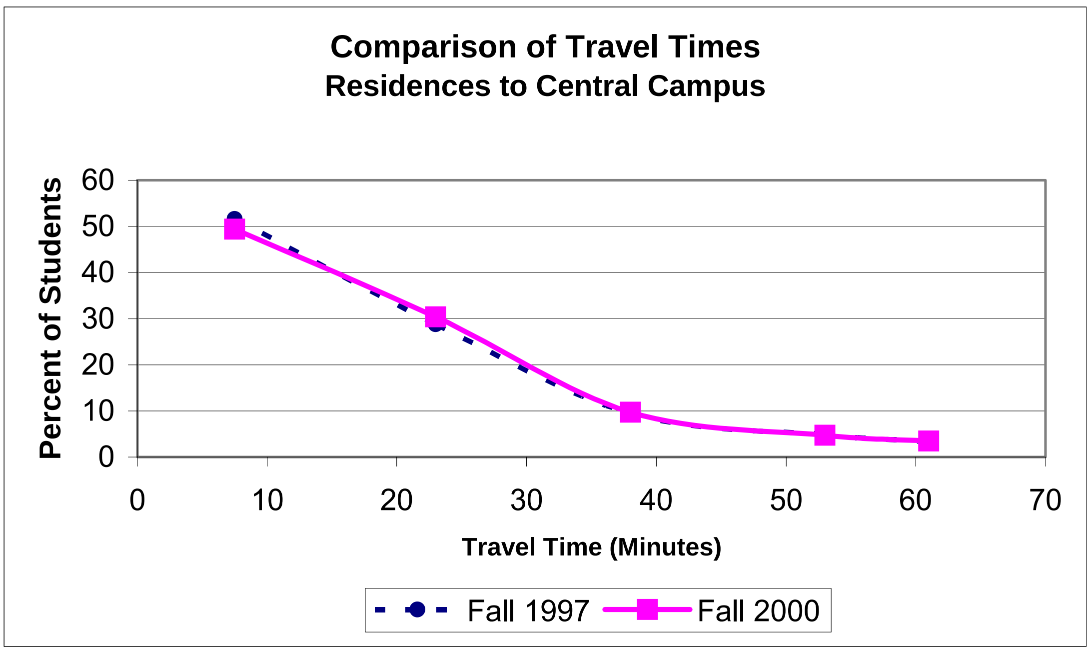
- Auto drive-alone commuters reside over all distances but predominantly between 2 miles and 40 miles from central campus before the ClassPass. Their spatial distribution pattern after the pass remained essentially the same. While the shifts away from auto drive-alone occurred over all distances, it was most noticeable over distances up to 5 miles from central campus.

- AC Transit use was concentrated among students who lived between 1 mile and 5 miles from campus before the ClassPass. With the pass, its gain in mode shift shot up and extended spatially among those who resided over all the distances but mainly up to 20 miles from central campus.
- BART riders typically resided between 5 miles and 40 miles of central campus. With the pass, choice of the mode was over the same typical distances.
- Another noticeable change was the increase in mode shift in favor of campus shuttle and the spatial extension in its patronage from students who resided up to 1 mile to those who resided up to 2 miles from central campus.

8.6 EFFECT ON TRAVEL TIMES

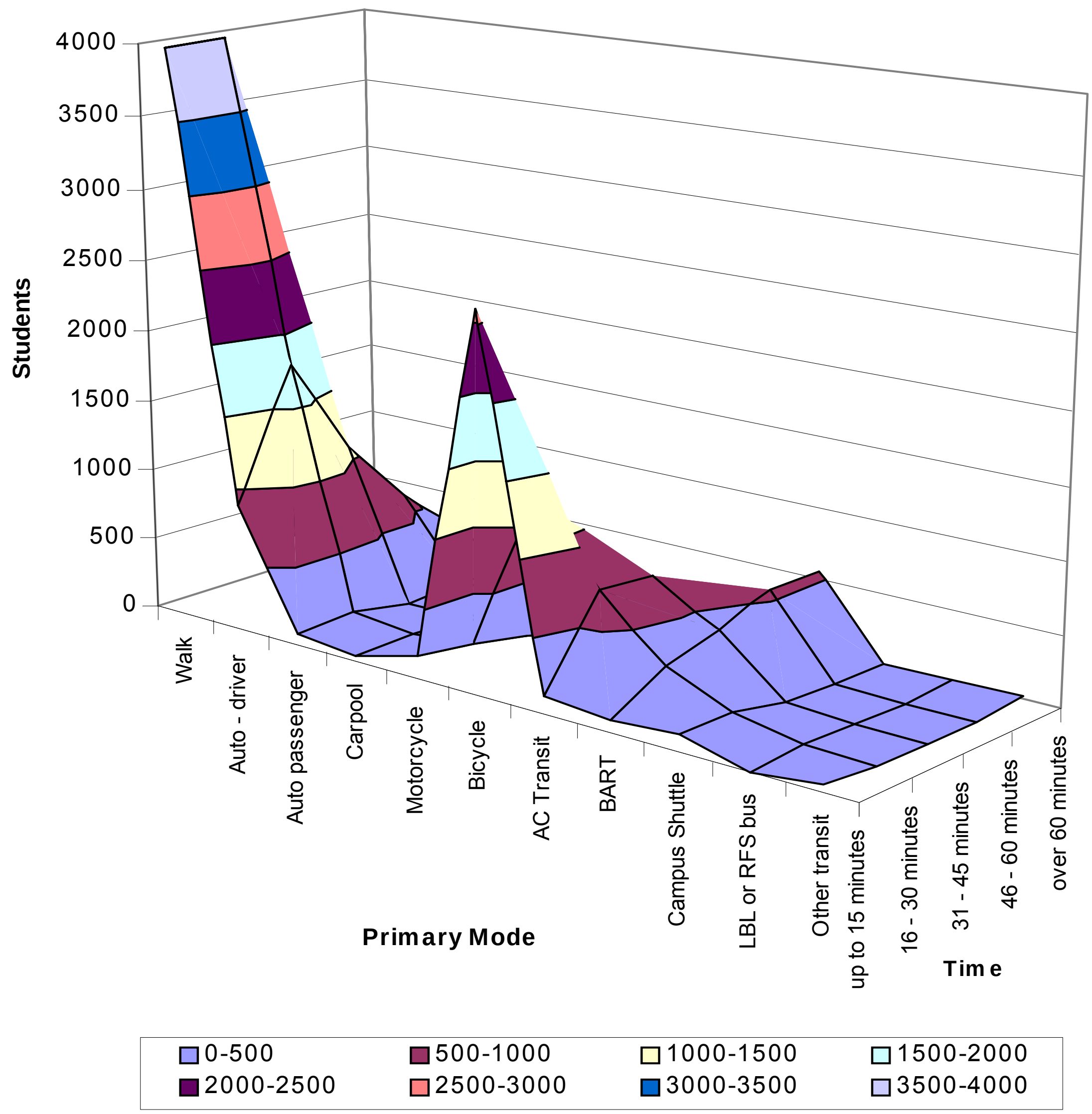
The distribution of average travel times was analyzed to determine the effects of both change in residential location and increased transit mode choice. Figure 8-4 suggests that the ease of transit use provided by the ClassPass may have contributed to a slight reduction in the number of students who traveled up to 15 minutes to central campus. Expectedly, the proportion of students who traveled more than 15 minutes increased slightly since the introduction of the ClassPass. The latter may be explained by a combination of factors including increasing traffic congestion for those who drove and the generally longer travel times for transit trips that occurred over relatively longer distances. The overall average travel times increased slightly from almost 18.6 minutes in 1997 to 19 minutes in 2000. Additional details are included in Appendix 8-5. Statistical tests of the proportions of student travel times before and after the introduction of the ClassPass (Appendix 8-8) reveal that the differences in the proportions are not statistically significant.

Figure 8-4: Comparison of Travel Times



3-D surface charts were prepared to illustrate changes in travel times relative to mode choice changes. Figures 8-5 and 8-6 compare the distributions of travel times between student residences and primary modes of travel before and after the introduction of the ClassPass. Findings are consistent with the spatial distributions of travel distances. Additional details are included in Appendix 8-6. The following are noteworthy:

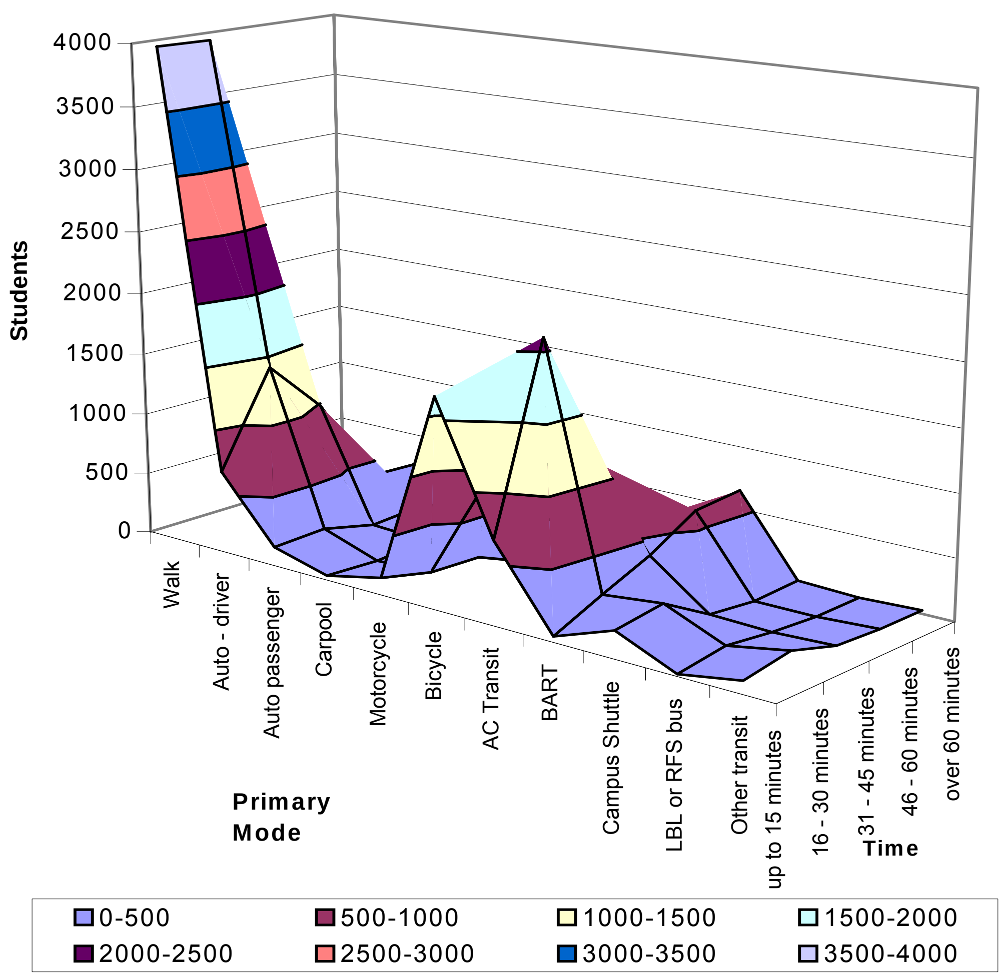
Figure 8-5: Student Travel Times (Home to Campus) by Primary Mode (1997)



- As expected, most walkers (72%) traveled up to 15 minutes to central campus. The slight drop in the number of walkers after the pass was introduced occurred among those who traveled more than 15 minutes to campus. .

- Similarly, bicycle riders mainly traveled over the shorter commute times up to 30 minutes to central campus. The shift away from biking therefore occurred among students within the 30-minute commute time to campus.

Figure 8-6: Student Travel Times (Home to Campus) by Primary Mode (2000)



- Auto drive-alone students traveled over all the lengths of commute times to central campus before the ClassPass. Their distribution pattern after the pass remained essentially the same. The shifts away from auto drive-alone occurred over all the lengths of commute times.

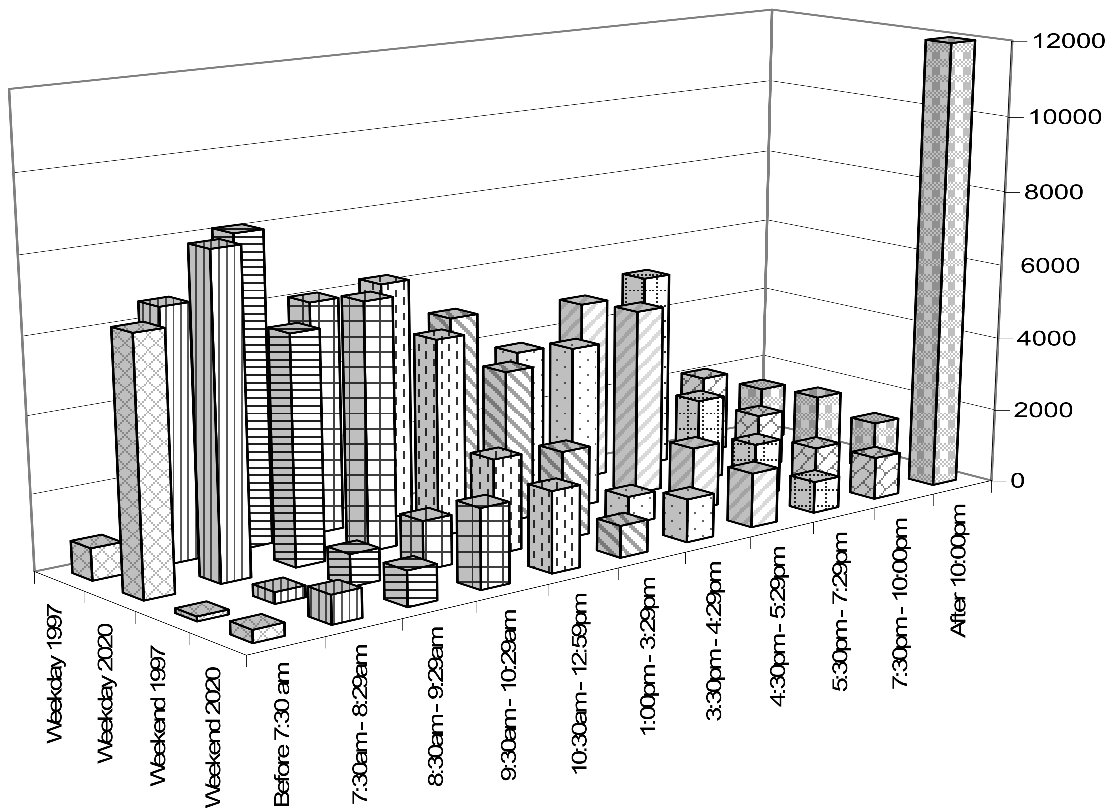
- Students who chose AC Transit traveled between 15 minutes and 45 minutes to campus before the ClassPass. With the pass, its gains in mode shift occurred among those who traveled over all the lengths of commute times.
- BART riders typically traveled 15 minutes or more to central campus. With the pass, choice of the mode was over the same typical lengths of commute times.

8.7 CHANGES IN PERIODS OF TRAVEL

The time of day when students traveled to and from campus was examined to see if there were any significant changes in pattern that could be attributed to the ClassPass. See Appendix 8-7 for details. Figure 8-7 shows the comparative distributions of average daily trips by time of day on weekdays and on weekends before and after the introduction of the ClassPass program. The following are noteworthy:

- Student travel times with and without the ClassPass did not exhibit the type of severe peaking typically associated with work-related commute travel. Hourly distribution of student trips in the day depicted low variability of approximately 10% to 15% across the midday hours that lie between 8:30 a.m. and 3:30 p.m. With low peaking in the hourly distribution of trips, the danger of growth in ridership overwhelming the bus service capacity especially during peak periods is less pronounced.

Figure 8-7: Comparative Distribution of Average Daily Trips by Time of Day



- The majority of student travel to and from campus occurred in the midday, which lies between the morning and afternoon periods of work commute. As summarized in Table 8-4, about 50% of student travel to and from campus occurred during midday in 1997 while 42% occurred in 2000. The concentration of student travel in the off-peak period points to the increased likelihood of available bus capacity to accommodate surges in demand due to the ClassPass.

Table 8-4: Distribution of Daily Student Trips In & Out of Campus by Time of Day

	1997	2000	% Change in Quantity	Statistically Significant Difference[1] 1997 - 2000
Weekday Distribution				
AM Peak -- Before 8:30 a.m.	14.67%	**29.17%**	101.67%	**Y**
Midday -- 8:30 a.m. – 3:30 p.m.	50.59%	42.25%	-15.30%	**Y**
PM Peak -- 3:30 p.m. – 7:30 p.m.	27.59%	22.53%	-17.19%	**Y**
Evening -- After 7:30 p.m.	7.15%	6.05%	-14.19%	N
Total Daily	100.00%	100.00%	1.42%	--
Weekend Distribution				
AM -- Before 8:30 a.m.	3.12%	3.77%	155.62%	N
Midday -- 8:30 a.m. – 3:30 p.m.	51.36%	20.96%	-13.80%	**Y**
PM -- 3:30 p.m. – 7:30 p.m.	28.60%	12.04%	-11.08%	**Y**
Evening -- After 7:30 p.m.	16.92%	**63.22%**	689.16%	**Y**
Total Daily	100.00%	100.00%	111.21%	--

[1] Null hypothesis: $\%_{1997} = \%_{2000}$; alpha level = 5%; **Y** = **significant**; N = not significant

- With the ClassPass, some student travel shifted to the morning commute period to levels comparable to what occurred in the midday hours. Despite this shift, the overall distribution of student travel periods in the day depicts the same general pattern with the ClassPass as before it.

- The volume of weekend travel to and from campus in 1997 was only about a third of typical weekday travel. With the ClassPass, weekend travel doubled. Since transit services traditionally operate at low occupancy levels on weekends, the growth in student travel on weekends should not ordinarily pose a problem with availability of seat capacity.

Statistical tests of proportions of students who traveled during various periods of the day before and after the introduction of the ClassPass (Appendix 8-8) reveal the following:

- Despite the generally similar pattern in the near-hourly distribution of trips by time of day shown in Figure 8-7, the differences in the proportions of students who traveled during the broad periods of the day summarized in Table 8-4, the periods before, during and after midday were statistically significant for weekdays.
- The differences in the proportions of students who traveled during late evening hours were not statistically significant for weekdays.
- The differences in the proportions of students were statistically significant for all periods on weekends except for the early morning hours.

It is possible to assert from the statistical test results that the introduction of the ClassPass caused significant adjustments in the periods many students chose to travel to and from campus. However the distribution of travel throughout the day, especially in terms of peaking, followed the same general pattern after the introduction of the ClassPass as before it.

8.8 EFFECT ON AC TRANSIT

8.8.1 Impact on Revenue

The 1997 "Before" Survey revealed that 5.6% of U.C. Berkeley (UCB) students used AC Transit before implementation of the ClassPass. That is approximately 1690 students. Although not all students rode AC Transit daily and thus would not purchase a monthly pass, let us assume for simplicity that they all did. The maximum revenue AC Transit would have earned from the UCB student-rider market would therefore have been $84,500 per month in those months that the university was in session.

The 2000 "After" Survey revealed that 14.1% of UCB students used AC Transit after implementation of the ClassPass. That is approximately 4410 students. However according to the terms of the program, AC Transit obtained negotiated annual fare revenue of $1,251,000 covering the entire enrolled student population. Assuming a 10-month calendar year, the equivalent monthly revenue to AC Transit was $125,100.

The net revenue was $40,600 per month ($125,100 - $84,500) or more than $406,000 per year. The net increase in revenue therefore was approximately 50% above the pre-ClassPass level.

8.8.2 Impact on Ridership

Approximately 1690 students rode AC Transit before and 4410 students rode AC Transit after the implementation of the ClassPass. The net increase in riders of 2720 (4410 – 1690) is approximately 160%. Viewed differently, the number of riders jumped to 2.6 times the pre-ClassPass level.

FTA Section 15 data for 2000 shows that AC Transit generated 21.3 million vehicle revenue miles while service consumption stood at 197.8 million passenger miles. This calculates to approximately 9.3 passenger-miles per revenue vehicle-mile. If the average vehicle capacity were 40 seats, then occupancy in 2000 would stand at 23%. For an average vehicle capacity of 30 seats, occupancy in 2000 would stand at 31%. This occupancy range straddles the national average for 1998.

Assume the 1998 average national seat occupancy of 27% held true for the UCB student-rider market, before the ClassPass. Then the increase in riders to 2.6 times the original level would result in 70% average seat occupancy (27% * 2.6). On average therefore, this would not necessitate expansion in AC Transit service to accommodate demand. Since overcrowding is not known empirically to have plagued the AC Transit services serving the campus area and pre-existing service frequencies have been largely maintained, it could be assumed that the frequency of boardings per person did not change significantly after the implementation of the ClassPass. Under the foregoing assumptions, it will take approximately a 50% additional increase in boardings per rider to exhaust the available seating capacity on AC Transit buses in the campus area.

8.9 SUMMARY

The deep discount program for students at the University of California, Berkeley is an example case study of a college campus-based program, the largest and most rapidly expanding group of deep discount programs around the nation. Surveys of student behavior before and after the introduction of the program reveal statistically significant changes that include the following:

- Changes in the choice of AC Transit and campus perimeter and shuttle service modes. The pass permits use of both types of services.
- Adjustments in the periods of the day that students travel to and from campus. However, the distribution of student travel throughout the day especially in terms of peaking followed the same general pattern after the introduction of the ClassPass as before it.

Student rides on AC Transit jumped 160% with the ClassPass. The combination of a generally low seat-occupancy on AC Transit buses and the wide distribution of student travel times throughout the day prevented the increase in ridership from overwhelming the existing service. While revenue per boarding data on students was not available for comparison, the program nevertheless increased the total revenues that AC Transit generated from this student-rider market by more than \$40,500 per month or \$405,000 a year, which was nearly 50% over the pre-ClassPass level.

The next chapter presents the detailed case study of an employment-based program offered by AC Transit, the same agency that offers the ClassPass. Unlike the student program, the city of Berkeley employee deep discount program uses the magnetic dip fare card, which permits tracking of aspects of the travel behavior of participants.

9. THE EMPLOYEE ECO PASS, CITY OF BERKELEY

9.1 THE PROGRAM

This program provides employees of the City of Berkeley with unlimited ride AC Transit passes in exchange for a contractual payment per employee per year by the city government. The City has approximately 1600 full-time employees (excluding the Police Department) of whom 1330 are covered under the program even if they do not use transit. The large volume allows the passes to be sold at the relatively low unit cost of $60 a year or $5 per month. Thus the ECO pass is offered at approximately 10% of a basic adult monthly pass. The negotiations required that AC Transit restructure some of its routes within Berkeley to include stops at city offices. The restructuring is intended to better serve the work destination of pass users.

9.2 HISTORY

The idea of a free, that is, employer-paid transit pass was first proposed to the Berkeley City Council four years prior to its adoption[52]. It took two years to convince the Council of its efficacy and an additional six months to get it approved. The program was initiated on January 1, 2002 as a one-year pilot program. During that period, it was voluntary and employees had to request for the pass; 703 employees picked up the pass. The second year of the program went into effect on January 1, 2003 as a universal program whereby 1330 eligible full-time City employees were issued the pass.

9.3 INITIAL OBSTACLES TO IMPLEMENTATION

The eventual adoption of the ECO Pass was not without obstacles. The following obstacles partially explain why it took two years to get the proposal through City Council:

- The then City Manager's office insisted a free pass was an additional benefit that needed to be negotiated with the Unions. The Unions would have to give up some benefit to get another. Proponents argued that providing the pass free was necessary to get the generally auto-dependent workers to assess the convenience of using transit and to make the necessary adjustments to their travel routines.
- The then City Manager's office insisted the City could not afford the free pass. Proponents admit the economic boom at the time helped overcome this excuse.
- There was a less formidable obstacle in the form of a counter proposal to conduct a feasibility study that would include BART and other transit services with AC Transit and consider other employers in the city. Proponents of the free pass prevailed by suggesting that the pilot program be restricted to City employees and AC Transit service after which non-city employees, BART and other service providers could be included. Effectively, the funds to be spent to conduct the study were instead used for a practical demonstration project that could guide future decision.

A major obstacle related to the City's inability to negotiate a deal with BART. City officials were convinced it would take a long time, (about half a decade or more) to negotiate a similar pass deal with BART for the following reasons:

- BART service area encompasses many of the nine counties in the Bay Area from which it is much more difficult to obtain consensus. In comparison, AC Transit service area lies in two counties.
- There did not seem to be adequate support from Board members of BART for the idea of an ECO Pass at the time.
- BART was still "studying" the region-wide TRANSLINK program that many other transit service providers were in favor of implementing. Implementation of TRANSLINK would pave the way for seamless travel by transit in the region and facilitate the issue of a region-wide ECO Pass. In the meantime, City employees were able to use their Commuter Checks to purchase BART parking or tickets. [The City of Berkeley offered $20 a month as a tax-free benefit and City employees could request for up to $20 a month as a pre-tax deduction. Internal Revenue code 132(f) provides for a maximum of $100 a month per employee in combined tax savings to both employers and employees. See Appendix 10-1.]

9.4 VISION FOR THE PASS

City officials envisioned a transit pass for both employees and residents of Berkeley. Initially the City would like to focus on employers. Before requesting the program from other employers, the City chose to set an example by covering its employees. Employers had databases in place that would enable program implementation at relatively low administrative cost. Large employers were to be initially targeted in order to obtain "the best bang for the buck". Large employers offered the potential to realize economies of scale and could provide the critical mass of employees that would make a citywide program feasible. Major employers in Berkeley include the University of California, the Berkeley Unified School District, the Alta Bates health institution and the U.S. Postal Service. The pass price for small employers could be slightly higher than for others because of anticipated differences in unit administrative costs to AC Transit. The Denver case study (Chapter 7) revealed that the employment-based programs yielded the highest net revenues to the RTD. This supports the City of Berkeley's vision to make employers its primary target for the program a good idea.

The long-term vision for the ECO Pass therefore included the following:

- Expansion of the program to include BART service
- Making the pass available to employees of both the city government and other employers in the city.
- Creation of citywide bus passes for Berkeley residents grouped by neighborhood. Currently the residential ECO Pass exists in Santa Clara County, California and in the service area of the Regional Transportation District at Denver, Colorado.

The City therefore actively sought to get other employers, the Alameda County Congestion Management Agency and the Metropolitan Transportation Commission (MTC) involved in adopting the idea of a widely deployed ECO Pass. The City would also like to seek matching funds for the program from regional agency sources.

9.5 OPINIONS AND OBSERVATIONS OF CITY OFFICIALS

Observations and opinions expressed by City officials on the ECO Pass program include the following:

1. People argue against the universal pass program because “not everyone is going to use it”. Not everyone needs to use it for the program to be successful. Programs elsewhere in the country are known to obtain much more than a 7% shift from auto use. Even a 7% reduction in auto use can be considered a success.
2. City officials contend that funding from the State and Counties will make the program successful. For instance, 20% funding from the government can make the program very popular with employers.
3. Why not make employees pay for the passes? If employees are required to pay, one cannot realize universal participation. The auto dependent might not see the pass as an opportunity for a convenient alternate means of commuting. Offering it free initially could get employees hooked on using transit.
4. Employers in Berkeley looking to expand are required to provide additional parking. The city could negotiate with employers to provide cash for pass in lieu of constructing expensive new parking.
5. It is observed from the Pilot program that the pass is getting mainly middle class and upper middle class individuals to use transit.

9.6 TERMS OF AGREEMENT FOR THE ECO PASS PROGRAM

City employees are issued a magnetic dip card with the employee's picture for identification and prevention of fraud. The magnetic dip feature enables collection of detailed travel data on individual travel patterns. Unlike the basic monthly pass, the unlimited-ride ECO Pass permits rides on every AC Transit bus including Transbay travel to and from San Francisco. Travel with the pass is therefore only restricted where AC Transit service does not go, but in most cases it can provide access to other transit services in the Bay Area. The following are some specifics of the terms of agreement for the Pass:

- The card is valid for a whole calendar year through December 31.
- The full flat fare of $60 per person is charged through June 30th and a lower flat fare of $30 per person is charged after June 30th.
- The production of the magnetic strip, picture identification card is charged to the City at $7 each.
- The original contract proposal required a bulk purchase of passes for a minimum of 1400 and a maximum of 1600 at the quoted unit price. Representatives of the City and the transit operator settled on the current enrolment of 1330 employees.

9.7 THE GUARANTEED RIDE HOME PROGRAM[53]

The city participates in a countywide guaranteed ride home program (GRHP) for transit riders who would need to leave in a hurry in response to emergencies. The Alameda

County Congestion Management Agency administers the countywide GRHP. The terms of the program are the following:

- The employee must sign up on condition that the employer is signed up for the program.
- Each employee who signs up is guaranteed no more than one ride per month for a maximum of six rides per year.
- The employee could only use the service in such emergencies as (a) severe illness or crisis involving the employee or immediate family member, (b) unscheduled overtime work, (c) breakdown of rideshare vehicle or either early or late departure of rideshare driver.
- The employee must have walked, bicycled, carpooled, van-pooled or taken the ferry, bus or train on the day of GRHP need

GRHP is provided through a pre-specified taxi service provider for trip distances less than 20 miles. The employee pays the taxi fare with a voucher issued by the program and covers only the tip of approximately 10% to 15% out of pocket. For distances longer than 20 miles, an employee who is 21 years or older and has a valid California driver's license may use a rental car from Enterprise.

9.8 THE "BEFORE" ECO PASS SURVEY

9.8.1 Survey Sample

Before instituting the Eco Pass, an employee transportation survey was conducted in May 2001. Including both full time and part-time employees at the time, all 1938 city employees were surveyed of whom 428 responded. This represented a response rate of 22%. The margin of error is 4.7% with a 95% confidence interval. The survey data is weighted with a census of employees in 18 departments.

9.8.2 Commute Modes

Table 9-1 shows survey results of commute modes used by City of Berkeley employees prior to the introduction of the Eco Pass. The following are noteworthy:

- Nearly half of the employees drove alone while an additional 12% carpooled.
- Twice as many took BART (12.9%) as those who rode bus transit (6.2%)
- About as many employees walked as those who biked and together the non-motorized modes were chosen by just under 10% of all employees.
- Nearly 10% of employees are typically off duty on a weekday.

Table 9-1: Choice of Commute Mode Before Eco Pass

Motorized Mode	Percent	Other Mode	Percent
Drive alone	47.4%	Bicycle	4.9%
Carpool	11.9%	Walk	4.7%
BART	12.9%	"Other"	2.8%
Bus	6.2%	Off duty	9.1%
Subtotal Motorized	78.4%	Subtotal Other	21.5%

9.8.3 Reasons for Choice of Commute Mode

Table 9-2 lists the top three reasons advanced by city employees for their various choices of commute modes. These reasons are consistent with the selection of automobile-based commute modes by almost three out of every five employees. As indicated, the automobile offers more convenience, flexibility, and travel time advantages over public transit.

Table 9-2: Top Three Reasons for Choice of Commute Mode

Rank	Reason	% Of Respondents[1]
1st	Convenience and flexibility	67.5%
2nd	Travel time	65.2%
3rd	Cost	39.7%

[1] Can sum to more than 100% because multiple responses allowed

9.8.4 Reasons Preventing Use of Alternative Modes

As shown in Table 9-3, the most common reason advanced for not choosing an alternative mode is the conviction that alternates increase commute time. Closely following is the reason that employees need to work late or irregular hours. Not too far behind is the reason that the employee needs a car for work related assignments.

Table 9-3 Top Three Reasons Preventing Use of Alternatives to Driving Alone

Rank	Reason	% Of Respondents[1]
1st	Alternate increases commute time	38.7%
2nd	Respondent works late or irregular hours	38.3%
3rd	Respondent needs car for work related assignments	25.3%

[1] Can sum to more than 100% because multiple responses allowed

9.8.5 Incentives to Choose Alternative Modes

Table 9-4 shows the top three incentives for choosing alternatives to driving alone. The most preferred incentive is to be offered the opportunity for a flexible work schedule. Not too far behind is the availability of a guaranteed ride home program. As previously indicated, this program is already available to City of Berkeley employees. The next choice of incentive is financial subsidy to alternative modes. The employer-provided ECO Pass is such a subsidy.

Table 9-4: Top Three Incentives to Choosing Alternatives to Driving Alone

Rank	Reason	% Of Respondents[1]
1st	Flexible work schedule	30.9%
2nd	Guaranteed ride home in emergency	24.2%
3rd	Financial subsidies to alternative modes	22.3%

[1] Can sum to more than 100% because multiple responses allowed

9.8.6 Potential Commute Options

Table 9-5 identifies the top three options that drive-alone commuters would consider one or more days per week. Bus transit ranked 7th beating only walking. It is apparent from both existing choice levels and this stated preference information that BART is the favorite choice among the transit modes available to City of Berkeley employees. This fact would suggest that a pass program for BART transit be pursued.

Table 9-5: Top Three Options that Drive-Alone Commuters Would Consider

Rank	Reason	% Of Respondents[1]
1st	BART	22%
2nd	Telecommuting	17%
3rd	Carpooling	17%

[1] Can sum to more than 100% because multiple responses allowed

9.9 THE "AFTER" ECO PASS SURVEY

9.9.1 Survey Sample

After instituting the Eco Pass, a random, online survey of employees was conducted in spring 2002. There was a relatively low response of 202 employees. The margin of error is therefore 6.9% with a 95% confidence interval. The survey data is weighted with a census of employees.

9.9.2 Trip Purposes

As summarized in Table 9-6, the survey revealed, that the ECO Pass was used predominantly, but not by any means exclusively, in relation to work travel. Nearly 40% of ECO Pass use was for travel either to and from work or in at least one direction to work. A good 13% of ECO pass users also used it during the day to conduct travel related to work activities. Other trip purposes for which the ECO pass was used include, in descending order of importance, errands, recreational, lunch and medical trips.

Table 9-6: Trip Purposes of ECO Pass Users

Trip Purpose	Percent of ECO Pass Users[1]
To/From Work	24.8%
One Direction to Work	14.4%
Errands	21.3%
Recreational	14.4%
Lunch	8.9%
Medical	7.4%
Work Related	12.9%

[1] Can sum to more than 100% because multiple responses allowed

9.9.3 Factors to Encourage ECO Pass Use

When asked the single most important factor that would encourage employees to use the ECO Pass (Table 9-7), by far the most important factor indicated by 31% of respondents was "increased frequency of bus service near the home". Since the workplace is a location that is already served by several bus lines, which also connect with other lines, the frequency of service near the work place was not an issue. The rather dispersed home locations are therefore a source of limitation to the use of the ECO Pass. Accessibility at the home end could be enhanced if the ECO Pass program were extended to the many transit operations in the metropolitan area.

Table 9-7: Factors to Encourage ECO Pass Use

Trip Purpose	Percent of ECO Pass Users
Increased bus frequency near home	31.2%
Increased bus frequency near work	5.4%
Bus ride information	2.0%
ECO Pass incentives	6.4%
ECO Pass reminders	0.0%
Night bus near home	5.9%
Night bus near work	0.0%
Passenger amenities at stops	2.0%
Increased safety at stops	5.0%
Nothing	13.9%
No Response	28.2%

9.9.4 Changes in AC Transit Patronage

Because of inconsistencies in some of the responses from the survey data, the magnetic dip data was used to determine the number of City employees who used AC Transit in the first year of the ECO Pass program. Table 9-8 shows the results. Approximately 30% of pass holders used the ECO Pass. The estimated number of AC Transit riders among the totality of City employees increased by two thirds from 6.2% to 10.7% in the first year of the deep discount pass program.

The difference in the proportions of riders who chose AC Transit before and after introduction of the ECO Pass is statistically significant (Appendix 9-3). However this is only the initial change due to the program. Additional tracking of use over time is necessary to make more definitive judgment about mode choice changes.

Table 9-8: Change in AC Transit Patronage

	Population	Percent Riding AC Transit	Number Riding AC Transit
Before ECO Pass (2001)			
Total Employees[1]	1938	6.2%	120
With ECO Pass (2002)			
Participants	703[2]	29.6%	208[3]
Total Employees[4]	1938	10.7%	208

[1] 2001 "Before" Survey

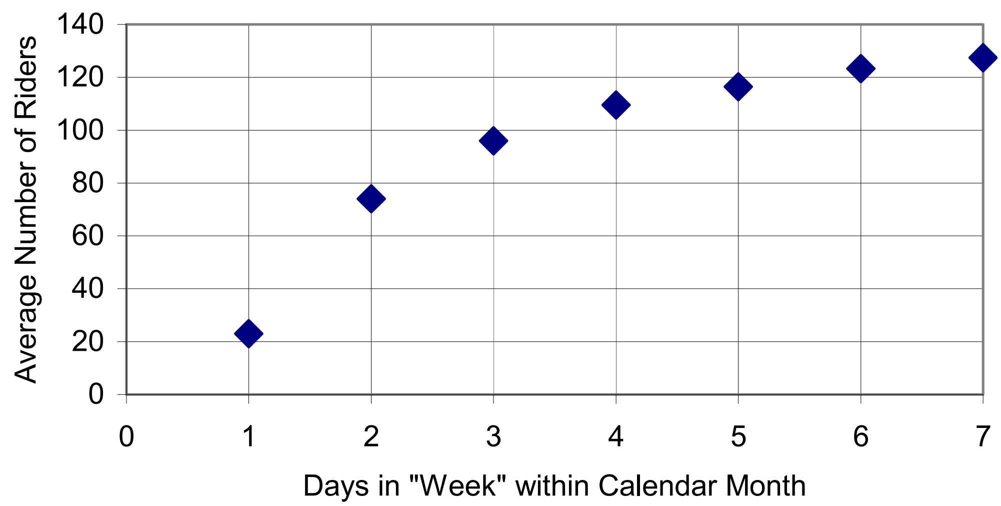
[2] The reported number of passes issued in the first-year pilot program

[3] 2002 Magnetic Dip Data collected and compiled by AC Transit

[4] Based on 2001 Survey and 2002 Magnetic dip Data

Figure 9-2 illustrates the fact that not all ECO Pass users are habitual AC Transit riders. The magnetic dip data (Appendix 9-1) are tallied weekly by calendar month. Weeks that begin or end calendar months often have less than seven days. The data show that on average there are 74 riders over a 2-day week, 116 over a 5-day week and 127 over a 7-day week. Apparently many participants only use the ECO Pass a few times a week rather than daily. This result conforms to the survey finding that the ECO Pass is used for multiple trip purposes and not for work travel alone.

Figure 9-1: Number of Riders by Length of Week



9.10 RIDERSHIP TRACKING

9.10.1 Weekday vs. Weekend ECO Pass Use

Eleven months of magnetic dip data collected and compiled by AC Transit is presented in Appendix 9-1 and 9-2. The data summary in Table 9-9 shows that an average weekday has nearly three times as many boardings as a weekend. This fact suggests the dominance of ECO Pass use for work trips, the primary motivation for instituting the deep discount pass program. However, the relative level of weekend use is by no means trivial.

Table 9-9: Summary of Average Monthly ECO Pass Boardings and Riders (2002)

Average total boardings per month	3094
Average daily boardings on a weekday	125
Average daily boardings on a weekend	44
Average number of passes used (Riders) per month	194
Average of total boardings per pass used	16

9.10.2 ECO Pass Use by Time of Day

Conforming to the use of the ECO Pass primarily for work trips is the fact that nearly three quarters of all boardings on the most frequently patronized routes occur in a nearly even split between the morning and the afternoon commute periods as shown in Table 9-10. The sampling of the frequently patronized routes represented nearly three of five boardings by ECO Pass participants.

The strong showing of midday use at 26.2% suggests the following:

- Some work trips are made in the off-peak by those who participate in staggered or flexible work-hour schedules.
- There is a substantial proportion of either non-work travel or travel related to other work activity in the middle of the workday.

Table 9-10: Average Monthly Distribution of Boardings by Time of Day

Period of Day	Hours of Day	Percent of Boardings	Average Hourly Percent
AM Peak	6:00 a.m. – 10:00 a.m.	31.5%	7.9%
Midday	10:00 a.m. – 3:00 p.m.	26.2%	5.2%
PM Peak	3:00 p.m. – 7:00 p.m.	33.9%	8.5%
Evening	7:00 p.m. – 12:01 a.m.	8.4%	1.7%

Nearly one in ten boardings occurs outside the commute and traditional work hours. This and the previous observations confirm that the ECO Pass is used for multi-purpose travel needs as reported in the 2002 Survey.

9.10.3 Frequency of ECO Pass Use

During the average month, approximately 28% of ECO Pass holders (194 of 703) used the pass. This first year of use, is comparable although lower than other employment-based ECO Pass programs in which 58% of pass holders at downtown Denver, 44% at Denver Airport, and 40% at Silicon Valley use their passes. Table 9-11 shows that the majority (56%) of ECO Pass riders are infrequent users. About 17% each fall in the categories of occasional and regular users. About 10% of pass riders take maximum advantage of the availability of the ECO Pass to them. The facts of this distribution suggest that there should be little concern about patronage due to the ECO Pass overwhelming existing service. This is especially true in light of the generally low seat-occupancy levels on urban transit buses.

Table 9-11: Frequency Distribution of Average Monthly Riders

User Label	Range of Use per Month	Frequency	% of Riders	Cumulative %	Estimated Lost Fare Revenue	
					Maximum[1]	Typical[2]
Infrequent	1 – 10	108	55.5%	55.5%	$ 835	$ 415
Occasional	11 – 20	34	17.5%	73.0%	$ 525	$ 395
Regular	21 – 40	33	16.8%	89.8%	$ 1,000	$ 1,000
Heavy	> 40	20	10.2%	100%	$ 600	$ 600
All		195	100%	--	$ 2,960	$ 2,410
Net monthly revenue gain[3]					$ 3,690	$ 4,240
Net annual revenue gain					$44,280	$50,880
Percent revenue gain over pre-ECO Pass level					125%	176%

[1] Assumptions for estimate:

(a) Proportion of riders by category the same before the ECO pass (120 riders) as with it;

(b) Infrequent riders purchased the maximum number of rides within each range at $1.25 each;

(c) Regular and heavy riders purchased the monthly pass at $50 each.

[2] Assumptions same as above except for (b):

(b) Infrequent riders purchased number of rides at midpoint of range at $1.25 each.

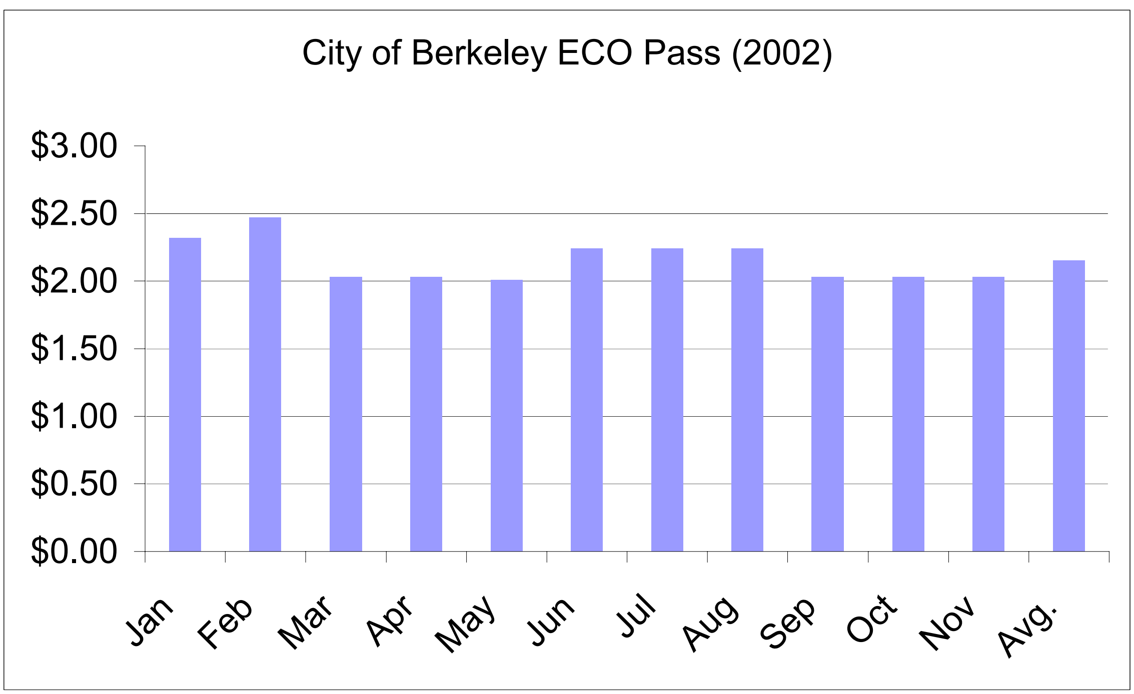
[3] Difference from equivalent monthly payment of $6,650 for ECO Pass participants.

9.11 PROGRAM EFFECT ON AC TRANSIT

9.11.1 Revenue

Figure 9-2 depicts trends in revenue generated per boarding by the ECO Pass program for AC Transit in 2002. Variations in levels of use over the months indicate that revenues ranged between $2.00 and $2.50 per boarding with a tendency to level off close to $2.00 per boarding. The ECO Pass program appears to yield three times the system-wide unit revenue of $0.67 that AC Transit recovered in 2000. The City of Berkeley ECO Pass program is therefore a deep discount group pass program that generates much higher unit revenue to the operator than most other programs. This level of yield is higher than, but consistent with the yield reported in Chapter 7 for deep discount programs offered by the Denver RTD.

Figure 9-2: Trends in Revenue per Boarding



Following from the increase in unit revenue per boarding is the positive net effect on total revenue from the City employee market. The survey data in Table 9-8 indicates that approximately 120 employees commuted to work by AC Transit before the ECO Pass program. By incrementally relaxing the conservativeness of assumptions, the following three estimates all indicate net revenue gains to AC Transit.

1. With the findings that most employee riders did not ride AC Transit regularly, not all would have purchased regular monthly passes prior to the ECO Pass program. However, assuming for simplicity that they all did at $50 per month for a regular adult pass, revenue lost is $6,000 per month. In comparison, the City pays the equivalent of $6,650 (i.e. 1330 * $5) per month for all months of the year. This translates to a net profit of $650 a month, a minimum of 11% increase over previous fare revenue that AC Transit collected from the City employee market.

2. More realistically, even if infrequent riders purchased the maximum number of rides within the ranges shown in Table 9-11 while regular riders purchased the monthly pass, the estimated lost revenue would be approximately $2,960 a month. This would translate to net revenue of $3,690 a month, approximately 125% increase over previous fare revenue. This estimate is consistent with the revenue per boarding data. For offering the program therefore, AC Transit would realize a net annual increase in revenue of approximately $44,280 from that market.

3. Most realistically, if infrequent riders purchased the average number of rides within the ranges shown in Table 9-11 while regular riders purchased the monthly pass, the estimated lost revenue would be approximately $2,410 a month. This would translate to net revenue of $4,240 a month, approximately 175% increase

over previous fare revenue. This estimate is most consistent with the revenue per boarding data. For offering the program therefore, AC Transit would realize a net annual increase in revenue of approximately $50,880 from that market.

9.11.2 Ridership

The data in Table 9-8 indicate that AC Transit riders among City of Berkeley employees increased by nearly 75% (from 120 to 208) in the first year of the institution of the ECO Pass program. However, the number of riders as a percentage of the total population of employees is small relative to other modes; it increased from 6.2% to 10.7%. As indicated earlier, this would not necessitate expansion in AC Transit service to accommodate demand. Indeed no incidence of overcrowding has been known to occur, or have increases in service levels been warranted on the routes serving downtown Berkeley since inception of the ECO Pass program.

9.12 SUMMARY

The City of Berkeley Eco Pass is a case study of an employment-based deep discount program. Its attractiveness lies with its magnetic dip fare card, the future of deep discount fare cards. This feature offers opportunities to collect rich travel data on program participants. Surveys of employee travel choices before and after introduction of the deep discount program reveal a statistically significant difference in the proportions of employees who chose AC Transit, the operator that offers the program. The magnetic dip data on employee travel with the Eco Pass during the first year of the program revealed the following:

- An average weekday registered nearly three times as many Eco Pass boardings as an average day on a weekend.
- Approximately a third each of all Eco Pass boardings occurred during the morning and afternoon peak periods of commute travel. An additional quarter of all Eco Pass boardings occurred in the midday between the two peak periods.
- These findings confirmed survey results, which indicated that the Eco Pass was used for multiple trip purposes although its use for work travel was dominant.
- Approximately 28% of pass holders used it in the first year of its introduction and more than 50% of the riders were infrequent users.

The number of AC Transit riders among City of Berkeley employees increased by nearly 75% (from 120 to almost 210 riders) in the first year of the program. In spite of this increase, and the fact that the deep discount pass was offered at 90% discount, the program yielded higher than $2.00 in revenue per boarding to AC Transit. This is approximately three times the system-wide revenue per boarding. By offering the program, AC Transit stood to earn a net annual increase in revenue of almost $51,000.

In the next chapter, the various findings from program evaluations reported in the literature and the detailed case study analyses of this dissertation are synthesized. The discussion addresses the policy issues identified in the statement of research purpose outlined in Chapter 1.

10. POLICY IMPLICATIONS

10.1 POLICY QUESTIONS

From the literature review through the analyses of the theoretical bases of the research to the case study analyses, this dissertation documented the effects of deep discount pass programs in terms of pertinent policy questions on: (1) the terms and conditions of the programs; (2) opinions, perceptions and equity concerns; (3) effect on mode choice; (4) effect on parking; (5) effect on the environment; (6) direct operating and maintenance cost implications; (7) net revenue effects; and (8) benefits to providers and recipients. Ultimately, the various policy questions translate into effects on the use of transit and the automobile. This in turn has implications for parking and for the costs and benefits to service providers and recipients. In this chapter, answers to these policy questions are distilled and analyzed.

10.2 HOW THE PROGRAMS WORK

Deep Discount Transit Pass Programs provide a defined group of people with unlimited ride transit passes in exchange for some contractual payment for or on behalf of pass users by an employer, other governing body or other organizing body. The programs fall into four categories: the *employment-based ECO Pass*, the *Neighborhood ECO Pass,* the campus-based *College Pass*, and the *TeenPass* that is sold through middle and high schools. Deep discount group pass programs exhibit the following general features:

(a) *Universal coverage* of members of an identified group – Most often all members of a participating body are included. In some cases, as at the University of Washington, Seattle, members could opt out of the program. In all cases, there are criteria for qualifying a distinct body. For instance, qualified participants were defined as "benefit-receiving employees" by the City of Berkeley when the City opted to pay for the passes as an employee benefit. At U.C. Berkeley where the students pay for the program, the body is qualified as "all students enrolled during the semester". In many campus-based programs, participants always include students and in some, programs also include faculty and staff.

(b) *Unlimited ride* – In most programs, participants use validated picture identification cards as passes to board the transit vehicles. Participants are permitted rides on the various types of transit modes offered by the transit provider typically for a whole calendar year.

(c) *Pricing* **–** All programs offer deep discount pricing that covers a relatively large number of people as a form of *innovative financing*. Deep discount prices are as low as 6% and as high as 60% of the price of the regular monthly pass. Not all passes are priced equally because the pricing is designed to cover costs of providing service that include operational, maintenance and administrative expenses of the transit agency and program marketing as well as administrative assistance to participating employers. As an example, the price of an ECO Pass per employee is considerably higher in downtown Denver, where there is a concentration of services and peak period travel and where parking is expensive, than in the suburbs, where there are fewer services and peak period travel and plenty of free parking.

Some employment-based and neighborhood-based programs offer *guaranteed rides home* either through the transit operator (as by Denver RTD and Santa Clara VTA) or through the employer (as by the City of Berkeley in collaboration with the local congestion management agency).

10.3 PERCEPTIONS AND EQUITY

Despite the successes of various deep discount pass programs, there has been substantial skepticism on the part of the management of transit agencies toward their adoption and wide-scale deployment. Discussions with operators revealed that management is not generally convinced of the efficacy of the programs. Rather they are considered "special treatments" or "favors" to segments of the population. They fear the perception of special treatment could raise questions about equity. An operator would make such an argument by comparing the $5 a month charge per person per month for the City of Berkeley ECO Pass with the regular monthly pass rate of $50 each. By such comparison, AC Transit offers the ECO Pass to the City of Berkeley at 10% of the regular rate or at a 90% discount. Similarly, Santa Clara VTA offers the pass at 20% of the regular monthly rate to Silicon Valley commuters. The Denver RTD offers the passes at 6% to 60% of the regular monthly rate depending on the number of participants and geographic location.

Comparisons with regular fares are interpreted as discounts that are easily misconstrued as special treatments because the argument fails to see the fundamental difference in the fare structure of the “group pass” from individual ticket purchases. The group pass covers a large number of people and is paid for the whole year in advance whether the service is going to be used or not. In this regard it operates similar to an insurance scheme which can charge a relatively low premium as membership in the pool grows large and yet be profitable.

In spite of the deep discounts, analyses of the three case studies revealed that all the programs produce higher revenues per boarding than the system-wide averages of the respective transit agencies. For instance, the City of Berkeley ECO Pass produces $2.00 per boarding. This is three times the system-wide average of approximately $0.67 per boarding over all fare media for AC Transit. This illustrates the potential of the programs to increase operating revenue for transit agencies. Where the programs necessitate additional operating costs, these added costs should be considered in setting the prices for the passes as depicted in the proposed pricing methodology in the next chapter.

When equity is viewed from the perspective of the *equality of opportunity,* a deep discount pass program has the potential to provide equality of opportunity either because it is available to all members of a target group or it is available to many groups via the work place or residential location. Where the program is offered, it is left to potential participants to organize and take advantage of the opportunity it offers. Wide scale deployment of deep discount programs in a transit service area can, in this regard, provide equality of opportunity.

10.4 CHANGES IN TRAVEL BEHAVIOR

10.4.1 Mode Choice Changes

Table 10-1 summarizes mode choice changes associated with the auto-drive-alone and the transit modes following the introduction of selected deep discount programs. The following facts are notable:

- The auto-drive-alone mode consistently loses shares to transit, as to be expected. The loss is more pronounced among students than faculty, staff or other employees.
- The transit mode consistently gains shares by approximately 5 to 15 percentage points. The gain is typically more pronounced among students than faculty, staff or other employees.

These facts emphasize the notion that deep discount programs are more likely to be embraced by certain groups than others. In a university community, for instance, students are a great clientele because many live relatively close to campus, automobile ownership among them is low and many have the flexibility to adjust their travel patterns. Faculty may be the least appropriate clientele because they have the least schedule flexibility due to commitments to appointments and complex travel patterns to attend to multiple chores.

The magnitude of increase in transit ridership has varied widely among deep discount programs. This fact is illustrated by the following:

- Brown, Hess and Shoup (1999) found from their survey of "Unlimited Access" programs in 31 Universities around the nation that during the first year of program implementation, increases in student transit ridership ranged between 70% and 200%.

Table 10-1: Change in Mode Choice Following Deep Discount Pass Programs

	Auto Drive Alone		***Transit***	
	Before	**After**	**Before**	**After**
Univ. of Washington Students[1]	25%	14%	21%	35%
Univ. of Washington Faculty & Staff[1]	49%	40%	21%	28%
Univ. Of Wisconsin, Students[2]	54%	38%	12%	25%
Univ. of Cal. Berkeley Students[3]	12.5%	11.5%	12.2%	21.7%
Univ. of Cal. Berkeley Students[4]			5.6%	14%
City of Berkeley Employees[5]	47.4%		6.2%	10.7%
Silicon Valley Employees[6]	76%	60%	11%	27%

[1]Source: Williams and Petrait (1993)

[2]Source: Meyer and Beimborn (1996); transit rides on MCTS

[3]Source: 1997 and 2001 Surveys; Transit refers to all forms

[4]Source: 1997 and 2001 Surveys; Transit refers to AC Transit (& Pass Program)

[5]Source: 2001 Survey and 2002 Magnetic Dip Data; AC Transit only

[6]Source: Brown, Hess and Shoup (1999)

- Approximately 1690 students rode AC Transit before and 4410 students rode AC Transit after the implementation of the U. C. Berkeley ClassPass. The net increase in riders of 2720 (4410 – 1690) is approximately 160%. Viewed differently, the number of riders jumped to 2.6 times the pre-ClassPass level.
- A relatively low increase of 33% occurred among the faculty and staff of the University of Washington at Seattle.

This fact reinforces the previous assertion that deep discount programs are more likely to be embraced by certain groups than others. It can also help in identifying the groups to be targeted for deep discount programs.

10.4.2 Level of Pass Use

The data revealed that use of the deep discount pass among program participants tended to increase over time. In general, about a third to two thirds of participants use the pass for travel. Among the City of Berkeley employees, approximately 28% of ECO Pass holders used the pass in the first year of the program. In the longer established employment-based ECO Pass programs, level of participation is higher whereby 58% of pass holders at downtown Denver, 44% at Denver Airport, and 40% at Silicon Valley travel with their deep discount passes.

10.4.3 Fare Elasticities

The levels of mode choice changes relative to price translate into the fare elasticities presented in Table 10-2. The following are noteworthy:

- In general, all elasticities are larger than -1 and range between -0.26 and -0.6 indicating that the demand for transit service is quite inelastic. However, the figures suggest that the demand may expand as a result of reduction in the effective fares whether directly in per ride fares or indirectly in out-of-pocket cost through deep discount programs.

Table 10-2: Comparative Fare Elasticities of Deep Discount Programs[1]

Transit in General		
By Time of Day[2]	Peak	-0.17
	Off-Peak	-0.40
By Trip Purpose[2]	Work	-0.10
	School	-0.19
	Shopping	-0.23
By Mode[3]	Rail	-0.26
	Bus	-0.46
College Campus-Based Student Deep Discount Programs[4]		
California State University, Sacramento		-0.26
University of California, Davis		-0.28
University of Wisconsin, Madison		-0.34
University of Illinois, Urbana-Champaign		-0.49
University of Colorado, Boulder		-0.50
University of California, Berkeley[5]		-0.60
Employment-Based Deep Discount Programs[5]		
City of Berkeley Employees – AC transit		-0.33
Silicon Valley Employees – Santa Clara VTA		-0.60
College Campus-Based Mixed-Affiliate Deep Discount Programs[5]		
University of Washington, Seattle – Students		-0.28
University of Washington, Seattle – Faculty and Staff		-0.17

[1] Mid-point arc elasticities

[2] Mayworm et al, 1980, p xi[54]

[3] Savage, 2002, Table 1[55]

[4] Shoup et al, 1999, Table 3[56]

[5] Author's estimate[57]

- These observations carry the policy implication that implementation of deep discount programs would not overwhelm existing operations. This is especially so vis-à-vis the fact that approximately 27% of existing transit capacity is used overall in urban areas (Brown, Hess and Shoup, 1999).

- The largest responses are likely to occur during off-peak periods (when excess capacity is most likely to be available) and for the bus travel mode, which is more ubiquitous than the rail modes. This implies that groups need to be carefully selected to maximize benefits from the use of existing transit capacity. Participants, such as students, who need to travel more during the off-peak than peak periods are therefore prime candidates for deep discount programs.
- In general, deep discount programs exhibit higher fare elasticities than the industry as a whole. This implies that it may be more beneficial to direct efforts at promoting deep discount programs than general fare reductions.

10.4.4 Time of Travel

Survey data and statistical test results show that the introduction of the U.C. Berkeley ClassPass caused significant adjustments in the periods many students chose to travel to and from campus. However the distribution of travel throughout the day especially in terms of peaking followed the same general pattern after the ClassPass program began as before it.

Magnetic swipe data on the City of Berkeley employee pass users revealed that their travel times were concentrated in the traditional morning and afternoon commute periods. The data also revealed that there was a substantial proportion of either non-work travel or travel related to other work activity in the middle of the workday. Nearly one in ten boardings occurred outside the commute and traditional work hours. This and the previous observations confirm that the ECO Pass was used for multi-purpose travel needs and not strictly for work travel.

The City of Berkeley data also show that an average weekday had nearly three times as many boardings as a weekend. While this fact may suggest the dominance of ECO Pass use for work trips, the primary motivation for instituting the deep discount pass program, the relative level of weekend use was by no means trivial.

10.5 IMPACTS AND IMPLICATIONS FOR PARKING

The provision of parking is integral to all major land use activities. In as far as deep discount programs trigger mode shift away from the auto-drive-alone mode, they have direct cost implications for parking. For instance in Santa Clara County, a survey of commuters to the Silicon Valley indicates that the program resulted in a reduction in parking demand by approximately 19%[58]. Traditionally, parking is viewed as a source of revenue to university campuses. Parking is also considered a necessary infrastructure that supports campus activities. The economics of campus parking vis-à-vis the presence of a deep discount transit pass program may be illustrated with the UCLA case as follows:[59]

Effect on parking demand – With the introduction of the BruinGO program at UCLA, 1,000 drive-alone commuters living within the Santa Monica Municipal Bus Lines (Blue Bus) service area gave up their parking spaces. These spaces did not remain vacant because there was usually a long waiting list (typically of students) for parking permits. Table 10-3 summarizes the effect of the pass program on parking at UCLA.

Similarly at U.C. Berkeley, permits sold represented around 135% of available spaces. If the introduction of a transit pass reduces auto drive-alone commuting, the ratio of permits to spaces is likely to reduce, but the spaces are not likely to remain vacant. In general, a deep discount transit pass program that can help reduce the demand for parking may be a relief mechanism for situations of acute shortage of parking spaces.

Table 10-3: Effect of BruinGO on Parking Demand at UCLA

Introduction of BruinGO	Auto Drivers			Students on Wait List for Parking
	Faculty & Staff	Students	Total	
Before	3,400	3,000	6,400	3,969
After	3,100	2,000	5,100	2,637
Difference	- 300	-1,000	1,300	-1,332

Source: Donald Shoup et al, BruinGO: An Evaluation, 2002, p8,

Effect on future parking construction – A direct result of the reduction in parking demand is the potential reduction in the need to construct new parking spaces. The estimated monthly total cost (construction, interest and operation) of a debt-financed space on a 1,500-space parking structure at UCLA was $223 per month in 2002.[60] This was four times the monthly rate for parking permits at UCLA. Similarly, the estimate for a space in a new parking structure at the University of Colorado, Boulder was $227 per month. The policy issue of interest is the periodic cost of the deep discount program relative to the cost of financing and maintaining parking for those who shifted away from onsite parking.

Potential for additional short-term parking – The reduction in the demand for parking spaces could create opportunities to convert available or less used spaces to daily, short-term visitor parking, which attracts higher parking rates than long-term, permit rates. At UCLA, visitors paid $2 per hour and $7 per day for parking on campus, while faculty, staff and students paid approximately $54 per month for permits in 2002. Assuming a month had just 20 weekdays, a visitor parking space could generate $140 per month, which was more than two and a half times the revenue from a permit. In situations where short-term visitor parking is also in short supply as around U.C. Berkeley, a deep discount program that could free up parking spaces might help generate increased parking revenue.

10.6 ENVIRONMENTAL IMPACTS

Shifts away from the auto-drive-alone mode to transit carry implications for the environment through reductions in roadway congestion and environmental pollution as follows:

- Reduction in drive-alone travel means a reduction in the number of vehicles that could have been on the roads. If demand for roadway use does not shift geographically or in time, a reduction in roadway congestion may be realized in a subject area.

- Whether reduced demand for roadway space is replaced by latent demand or not, reduction in vehicle travel could result in the avoidance of emissions from the private vehicles of those who shifted away from drive-alone travel.

While the levels of emissions vary widely by type of vehicle, climate and vehicle operating conditions, Table 10-4 shows generalized unit averages of emissions that may be avoided when reductions in auto-drive-alone travel occur. It also shows, as proxy for marginal social cost, unit cost savings based on the average transaction prices for offset purchases reported by the California Air Resources Board. These generalized figures make the point that deep discount programs that reduce auto-drive-alone can contribute to reduction in emissions and associated costs to society.

Table 10-4: Generalized Unit Emissions and Costs[1]

Type of Emission	Unit Emission		Unit Cost
	Pounds per VMT	Pounds per Gallon of Fuel	Dollars per Pound
Carbon Monoxide (CO)	0.02420	0.593	$3.88
Nitrogen Oxide (Nox)	0.00251	0.062	$9.68
Particulates (PM10)	0.00009	0.002	$8.53
Reactive organic gases (ROG)	0.00242	0.059	$3.28
Carbon Dioxide (CO_2)	1.25823	30.827	$0.02

[1] Compiled from multiple sources: The California Air Resources Board (2000); U. S. Department of Energy (1994); Bernow and Dougherty (1998)

In concept, emissions reductions should lead to improvements in the personal and environmental health of the community. Such improvements may be viewed in terms of reductions in the incidence of illnesses related to the respiratory system, stress and damage to structures. The following reported examples of external effects of deep discount programs illustrate this:

UPASS program at the University of Wisconsin Milwaukee – Meyer and Beimborn (1996) reported reduced vehicle trips to the university, which resulted in reductions in emissions and fuel consumption and translated to dollar savings to students during the 1994-95 academic year as follows:

- 221,055 fewer vehicle trips
- 5,084,265 fewer VMT for trips to UWM, which implies an average of 23 vehicle miles per trip
- 242,108 gallons of fuel savings, which checks to 1.1 gallons of fuel per trip at an average fuel consumption of 21 miles per galloon.
- $295,372 savings in fuel costs, which calculates to $1.22 per gallon of fuel.
- 20% reduction in emissions for trips to UWM and approximately 0.1% for the entire Southeastern Wisconsin region.

Denver ECO Pass – Fay Lewis reports estimates in TransAct that the average employee who used the ECO Pass in 1996 would have eliminated the following[61]:

- 300 single occupancy vehicle trips
- 5,000 miles of driving, which implies an average of 17 vehicle miles per trip
- 200 gallons of gasoline, which checks to 0.7 gallons of fuel per trip at an average fuel consumption of 25 miles per gallon

- 200 pounds of pollutants, which implies approximately 0.7 pounds per trip or 0.04 pounds per mile or 1 pound per gallon of fuel used.

10.7 IMPACTS ON AGENCY OPERATING COSTS

Under ordinary circumstances, when deep discount programs do not necessitate service expansion, the programs exert minimal effect on the operating cost of transit operators. The following examples illustrate:

- *Denver RTD* -- The administrative cost associated with implementing the employment-based ECO Pass program ranged between 1% and 7% of total sales receipts each year. The cost of administering the ECO Pass, therefore, did not appear to be excessive and indeed appeared to be less than what was typical with comparative objects of expenditure in the transit industry.

- *AC Transit* -- Unofficial estimates from AC Transit officials place the cost of administering their deep discount programs at 3% of receipts from the programs.

  AC Transit riders among City of Berkeley employees increased by nearly 75% (from 120 to 208) in the first year of the institution of the ECO Pass program; this did not necessitate expansion in AC Transit service to accommodate demand. Indeed no incidence of overcrowding has been known to occur and no increase in service levels have been warranted on the routes serving downtown Berkeley since inception of the ECO Pass program.

The situation may be drastically different when program expansion occurs. For instance, in response to ridership gains after the U-PASS program at the University of Washington, Seattle began, Metro added 60,000 annual hours of new bus service, the equivalent of 10 more buses operating for approximately 18 hours a day. Program-specific operating cost additions that may arise could relate to route extensions, increase in service runs, cost of tripper operators, cost of guaranteed ride home service, cost of additional administrative assistance to the participating group and the production cost of the pass instrument. These costs can grow rapidly because of the traditionally large unit costs of labor and vehicle operation. This is illustrated in an example application of the pricing method developed in the next chapter.

10.8 NET REVENUE EFFECTS

This dissertation has found consistently that the deep discount group pass programs of the case studies generated much higher unit revenues to the transit operators than most other programs. The following findings illustrate:

- The tracking of rides by City of Berkeley employees with monthly magnetic swipe data revealed that AC Transit earned revenues that ranged between \$2.00 and \$2.50 per boarding in 2002. The ECO Pass program appeared to yield three times the system-wide unit revenue of \$0.67 that AC Transit recovered in 2000. It is interesting to note that this rate of revenue yield was obtained from a deep discount program that AC transit offered at a 90% discount over the regular adult monthly pass.
- Data reveal that every deep discount program offered by the Denver RTD yielded more revenue per boarding than the system-wide average. As shown in Table 10-

5, ECO Pass programs yielded almost two times as much as the system-wide average in the year 2002. Generally, the employment-based program appears to yield the highest revenue per boarding among the various deep discount programs.

- Results of Granger Causality Tests of the RTD data imply that while the Eco Pass program might draw from the existing transit riding population, it yielded more than proportionate increase in revenue resulting in a net gain in fare revenue. This finding and the findings on fares per boarding are consistent with the basic hypothesis of this study that deep discount group pass programs may be instruments for increasing transit revenue.
- When the U.C. Berkeley ClassPass program began, AC Transit earned net monthly revenue of approximately $40,600 ($125,100 - $84,500), which projected to net annual revenue increase of approximately $406,000. This net increase in revenue is nearly 50% over the estimated pre-ClassPass level.

Table 10-5: Trends in System-wide vs. ECO Pass Revenue – Denver RTD

	System-wide		**Deep Discount Programs**	
	Revenue Per Boarding		**Revenue Per Boarding**[1]	
	Nominal	**1983 Dollars**	**Nominal**	**1983 Dollars**
1994	$0.43	$0.29	$1.09[2]	$0.76
1997	$0.51	$0.32	$0.77	$0.48
2000	$0.58	$0.34	$1.07	$0.62

[1] Revenue per boarding for combined three major programs

10.9 PROVIDERS AND RECIPIENTS

Another issue that has wide implications for costs relates to the decision on how to pay for the program. The fundamental distinction is between making payments to the operator per boarding as at UCLA (with the benefit of magnetic swipe card) or per person as at U.C. Berkeley and the majority of ECO Pass programs. The following paragraphs review related issues.

Riders – When payment for the deep discount pass is made by a sponsoring organization, as at UCLA, there is no cost implication for the riders. However, in the UCLA-specific case, there is cross subsidization of transit users by parkers since the cost of the transit pass program is fully funded from parking revenues. Where lump sum payments are made for all members of the group, as at U.C. Berkeley and the ECO Pass programs, there is an element of cross-subsidization of riders by non-riders. However where individual members of a group can opt out, as at the University of Washington, Seattle, cross-subsidization may diminish.

Operators – Operators could view payment per ride as the fairest method especially if there are many new riders during periods of excess capacity. If there are several peak period rides, capacity expansion and consequent increases in operating cost could result. If there are few off-peak riders, the potential to increase revenue becomes limited.

Payment per participant will ensure a guaranteed amount of revenue and can result in a windfall for operators if there are many non-riders or if rides are concentrated in the off-peak periods of excess capacity. However if there are several peak period rides, capacity expansion and consequent increases in operating cost could result.

Universities – There may be little or no direct cost implications to such recipient agencies as universities if participants pay the entire fare as at U.C. Berkeley. On the contrary, there is some expense if fares are subsidized as at the University of Washington, Seattle or are fully covered as at UCLA. However, a university could realize savings from paying for transit passes instead of constructing more parking spaces. For instance UCLA spent approximately $71,000 a month for bus rides by faculty, staff and students that resulted in the reduction in parking demand by more than 1,000 spaces.[62] At $71 per space saved per month, the pass is a bargain compared to the total monthly debt service cost of $223 per parking space. In a situation where there is no reduced need to construct new parking spaces, the pass might not be a bargain if the institution continued to pay for both the parking spaces and the bus use.

10.10 COSTS AND BENEFITS

Conventionally, the efficacies of programs are judged by their benefits relative to the costs incurred in their realization. The incidence of costs and benefits fall differently on individuals, agencies, groups, communities and other constituents. Therefore benefit-cost analyses should ideally target various constituents of programs. Table 10-6 identifies the key elements of costs and benefits attributable to deep discount pass programs as well as the constituents of each item.

The key cost elements are: (1) payments for passes by payers; (2) additional service operating cost, if any, to service providers; (3) loss of parking revenue to parking providers; and administrative costs to program administrators.

The key benefit items include: (1) reduction in fare payments by buyers; (2) reduction to parking providers in capital construction and maintenance costs of new parking spaces due to reduced demand; (3) additional revenue to parking providers from increased availability of short-term parking spaces; (4) increased fare revenue to service providers; (5) reduced roadway congestion in the community; and (6) reduced environmental pollution in the community. It may be argued that other less determinable benefits could potentially accrue to society in the wake of deep discount pass programs. They include savings from reduced roadway construction; reduced amount of land used for roads; and increased safety, which may stem from reduced roadway congestion.

The evaluation of the UCLA deep discount pass program provides one example of benefit-cost analysis of a deep discount pass program. It uses applicable elements of costs and benefits identified in Table 10-6 to assess the net benefits of the program on various constituents of the campus community. Table 10-7 is a summary of the results. Additional details are included in Appendix 3-3 of Chapter 3. The evaluation parsimoniously considered two elements each of costs and benefits. Included among costs are payments for rides and program administration costs. Benefits relate to reduced fare payments and reduced parking demand.

Table 10-6: Key Elements of Costs and Benefits of Deep Discount Pass Programs

Anticipated Element	Constituents
Potential Costs	
1. Payment for passes	*The payer*: universities, employers, participants
2. Additional service operating costs, if any	*Service provider*: transit agency
3. Parking revenue lost from reduction in permits	*Parking provider*: university
4. Administrative costs	*Program administrators*: universities, employers, transit agency
Potential Benefits	
1. Reduction in fare payments	*The payer*: universities, employers, participants
2. Reduction in construction cost of parking spaces due to reduction in demand	*Parking provider*: university
3. Additional revenue from increased short-term parking	*Parking provider*: university
4. Increased fare revenue.	*Service provider*: transit agency
5. Reduced congestion	*Community*
6. Reduced emissions	*Community*

Table 10-7: Estimated Annual Costs and Benefits of BruinGo[1]

Constituent	Costs	Benefits	Benefit-Cost Ratio
Students	$137,700	$862,000	6.3
Faculty and Staff	$202,500	$807,000	4.0
University Departments	$32,400	$109,000	3.4
Campus Visitors	$437,400	$1,472,000	3.4
Overall	$810,000	$3,250,000	4.0

[1] Source: Brown, Hess and Shoup (2002), Table 3

Results demonstrate and reveal the following:

- The incidence of costs and benefits fall on various constituents at different levels. From stratifying the analysis by constituents, the program may be designed to achieve specific objectives or to address specific equity concerns. For instance, a decision could be made whether payment for the pass should fall on a particular constituency or whether they should be shared among them.
- All constituents realized high benefit-to-cost ratios above 3.0. Effectively, the benefits of the BruinGO deep discount program are more than three times the costs incurred in its implementation. Such a finding is indicative of the efficacy specifically of the UCLA program and generally of deep discount pass programs.

10.11 SUPPORT POLICY AND LEGISLATION

This dissertation has highlighted the efficacy of deep discount group pass programs as a fare instrument for efficiency in transit operations. This section will address a general policy framework for the success and widespread adoption of the deep-discount transit pass program.

National policy and legislation ~ Federal laws (**Internal Revenue Code 132(f)**), provide significant tax savings to both employers and employees for the use of public transit. See Appendix 10-1 for an interpretation of the Federal law on employer provided transit benefits. These laws offer opportunities for wide scale deployment of the deep discount program. Potentially, either employers could pay for deep discount passes as benefits or employees could pay through their places of work as pretax deductions. The combination of benefits and deductions can sum up to $100 per month. Many employers already take advantage of the provisions of this law. The City of Berkeley, for instance, offered $20 a month as a tax-free benefit while City employees could request for up to $20 a month as a pre-tax deduction toward “Commuter Checks” for the purchase of transit tickets or parking at BART stations. The University of California similarly offered subsidies of $6 to $15 a month for a variety of transit ticket purchases under its “New Directions” programs of transit discounts and pre-tax deductions.

Local legislation and policy ~ Control of transit operations is largely a local affair with state and federal input. Since local governments are primary stakeholders in the success of transit, it is in their interest to find innovative methods of financing including the deep discount pass program. Even in the absence of state and federal enabling legislation, local policy and legislation can aid in the deployment of the deep discount group pass as exemplified by the trend in Denver, Colorado, Santa Clara County, California and King County, Washington as previously discussed in the literature review (Chapter 3) and in the case study of Chapter 7.

Transit agency roles and proactive steps ~ In spite of legislation, how the deep discount program is implemented is a major factor in its success. Transit agencies will need to market the idea effectively and include appropriately selected discounts that can attract ridership without reducing revenue. In addition to the many lessons learned from the analyses, transit agencies need to take proactive steps toward the successful implementation of deep discount programs. Examples of proactive steps by transit agencies are reflected in the variety of deep discount programs offered by the Denver RTD and, to some extent, by the Santa Clara VTA.

10.12 IMPLICATIONS OF WIDE SCALE DEPLOYMENT

Wide scale deployment of deep discount group pass programs implies that in the limit, urban public transit is to be viewed much like such community facilities as public schools and libraries without General Fund support. Experience with transit systems under public ownership in the USA revealed the tendency for inefficiency on the part of transit management and unreasonable demands from labor unions whenever there appeared to be such "deep pocket" sources of funding as the General fund. The pursuit of deep discount programs places the burden of raising revenue with the transit agencies. The revenue thus collected is therefore specifically dedicated to funding service operations thereby maintaining the *user fee* principle that characterizes transportation finance in the USA. It is arguable that adoption of the program constitutes the exchange of one form of subsidy for another. However the main difference is the following:

- The existing form of subsidy comes mainly from tax-payers in general, General Fund resources, or special sales tax initiatives. However all must pay to use the transit service in spite of making contributions to subsidize operations.
- With group pass programs, cross-subsidization comes from potential riders within the service area or with access to the services. And it offers to all contributors to the "pool" equal opportunity to use the transit service without additional out-of-pocket cost.

This and previous chapters have established the general efficacy of deep discount group pass programs. The next chapter presents a method of pricing them.

11. PRICING METHOD

11.1 PRICING FRAMEWORK

In this chapter, a methodology is developed for determining the prices for deep discount group passes that would ensure no net loss in revenue to transit agencies. The literature reveals two fundamental approaches to setting prices as follows:

1. *Pricing based on the concept of elasticity*. In microeconomics, price theory explains the economic behavior of individual decision-making units in a free-enterprise economy. Under this theory, there is an inverse relationship between price and quantity demanded. Normally, as one increases, the other decreases. Since the product of price and quantity is revenue, the demand responsiveness of users of the deep discount pass to prices would seem to be an area of interest. These issues were discussed in Chapter 4 and Chapter 6. Responsiveness is expressed in terms of elasticity, which is defined as "the percentage change in the use of a particular transportation service resulting from a 1 percent change in an attribute such as price, trip time, or frequency of service" (Small and Winston, 1999).

   This framework is not directly applicable to the pricing of deep discount programs because individual decision-making affects the quantity demanded, but does not directly affect the price of the pass. One of the key features of group passes is that they are issued to all members of the group regardless of whether every member is going to use the transit service or not.

2. *Pricing based on the concept of insurance.* Drawing on the analogy of the pass program to an insurance program as explained in Chapter 5, its pricing would essentially need to determine the cost associated with administering the program and then assign the cost to the program group. This framework fits the pricing of deep discount programs better than the elasticity-based method.

11.2 PRICE DETERMINATION TO INCREASE REVENUE AND RIDERSHIP

All deep discount group passes are not priced equally because the pricing is intended to cover the varied costs of providing service. For example, the price of an ECO Pass per employee is considerably higher ($200 to $245 per person per year) in downtown Denver where there is a concentration of services and peak period travel and where parking is more expensive than in the suburbs ($30 to $45 per person per year) where there are fewer services, much less concentration of peak period travel and plenty of free parking.

The deep discount is the primary ingredient for increasing ridership; it makes the pass relatively more "affordable" and, ceteris paribus, should result in higher demand, where that demand is downward sloping. Chapter 6 elaborated on this fact. Other factors include (a) the convenience of the pass, which eliminates the need to have exact change; and (b) universal coverage of a group, which expands the accessibility of the population base to transit service even for those who would ordinarily not choose transit. The revenue increase is the result of the innovative pricing mechanism. Based on the concept of pooling, the mechanism enables transaction costs to become smaller as the number of people in the pool becomes larger. A description of the analogy to insurance was presented in Chapter 5, the second of three chapters on the “Theoretical Framework” of the research.

Conforming to the goal of this research, the objective of the methodology is to safeguard at least and preferably increase revenue receipts following implementation of the program. The safeguard is ensuring that the new revenue received from a qualified group is higher than the sum of the revenue lost from existing transit riders in the group and the additional operating costs associated with program implementation. The method of determining pass prices would therefore be cognizant of the costs of providing service. The cost elements are outlined in Table 11-1. The elements include administrative costs, service operating costs and coverage costs related to number of participants and location. The method bases pricing of the deep discount pass per participant on participant location. The price of the pass therefore considers the following:

- Revenue lost from existing riders at prevailing fares
- Level of transit service in the primary location of transit use, that is, the origin or destination location of the identified “group”
- Additional cost, if any, necessitated by the program
- Attractiveness of program terms to participating groups
- A set target by the transit operator for increasing revenue.

Table 11-1: Cost Elements for Deep Discount Pricing

Administrative Costs	Service Operating Costs[63]	Coverage
• Administrative assistance to employers • Program marketing including production cost of the pass instrument	• Additional operating costs related to service extensions • Average cost of guaranteed ride home program, where applicable.	• Number of participants • Location of participants within the service area (place of employment, residence or campus respectively) • Density of transit service level at participant location, which may be classified into such location types as CBD, central city, urban fringe, suburban, rural, etc.

11.3 COMPONENTS OF THE REVENUE INCREASING METHOD

The method combines the considerations for pricing into a series of analytic steps. These steps are outlined in the following subsections.

11.3.1 Define Cost Factors

The primary factors that would affect the cost of administering deep discount programs relate to the following:

(a) Availability of applicable transit service at a location – a service extension would result in a higher unit price;

(b) Number of qualified group members at the location – the fewer the number of group participants the higher the unit price;

(c) The level of peak-hour service trips near the location -- the higher the level of peak-period service trips in the locality (such as a downtown business district), the higher the unit price. Additional ridership in the peak hour due to the deep discount program could necessitate the provision of additional buses with attendant operators in the form of trippers. These service changes could increase operating costs.

11.3.2 Determine Average System-Wide Operating Costs

A group of supporting factors relate to the existing elements of unit operating costs incurred by the transit agency. Implementation of individual deep discount programs is generally anticipated to exert only minor influences on these system-wide costs. However, specific programs could exert noticeable influences on costs of affected service lines depending on the extent of changes to service operations. The operating factors are:

- Vehicle operation – Its effect may be nil, but a need for additional deadhead or relief travel costs due to route expansion to accommodate deep discount programs could occasion increases in vehicle operating costs.
- Vehicle maintenance – Its effect may be nil, but maintenance costs could increase if there is the need to increase service frequency or extend hours of operation due to deep discount programs.
- Non-vehicle maintenance – Its effect may also be very small or insignificant.
- General administration – Its effect may be very small and may be especially relevant if additional personnel are to be dedicated to the planning, marketing and overseeing of deep discount programs.

The most recent operating expenses are available in the FTA Section 15 dataset of the National Transit Database. The data are used to calculate the following average system-wide costs:

- The respective *unit cost per revenue vehicle mile* (**OC_{um}**) is derived as the quotient of annual operating expenses (**OE_a**) in each of the categories above and total annual vehicle revenue miles (**vrm_a**).

  $$OC_{um} = OE_a / vrm_a \tag{11-1}$$

- Similarly, the respective *unit cost per revenue vehicle hour* (**OC_{uh}**) is derived as the quotient of annual operating expenses (**OE_a**) in each of the categories above and total annual vehicle revenue hours (**vrh_a**).

  $$OC_{uh} = OE_a / vrh_a \tag{11-2}$$

These unit costs are inputs in the estimation of additional program-specific operating costs. The latter are discussed in the next subsection.

11.3.3 Determine Additional Program-Specific Operating Costs

This group of factors identifies costs that are directly attributable to individual deep discount programs. They may be termed "marginal" operating costs that are the result of the following:

- *Extension of service routes* ~ The related additional cost per month (**L_r**) is the product of additional directional miles of service (**m_d**), the number of service runs affected per month (**r_m**) and the total of the unit operating costs per revenue mile (**TOC_{um}**), which is summed from respective applications of Equation 11-1.

$$L_r = m_d * r_m * TOC_{um} \qquad (11\text{-}3)$$

- *Increase in number of service runs either over time or in frequency* ~ The related additional cost per month (**L_f**) is the product of additional directional runs of service (**r**), the average directional run time in hours per month (**h_m**) and the total of the unit operating costs per revenue hour (**TOC_{uh}**), which is summed from respective applications of Equation 11-2.

$$L_f = r * h_m * TOC_{uh} \qquad (11\text{-}4)$$

- *Employment of additional operators as "trippers" for peak periods of service* ~ The two previous additional cost items include operator costs. However, if trippers are employed, then additional operator cost incurred per month (**L_t**) is the product of additional tripper operators per day (**t_{nd}**), the average unit tripper cost per day (**t_{cd}**) and the number of tripper service days per month (**t_m**).

$$L_t = t_{nd} * t_{cd} * t_m \qquad (11\text{-}5)$$

- *Provision of guaranteed rides home (GRH) to participants during emergencies* ~ The expected cost of guaranteed rides home **$E(L_g)$** is a function of the probability of a participant using the service a month (Π_g) and the cost of GRH service by location type (X_g) per month, and the two possible states of GRH (**N**): 1= use and 2 = no use

$$E(L_g) = \Sigma_N \ \Pi_g * X_g \tag{11-6}$$

- *Administrative assistance to participating groups* ~ Operators identified this cost to run between 1% and 3% of program costs. A multiplier of 1.03 is applied to the computed pass price that is based on the other factors.

- *Production cost of pass instrument* ~ Operators identified this cost to be approximately \$5 to \$7 each for the magnetic dip card with picture identification. For passes that are typically valid for one year, this cost is approximately \$0.50 per month per participant.

11.3.4 Identify Decision Variables

The primary decision is the determination of a pass price that ensures no net loss in revenue. Other potential decisions may include meeting targeted goals for revenue increase. For instance, an agency might seek to increase revenue receipts from a group of participants by 10% to 200% of receipts currently earned from existing riders.

11.4 FORMULATION OF THE PRICING METHOD

11.4.1 The Objective Function

The objective function is to maximize net revenue (**I_n**), which is defined as the difference between the revenue earned from the group due to the deep discount program (**I_c**) and the combination of the revenue previously earned by the operator from transit riders in the group (**I_o**) and additional operating cost due to the deep discount program (**C_a**).

$$\text{Maximize } \{I_n = I_c - I_o - C_a\} \tag{11-7}$$

Whereby revenue from the deep discount program is the product of the number of participants in the program and the unit pass price, say per month.

$$I_c = P_g * N_g = \Sigma_{Ng} P_g \tag{11-8}$$

And similarly, revenue previously earned by the transit agency from transit riders in the group is the product of the number of previous riders and the unit price of a regular transit pass, say per month. If monthly pass prices differ, then the latter is the weighted average price of monthly passes.

$$I_o = P_s * R_b = \Sigma_{Rb} P_s \tag{11-9}$$

So that combining the last two definitions, Equation 11-7 becomes:

$$\text{Maximize } \{I_n = \Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a\} \tag{11-10}$$

11.4.2 Constraints

The objective function is to be maximized subject to the following set of constraints:

(a) Net revenue is no less than the product of a goal set as a policy by the transit agency for increasing revenue (**T_m**) and the greater of either revenue previously earned by the transit agency from existing transit riders in the group (**I_o**) or a minimum level of revenue set as a policy by the transit agency to warrant the institution of the program (**I_m**).

$$I_n \geq (1+T_m) * \max (I_o, I_m) \qquad (11\text{-}11)$$

(b) Whereby the goal set as a policy by the transit agency could be 10% to 100% or even 200% to 300% increase over the revenue previously earned by the transit agency from transit riders in the group, or over unit revenue collected from a specific corridor or over average unit revenue collected system-wide, if the goal is to meet a budget shortfall.

$$T_m = 0.1 \; . \; . \; . \; 1.0 \; . \; . \; . \; . \; 2.0 \; . \; . \; . \; . \qquad (11\text{-}12)$$

(c) The revenue to be earned from the group due to the deep discount program is no less than the sum of revenue lost due to the deep discount program (**I_l**) and additional operating costs attributable to the deep discount program (**C_a**).

$$I_c \geq I_l + C_a \qquad (11\text{-}13)$$

(d) Whereby lost revenue due to the deep discount program is approximately equal to the revenue previously earned by the transit agency from transit riders in the group. Along heavily traveled corridors, additional loss of revenue may be incurred if riders are lost because of lower levels of service due to delays induced by increased deep discount ridership. If data is available to estimate it, then lost revenue could be higher than this approximation.

$$I_l \sim I_o$$

(e) A set of constraints that the decision variables: pass price (P_g), revenue target (T_m), number of participants (N_g) and net revenue (I_n) are all non-negative.

$$(P_g), (T_m), (N_g), (I_n) \geq 0 \tag{11-14}$$

(f) Additional operating cost due to the deep discount program (**C_a**) is a function of two groups of factors:

(i) Unit cost factors that may include vehicle operating cost (**Op_c**), vehicle maintenance cost (**Mt_c**), non-vehicle maintenance cost (**Nm_c**), and general administration cost (**Ad_c**). These are summed to a total unit operating cost.

(ii) Program-specific operating cost additions attributed to route extensions (**L_x**), increase in service runs (**L_f**), cost of tripper operators (**L_t**), cost of guaranteed ride home service (**L_g**), cost of additional administrative assistance to the participating group (**Aa_c**) and the production cost of the pass instrument (**P_p**).

$$C_a = f(Op_c, Mt_c, Nm_c, Ad_c, L_x, L_f, L_t, L_g, Aa_c, P_p) \tag{11-15}$$

Equations 11-3 through 11-6 explain components of this function.

(g) Finally, discounted pass prices vary by geographic location according to the level of peak-period service trips in the locality. This is measured in terms of the level of accessibility of transit service, which is converted to a multiplier (**AI_m**) so that a locality such as a downtown business district with the highest level of transit access justifies a much higher unit pass price than the others.

(h) The maximum location-based, periodic price of a deep discount pass (**P_{AI}**) should be no more than a percentage (π) of the price of a regular periodic pass. This constraint sets maximum price boundaries that ensure "deep discounts".

$$P_{AI} \leq \pi P_s \quad (11\text{-}16)$$

With sufficient expansion in population of participants, these maxima can eventually define feasible boundaries even if not initially. The proposed boundaries are constructed to cover equal ranges that are based on variations in deep discount pass prices by level of transit service in the Denver Regional Transportation District. They are shown in Table 11-2.

Table 11-2: Deep Discount Levels and Area Multipliers in Denver (2003)

Location Type[1]	**Discount Level**		**Multiplier Relative to Area A**	
	Pass Price as % of Regular Monthly Fare[2]	**Proposed Price as % (π) of Monthly Fare[3]**	**Existing[2]**	**Proposed[4]**
A ~ Suburban	11%	15%	1.0	1.0
B ~ Urban Fringe	23%	30%	2.6	3.0
C ~ Urbanized	58%	45%	7.3	5.0
D ~ Downtown	59%	60%	7.5	7.0

Notes to Table 11-2:
[1] Service Level Area with approximate land use definitions. "Downtown" includes major employment centers that are highly accessible to transit
[2] Data for Denver Regional Transportation District (2003); regular monthly pass cost = $35 each
[3] Constructed to cover equal ranges
[4] See the next section for derivation of multipliers

The definitions of variables included in the formulation are summarized as follows:

Aa_c = costs related to additional administrative assistance to the group

Ad_c = administration cost

AI_m = pass price multiplier related to location accessibility

C_a = additional operating cost necessitated by the program.

I_m = minimum revenue defined by agency policy to warrant program inception

I_o, I_c = revenue from passes sold to the group before and after pass implementation respectively

L_f = additional costs related to increase in service runs

L_g = additional costs related to guaranteed ride home service

L_t = additional costs related to tripper operators

L_x = additional costs related to route extensions

Mt_c = vehicle maintenance cost

N_g = number of persons passes are purchased for in a group

Nm_c = non-vehicle maintenance cost

π = maximum percentage of the price of a regular periodic pass

P_{AI} = maximum location-based, periodic price of a deep discount pass

P_g = unit price of the deep discount pass sold to a group, i.e. equivalent monthly cost per rider.

P_p = additional costs related to production cost of pass instrument

P_s = standard monthly pass price or weighted average price of monthly passes

R_a = number of transit riders in the group following implementation of the pass program

R_b = number of transit riders from the group before implementation of the pass program

T_m = targeted revenue goal, that is, proportional increase sought by the agency in revenue receipts

11.4.3 Measuring Location Accessibility

Location accessibility is measured as a gravity-based index of relative accessibility between geographic units in a transit agency's service area. To take advantage of readily available data, localities are identified with the travel analysis zones (TAZs) of the metropolitan area. The locality of the deep discount program is therefore assumed to be the same as the TAZ within which the place of employment, neighborhood, college campus or other focal point of the participating group resides.

The gravity-based index of the subject zone ($\mathbf{AI_{iT}}$) is inversely related to the travel time between that zone and others ($\mathbf{t_{ijT}}$) for travel by the transit mode.

$$AI_{iT} = \Sigma_j \, t_{ijT}^{-y} \tag{11-17}$$

Where travel time is the door-to-door time that includes access, wait, transfer, in-vehicle and egress. The subscripts, **i** and **j**, refer to the subject and other zones respectively. And **y** is a calibrated parameter[64].

The idea of travel between a subject zone and others stems from the rationale that whether the location is a place of employment, residential neighborhood or college campus, program participants can be expected to travel to and from any and all parts of the metropolitan area to access employment, housing, recreational, shopping and other activities to which the deep discount pass may be used for travel.

The index value calculated for each zone in the service area (**X_i**) is expressed in units (**Z_i**) of standard deviations (**S**) from the mean index value of the metropolitan area (**$\underline{X}$**).

$$Z_i = (X_i - \underline{X}) / S \qquad (11\text{-}18)$$

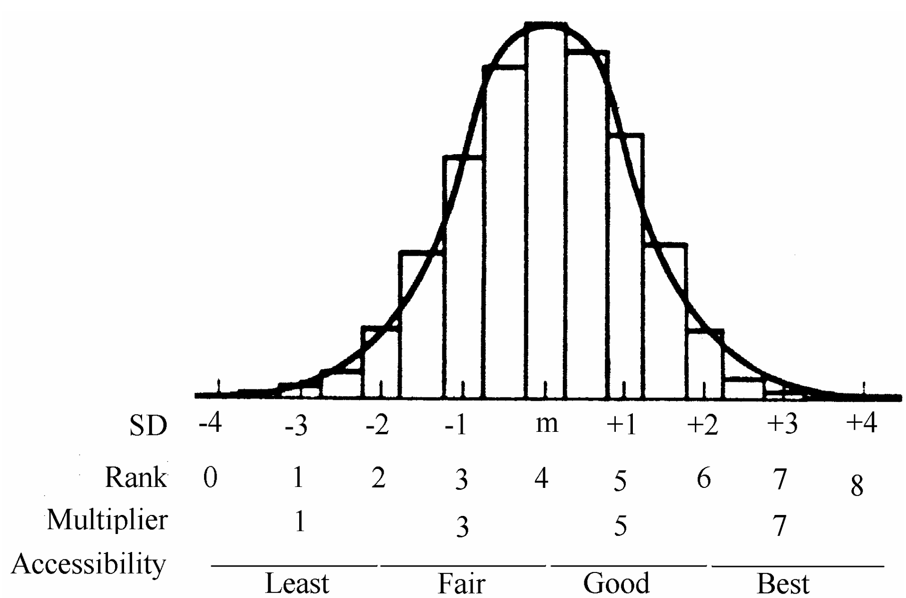
The standardized scores are then grouped into equal ranges to correspond approximately to location types. Zones with no transit access are identified separately. Table 11-3 shows the definitions of the area types.

Since over 99% of the area under the normal curve is typically within three standard deviations on both sides of the mean, all scores below -3 are grouped at the z-value of -4 as the assumed lowest point on the scale. Also all scores above +3 are grouped at the z-value of +4 as the assumed highest point on the scale. The abscissa of the normal curve is rank-numbered in discrete integer increments from the lowest point below the mean to the highest above the mean. Over this converted scale, the midpoint values of the location ranges defined above are selected as the multipliers. Figure 11-1 illustrates the standard normal curve, the ranking, the ranges and the multiplier.

Table 11-3: Definitions of the Area Types

Accessibility	Numerical Definition
Most accessible	index is more than two standard deviations above mean index value
Well accessible	index is between the mean and one standard deviation above mean index value
Fairly accessible	index is between the mean and one standard deviation below mean index value
Least accessible	index is more than two standard deviations below mean index value
Not accessible	Zone has not transit service

Figure 11-1: Standardized Curve with Multiplier Ranges



11.5 EXAMPLE APPLICATION OF THE PRICING METHOD

11.5.1 Case Description

The participating group is a hypothetical collection of 1330 persons located around U.C. Berkeley within the service area of AC Transit. Prior to the introduction of the deep discount pass program, AC Transit earned average monthly revenue of $2,410 from the 120 riders in the group.

The group location is served directly by several lines, but changes are proposed to be made to only Line 65. The existing Line 65 has the following characteristics:

- 30 runs in each direction per weekday for 22 days a month
- 12 runs in each direction on 4 Saturdays and on 4 Sundays a month
- 30-minute run time approximately in each direction.

To enhance accessibility to other transit services, the routing of line 65 is to be extended by 0.25 of a directional mile. Weekday hours of operation are also to be expanded by four runs in each direction from 8:10 pm to 10:10 pm.

Service enhancements necessitate employment of one tripper operator per weekday. Trippers are to be paid for a minimum of 4 hours per day at the rate of $15 per hour. Historically, the participants are known to call for 10 guaranteed rides home on average per month. The average cost per emergency trip is $30.

11.5.2 Average System-Wide Operating Costs

The latest available unit operating costs for AC Transit calculated from FTA Section 15 Reports for the year 2000 are presented in Table 11-4.

Table 11-4: Unit Operating Costs[1] – AC Transit 2000

	Vehicle Operating	Vehicle Maintenance	Non-Vehicle Maintenance	General Admin.	Total Operating
Unit cost per revenue vehicle mile	$4.85	$1.76	$0.18	$1.58	$8.38
Unit cost per revenue vehicle hour	$57.37	$20.87	$2.16	$18.71	$99.11

[1] All data for publicly operated transit service excluding privately operated services

11.5.3 Program-Specific Operating Costs

Two scenarios are tested. The first involves the hypothetical case, but without program-specific operation costs. The second involves the proposed service assumptions and enhancements outlined under the hypothetical case description. Table 11-5 summarizes the program specific operating costs arising from the case scenarios. Additional details are included in the Appendix to Chapter 11. It is noteworthy that two cost items are recognizable whether there are service improvements or not as follows:

- Administrative assistance to program participants is assumed to be 3% of program cost.

- Production cost of the pass instrument is assumed to be $6 per year or $0.50 per month.

Table 11-5: Program-Specific Operating Costs per Month

Cost Item	Scenario 1: No Service Expansion	Unit	Scenario 2: With Proposed Service Expansion
(a) Route extensions		Program	$3,166
(b) Increase in service runs		Program	$396
(c) Additional "tripper" operators		Program	$1,320
(d) Guaranteed rides home		Per Participant	$3.00
(e) Production cost of pass instrument	$0.50	Per Participant	$0.50
(f) Administrative assistance	1.03	Per Participant	1.03

11.5.4 Pass Price Calculation

Price determination involved three steps as follows:

First, the objective function, $I_n = \Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a$, (Equation 11-10) is maximized to obtain the *base monthly unit pass cost* (P_g). However, the program-specific cost (C_a) only includes the program-wide costs identified as items (a) through (c) in Table 11-5.

Next, the per participant costs identified as items (d) through (f) in Table 11-5 are used to adjust the unit cost to a *base monthly retail price per participant* (P_{ret}).

$$P_{ret} = [P_g * (1 + T_m) + L_g + P_p] * Aa_c \tag{11-19}$$

Finally, the base retail price is adjusted for the location and *accessibility-based pass price per participant* (P_{AI}). The location multiplier is assumed to be 1.

$$P_{AI} = P_{ret} * AI_m \tag{11-20}$$

11.5.5 Linear Program Results

To test for consistency in the application of the method, four variations of the objective function were compared. Three applications added the additional constraint that there is a finite population of 1330 participants while the fourth minimized the number of participants subject to the other constraints. The four objective functions investigated therefore are the following:

1. Maximize net revenue (I_n) with the condition that the number of participants is fixed: $\max \{I_n = I_c - I_o - C_a\} = \max \{\Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a\}$
2. Maximize net revenue (I_n) with the condition that the number of participants is fixed for the scenario that includes the set of proposed service improvements previously outlined.

3. Minimize the pass price (P_g) with the condition that the number of participants is fixed: min $\{P_g = [P_s * (1 + T_m) * R_b] / N_g\}$
4. Minimize the number of participants (N_g): min $\{N_g = (P_s / P_g) * (1 + T_m) * R_b\}$.

The solutions to the linear programs are derived with Microsoft Excel's built-in solver. Results are summarized in Table 11-6 and indicate the following:

- Without service improvements: (a) the base cost of a pass for 1330 participants to match revenue prior to program implementation is \$1.82 per month or \$21.84 a year; (b) the base retail price per pass including participant-specific costs (administrative assistance and production of pass instrument) is equivalently \$2.37 per month or \$28.44 a year; (c) for an area multiplier of one, the accessibility-based pass price is the same as the base retail price.
- Expectedly, the original objective function of maximizing net revenue provides a good revenue margin of 274%, but at three times the base retail pass price. The solution of the retail price is limited by the maximum ceiling constraint.
- With the inclusion of the proposed service improvements, the pass price is virtually the same as under the original objective function since it is also limited by the maximum ceiling constraint. However, a huge chunk of the revenue margin is wiped out by the additional costs of service expansion to a 71% margin.
- The objective function of minimizing the pass price is most likely from the point of view of the employer or other body representing program participants. It is expectedly the base retail pass price where the operator breaks even.

- The least likely objective function of minimizing the number of program participants yielded the highest base retail pass price. It is also limited by the maximum ceiling constraint. It offers a break-even in revenue with 27% as many participants as the original case.
- By way of comparison, the equivalent City of Berkeley pass price of $5 per month would yield 140% margin to the transit agency without service improvements under this example application.

Table 11-6: Comparative Application Results

Objective	Base Pass Cost	Retail Pass Price	Number of Participants	Revenue Margin
1. Maximize net revenue	$1.82	$7.50	1330	274%
2. Maximize net revenue plus service improvements	$1.97	$7.50	1330	71%
3. Minimize base pass price	$1.82	$3.76	1330	0%
4. Minimize number of participants	$6.78	$7.50	360	1%
As Implemented by City of Berkeley		*$5.00*	*1330*	*140%*

In summary, the results demonstrate that for the conditions defined in the example application, the equivalent monthly retail price of the deep discount pass should lie between, $2.37 where the transit agency would break even and $7.50 where the agency could earn 274% margin on existing revenue. In the event that service improvements are included, pass prices can increase dramatically sometimes above upper limits that may have been set previously as policy.

11.5.6 Additional Application Comparisons

Additional application results are compared in Table 11-7 to illustrate changes that would occur in revenue margins consequent to changes in various decision variables. Prior case descriptions and service characteristics are assumed to remain largely the same. And two potential groups are compared as follows:

(a) One group has a membership of 1330 employees (as presented previously in Table 11-6) of whom 120 used the transit service prior to implementation of the group pass program.

(b) The other group has a membership of 4000 employees of whom 850 used the transit service prior to implementation of the group pass program. An alternative proposal is tabled to include just half of the membership in the pass program.

The variables that changed and the associated results are the following:

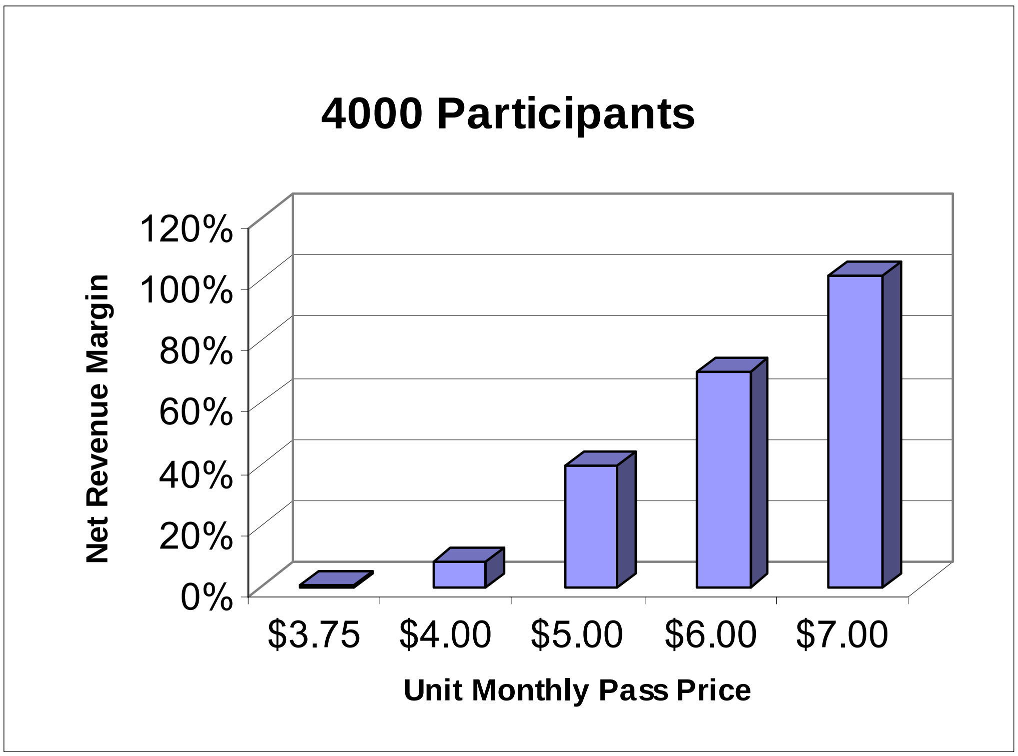
- *Group size* ~ It is shown for the large group with two alternative sizes of participants that at the maximum ceiling constrained pass price of $7.50 per person per month, the transit agency would realize hardly any increase (8%) in revenue margin if half of the group participates, but a healthy 117% if the entire group participates. The lowest feasible unit pass price of $7.00 chargeable over half the group is nearly two times the $3.75 chargeable over the entire group.

Table 11-7: Additional Application Comparisons

Objective	Base Pass Cost	Retail Pass Price	Number of Participants	Revenue Margin
Comparing Group Sizes				
1. Maximize net revenue	$6.78	$7.50	2000	8%
2. Maximize net revenue plus service improvements		$7.50	2000	-31%
3. Minimize base pass price	$5.57	$6.25	2000	-11%
4. Minimize number of participants	$6.78	$7.50	1840	0%
Break-even		*$7.00*	*2000*	*1%*
1. Maximize net revenue	$6.78	$7.50	4000	117%
2. Maximize net revenue plus service improvements		$7.50	4000	78%
3. Minimize base pass price	$2.53	$3.13	4000	-19%
4. Minimize number of participants	$6.78	$7.50	1840	0%
Break-even		*$3.75*	*4000*	0%
Comparing Pass Prices				
Break-even		$3.75	4000	0%
At $4 per pass		$4.00	4000	8%
At $5 per pass		$5.00	4000	39%
At $6 per pass		$6.00	4000	70%
At $7 per pass		$7.00	4000	101%
At $7.50 per pass		$7.50	4000	117%
Comparing Proportions of Riders before Group Pass Program				
	As % of Group			
At $5 per pass				
Half of Large Group	43%	*$5.00*	*2000*	-30%
All of Large Group	21%	*$5.00*	*4000*	39%
The Other Group	9%	*$5.00*	*1330*	140%
At $7.50 per pass				
Half of Large Group	43%	*$7.50*	*2000*	8%
All of Large Group	21%	*$7.50*	*4000*	117%
The Other Group	9%	*$7.50*	*1330*	274%

* *Pass price* ~ When the entirety of the large group participates, a wide variety of unit pass prices are feasible from the lowest or break-even price up to the maximum ceiling constrained price. Increases in the equivalent monthly unit retail price of the pass result in more than proportional increases in net revenue margin. This is illustrated in Figure 11-2.

Figure 11-2: Net Revenue Margin by Pass Price



* *Proportion of existing riders* ~ Comparisons demonstrate that at a given unit pass price, the proportion of riders in the group prior to implementation of the group pass program, which largely contributes to setting the lower bound of the unit pass price, significantly affects the revenue margin that a transit agency can attain.

11.6 SUMMARY

In this chapter, a methodology for determining the price for deep discount group passes was developed. The methodology is designed primarily to ensure no net loss in revenue to transit agencies. It is based on the concept of insurance by determining the costs associated with implementing the program and then assigning the costs to the program group. The procedure is embodied in the following sequence of steps:

1. Cost factors are defined that include the availability and level of transit service in the common locality of the participating group and the number of qualified group members. Variations in these factors affect the unit price.

2. Average system-wide operating costs are determined from FTA Section 15 data to be used in estimating service expansion costs that program implementation might induce. The primary figures of interest are: (a) the unit cost per revenue vehicle mile and (b) the unit cost per revenue vehicle hour.

3. Three other items of program-specific costs are participant-specific. They are determined as applicable to include: (a) 3% of program cost for administrative assistance (Aa_c), (b) production cost of the pass instrument (P_p) at approximately \$6.00 each, and (c) the probable cost per participant of guaranteed ride home service (L_g).

4. The pass price is determined in the following three phases:

   (a) To obtain a *base monthly unit pass cost*, an objective function is optimized subject to a set of constraints: max $\{I_n = \Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a\}$; (Equation 11-10). If service expansion costs are involved, they are included in this function, which maximizes net revenue (I_n) defined as the difference between the new group revenue (Σ_{Ng} P_g) and both previous revenue (Σ_{Rb} P_s) and additional program operating costs (C_a).

(b) The *base monthly retail price* per participant is obtained by adjusting the base monthly cost with the basic participant costs as applicable: $P_{ret} = [P_g * (1 + T_m) + L_g + P_p] * Aa_c$; (Equation 11-19). In addition to the basic participant costs is a proportional target for revenue increase (T_m) that is established as a policy goal.

(c) Finally, the base retail price is adjusted with a location multiplier (AI_m) to become the *accessibility-based pass price* per participant: $P_{AI} = P_{ret} * AI_m$; (Equation 11-20).

5. The calculated pass price is checked for total revenue and compared with the sum of existing revenue and program cost to ensure that there will be no net loss in revenue.

The methodology permits the investigation of alternative objective functions and thus can serve as a common tool for transit agencies, employers and other interest groups. These different constituents may choose to maximize or minimize either the cost of the pass or the number of participants subject to a set of constraints.

The next and final chapter highlights the major conclusions of this dissertation. It also includes ideas for further research.

12. CONCLUSIONS & FUTURE RESEARCH

12.1 CONCLUSIONS

This dissertation highlighted these facts: (a) transit fare increases have largely not had the desired effects on revenues; and (b) transit fare reductions can boost ridership but can also reduce revenue and increase subsidy. Studies of major transit systems produced results, which point to the conclusion that it is preferable to maximize social welfare through the number of persons carried with reduced fares than to maximize the level of transit service provided. The challenge lies in identifying and adopting such strategies as deep discount group pass programs that can produce more marginal revenue than cost.

The deep discount program case studies consistently revealed either higher revenue per boarding than the system-wide average or higher total revenues from target markets with the program than without it. Of the various types, the employment-based deep discount programs appear to yield the highest net revenues to transit agencies.

Among the various types of deep discount programs, those based on college campuses trigger the highest ridership increases notably among student participants. Since student travel times are distributed throughout the day, campus-based programs are prime targets for deep discount group passes since they offer opportunities for off-peak use when there is likely to be excess seat capacity on buses.

Under wide scale deployment of deep discount group pass programs transit may be viewed much like such community facilities as public schools and libraries without

General Fund support. The pursuit of deep discount programs places the burden of raising revenue with the transit agencies while the application of revenues to service operations maintains the *user fee* principle that characterizes transportation finance in the USA. Under the existing form of subsidy that comes from tax-payers in general via General Fund resources or special sales tax initiatives, riders must pay to use the transit service in spite of making contributions to subsidize operations. With group pass programs, cross-subsidization comes from potential riders with access to the services and offers to all contributors to the “pool” equal opportunity to use the transit service without additional out-of-pocket cost.

Although transit agencies recognize the factors for price determination, research reveals that no systematic methodology exists and pass prices are largely determined by watching what others have done. This dissertation has developed a methodology to aid operators in determining deeply discounted but favorable pass prices. The methodology considers: revenue lost from existing riders at prevailing fares; level of patronage in the primary location of transit use; any additional costs necessitated by the program; attractiveness of program terms to participants; and a policy goal of increasing operating revenue. The methodology permits the investigation of alternative objective functions and thus can serve as a common tool for transit agencies, employers and other interest groups. These different constituents may choose to maximize or minimize either the price of the pass or the number of participants subject to a set of policy constraints.

12.2 RECOMMENDATIONS FOR FURTHER RESEARCH

The following research efforts can complement the work presented in this dissertation.

Some of the case study data only reflect short term responses of program participants to deep discount programs. Future work should include additional periodic tracking of trends to assess the medium and long term impacts of deep discount programs on choice of (a) mode, (b) residential location, (c) time of travel, and (d) trip purpose.

The methodology developed in this dissertation is considered only the beginning of formalized methodologies that can aid operators in determining deeply discounted but favorable pass prices. A possible extension of the methodology may specifically focus on the determination of deep discount fares in areas with no existing transit service.

Yet a further extension is the development of a similar methodology for determining the selection of transit bus routes for upgrade to “express” or “rapid” service. The method would similarly seek to optimize an objective function subject to a set of policy constraints.

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APPENDICES

APPENDIX TO CHAPTER 3

Appendix 3-1: A Survey of Unlimited Access Programs (Source: Shoup et al, 1999, Table 1)

A SURVEY OF UNLIMITED ACCESS PROGRAMS AT THIRTY-ONE UNIVERSITIES

University	Who is Eligible to Ride Free?	Number Eligible to Ride Free (1)	Annual Cost 1997-1998 (2)	Annual Number of Rides (3)	Annual Cost Per Eligible Person (4)=(2)/(1)	Number of Rides per Eligible Person (5)=(3)/(1)	Cost per Ride (6)=(2)/(3)	Year Unlimited Access Began (7)
University of California, San Diego	students, faculty, staff, emeritus	35,200	$177,700	296,600	$5	8	$0.60	1969
University of Montana	students, faculty, staff	14,000	$83,600	190,100	$6	14	$0.44	1991
Boise State University, ID	students, faculty, staff	18,100	$160,000	175,000	$9	10	$0.91	1992
University of Georgia at Athens	students	30,000	$275,000	600,000	$9	20	$0.46	1977
Cal Poly State University, San Luis Obispo	students, faculty, staff, emeritus	17,500	$169,000	531,700	$10	30	$0.32	1985
University of New Hampshire - Durham	students	10,000	$95,000	140,400	$10	14	$0.68	1985
Cal State University, Sacramento	students	27,000	$300,000	597,700	$11	22	$0.50	1992
University of Nebraska - Lincoln	students, faculty, staff	26,000	$290,000	476,500	$11	18	$0.61	1994
University of North Carolina-Wilmington	students, faculty, staff	11,000	$120,000		$11			1997
University of Wisconsin at Eau Claire	students, faculty, staff	11,600	$125,000	195,700	$11	17	$0.64	1997
George Mason University, VA	students, faculty, staff	20,000	$300,000		$15			1986
Rensselaer Polytechnic Institute, NY	students, faculty, staff	10,000	$148,000		$15			1997
Appalachian State University, NC	students, faculty, staff	13,200	$251,000	361,800	$19	27	$0.69	1980
Colorado State University	students	20,000	$375,400	462,900	$19	23	$0.81	1975
University of Pittsburgh, PA	students, faculty, staff	31,200	$650,000	1,536,900	$21	49	$0.42	1995
University of California, Santa Barbara	students	17,400	$400,200	584,800	$23	34	$0.68	1986
Santa Barbara City College, CA	students	12,000	$277,000	525,500	$23	44	$0.53	1995
University of Massachusetts at Amherst	students, faculty, staff	39,000	$972,300	807,500	$25	21	$1.20	1969
Ohio State University	students	48,300	$1,400,000		$29			1997
University of Wisconsin at Madison	**students**	**39,000**	**$1,200,000**	**1,653,000**	**$31**	**42**	**$0.73**	**1996**
University of Utah	students, faculty, staff	25,000	$850,000	700,000	$34	28	$1.21	1992
Virginia Polytechnic Institute and State University	students, faculty, staff	32,000	$1,100,000	1,400,000	$34	44	$0.79	1983
Auraria Higher Education Center (UC Denver)	students	31,500	$1,204,000	1,965,000	$38	62	$0.61	1994
University of California, Davis	students	18,500	$719,000	2,021,900	$39	109	$0.36	1990
San Jose State University, CA	students	25,500	$1,020,000	1,150,300	$40	45	$0.89	1993
University of Colorado at Boulder	students	24,500	$1,000,000	1,500,000	$41	61	$0.67	1991
Marquette University, WI	students	6,700	$400,000		$60			1995
University of Wisconsin at Milwaukee	students	20,200	$1,247,400	2,300,000	$62	114	$0.54	1994
University of Illinois at Urbana-Champaign	students	30,400	$2,200,000	5,800,000	$72	191	$0.38	1989
University of Texas at Austin	students	49,000	$4,300,000	7,400,000	$88	151	$0.58	1988
University of California, Santa Cruz	students, faculty, staff	12,220	$1,203,800	1,253,000	$99	103	$0.96	1972
	AVERAGE	**23,420**	**$742,368**	**1,331,781**	**$32**	**55**	**$0.60**	
	MEDIAN	**20,200**	**$400,000**	**650,000**	**$23**	**32**	**$0.63**	**1991**

Appendix 3-2: Annual Rate of Change in Transit Performance Indicators (Source: Shoup et al, 1999)

TABLE 6. ANNUAL RATE OF CHANGE IN TRANSIT AGENCY PERFORMANCE INDICATORS
IN THE TWO YEARS BEFORE AND THE TWO YEARS AFTER UNLIMITED ACCESS BEGAN

	Year	Total Ridership			Riders per Bus			Operating Cost per Ride			Vehicle Miles of Service			Operating Subsidy per Ride			Total Operating Subsidy		
Transit Agency	Program Began	Before (1)	After (2)	Difference (3)=(2)-(1)	Before (4)	After (5)	Difference (6)=(5)-(4)	Before (7)	After (8)	Difference (9)=(8)-(7)	Before (10)	After (11)	Difference (12)=(11)-(10)	Before (13)	After (14)	Difference (15)=(14)-(13)	Before (16)	After (17)	Difference (18)=(17)-(16)
Santa Barbara MTD (UC Santa Barbara)	1986	-4%	+6%	+10	+3%	-9%	-12	+12%	-4%	-16	+3%	+2%	-1	+13%	-10%	-23	+8%	-5%	-13
Champaign-Urbana MTD (UI Urbana-Champaign)	1989	-2%	+76%	+78	-3%	+37%	+40	+5%	-28%	-33	+0%	+15%	+15	+7%	-32%	-39	+4%	+13%	9
Denver RTD (UC Boulder)	1991	+2%	+3%	+1	-3%	+4%	+7	+5%	+2%	-3	+2%	+7%	+5	+7%	+4%	-3	+9%	+8%	-1
Santa Clara Valley TA (San Jose State Univ.)	1993	+0%	-7%	-7	+1%	-4%	-5	+4%	+3%	-1	-4%	-2%	+2	+6%	+4%	-2	+5%	-3%	-8
Boise Urban Stages (University of Idaho)	1992	+5%	+17%	+12	+2%	-2%	-4	-5%	+0%	+5	+0%	+13%	+13	+2%	+3%	1	+6%	+20%	14
Utah Transit Authority (University of Utah)	1992	+7%	-5%	-12	-7%	-10%	-3	-1%	+13%	+13	+4%	+2%	-2	+8%	+6%	-2	+5%	+8%	4
Denver RTD (Auraria)	1994	+5%	+3%	-2	+4%	-3%	-7	-1%	+4%	+5	+4%	+4%	+0	-2%	+5%	7	+4%	+9%	5
Milwaukee County Transit (UW Milwaukee)	1994	-2%	+4%	+6	+5%	+3%	-2	+8%	-2%	-10	-1%	-1%	0	+9%	-4%	-13	+7%	-1%	-8
Milwaukee County Transit (Marquette University)	1995	+2%	+11%	+9	-1%	+12%	+13	+6%	+1%	-5	-1%	+1%	+2	+3%	-10%	-13	+6%	+0%	-6
Port Authority Transit (Univ. of Pittsburgh)	1995	-2%	-1%	+1	-7%	-3%	+4	+2%	+3%	+1	-5%	+0%	+5	+14%	-6%	-20	+12%	-7%	-19
Santa Barbara MTD (SB City College)	1995	+6%	+1%	-5	-5%	+4%	+9	+0%	-3%	-3	+1%	+3%	+2	+1%	-5%	-6	+6%	-4%	-10
Madison Metro (UW Madison)	1996	+1%	+6%	+5	+0%	+9%	+9	+5%	-2%	-7	+2%	-1%	-3	+0%	+3%	3	+1%	+8%	7
Sacramento RTD (Cal. State U. Sacramento)	1996	-1%	+2%	+3	+8%	+5%	-3	+7%	-6%	-13	-1%	+3%	+4	+1%	-2%	-3	+5%	+5%	0
Average (unweighted)		+1.3%	+8.9%	+7.6	-0.2%	+3.3%	+3.5	+3.6%	-1.5%	-5.1	+0.3%	+3.5%	+3.2	+5.3%	-3.4%	-8.7	+6.0%	+3.9%	-2.1
Average (weighted)		+1.3%	+2.7%	+1.4	-0.8%	+1.3%	+2.1	+3.7%	+2.0%	-1.7	-0.2%	+1.6%	+1.8	+6.0%	-0.9%	-6.9	+6.7%	+1.9%	-4.8

Note: The performance statistics consider motor bus transit only. Columns 1,4,7,10,13 and 16 refer to the annual rate of change over the two years *before* Unlimited Access began. Columns 2,5,8,11,14 and 17 refer to the annual rate of change over the two years *after* Unlimited Access began. Columns 3,6,9,12,15 and 18 refer to the *difference* between the before and after trends, as measured in percentage points. Three transit agencies are listed in the table twice because they participate in programs with more than one university. The average figures in the last two rows refer to the unweighted and weighted averages for the 13 programs; for the weighted averages, the transit agencies have been waited by the total bus transit ridership during the year that Unlimited Access began.

Appendix 3-3: Benefit-Cost Analysis of BruinGO (Source: Brown, Hess and Shoup (2002), Table 3)

Source: Brown, Hess and Shoup (2002), Table 3

Table 3. Measured annual costs and benefits of BruinGO

Distribution of costs

Costs	Students	Faculty and staff	University depts.	Campus visitors	Total	Share
BruinGO rides	$108,800	$160,000	$25,600	$345,600	$640,000	79%
BruinGO administration	$28,900	$42,500	$6,800	$91,800	$170,000	21%
Total cost	$137,700	$202,500	$32,400	$437,400	$810,000	100%
Percent of total cost	17%	25%	4%	54%	100%	

Distribution of benefits

Benefits	Students	Faculty and staff	University depts.	Campus visitors	Total	Share
Reduced fare payments	$399,000	$125,000			$524,000	16%
Reduced parking demand	$463,000	$682,000	$109,000	$1,472,000	$2,726,000	84%
Total benefits	$862,000	$807,000	$109,000	$1,472,000	$3,250,000	100%
Percent of total benefits	27%	25%	3%	45%	100%	

Comparing the benefits and costs

Benefit-cost measure	Students	Faculty and staff	University depts.	Campus visitors	Total
Net benefits (benefits – costs)	$724,000	$605,000	$77,000	$1,035,000	$2,440,000
Benefit/cost ratio	**6.3**	**4.0**	**3.4**	**3.4**	**4.0**

Appendix 3-4: Employment-Based Transit Pass Programs, USA (1997)

Source: Crain & Associates, Inc., "Employer and Student Pass Program Survey", Prepared for Central Florida Central Regional Transportation Authority, August, 1997

Metropolitan Area	Program Name	Type of Program	Pricing Basis
Denver, CO	Eco Pass	group pass	Price increases with peak hour trips to the CBD. Formula includes current revenue loss, new ridership revenue, required new service compensation, required capital expenditures, marketing and administration costs, and GRH costs.
Salt Lake City, UT	Eco Pass/ Co-Op Discount	group pass volume discount	Eco-Pass:Tiered pricing based on service level and number of employees. Co-Op: Volume discount w/order for more than 20% of employees with 30% employer subsidy.
Seattle, WA	FlexPass Employer Subsidy Program	group pass consignment	FlexPass:Trip rate is determined using employer survey data. Second year cost adds one-third of new trips; third year adds two-thirds of new trips; fourth year costs reflect total trips. Employer Subsidy: employer choses subsidy level ranging from $5 to 100% of fare
Santa Clara Co., CA	Eco Pass	group pass	Availability of transit service and number of employees.
Eugene OR	Group Pass Program/ Group Pass Program	group pass/ transit voucher	Group Pass: formula includes % of employee base currently using transit and projected increase in ridership. Transit Voucher: requires minimum 50% employer subsidy
Dallas, TX	Employer Support Program	group pass/ discounted pass	Annual group pass based on level of DART service and number of employees. Monthly pass requires employer discount.
Milwaukee, WI	Commuter Pass	group discout	20% discount off week pass price if employers contribute $20 or more per employee/month.
Houston, TX	RideSponsor	bulk sales purchase	Bulk sales discount for 25 or more employees based on payment terms and whether tickets are delivered or picked up.
Atlanta, GA	MARTA Partnership	volume discount	Consignment with volume discount of 4 to 15% depending on volume and if tickets are delivered by MARTA.
Phoenix, AZ	Bus Card Plus	electronic billing with discount	Electronic billing to employer based on actual use with no charge after twenty days of use for any employee.
Santa Cruz, CA	Aggregate Billing Program	volume purchase	Employer is billed for actual use; no discount.
Boston, MA	Corporate Pass Program	consignment	No-cost consignment program.
Des Moines, IA	Employer Support Program	consignment	No-cost consignment program. Tokens paid for on reciept.
San Diego, CA	Employee Transit Alternative Prog.	consignment	No-cost consignment for companies purchasing fourteen or more passes per month. Mail order for smaller orders.
San Antonio, TX	Employer Big Pass Program	consignment	No-cost consignment program.

Metropolitan Area	Transit District	Program Name	Year Began	Participation Companies	Participation Employees	Type of Program
Denver, CO	Denver Regional Transp. Dist. (RTD)	Eco Pass	1991	1,050	32,000	group pass
Salt Lake City, UT	Salt Lake City Transit Authority	Eco Pass/ Co-Op Discount	1991	36	47,000	group pass/ vol. disc. w/employer subsidy
Santa Clara Co., CA	Santa Clara Valley Transp. Auth. (VTA)	Eco Pass	1996	8	24,000	group pass
Seattle, WA	King Co. Dept. of Transp. (Metro)	FlexPass/ Employer Subsidy	1993	30/ 500	70,000	group pass/ consignment
Eugene, OR	Lane County Transit Dist. (LTD)	Group Pass Program/ Commuter Club	1994	17	29,000	group pass/ consignment w/employer subsidy
Dallas, TX	Dallas Area Rapid Transit (DART)	Employer Fare Share Program		225		annual group pass/ discounted monthly pass
Milwaukee, WI	Milwaukee Co. Transit Auth.	Commuter Pass/ Commuter Check	1997	8		group disc. w/employer subsidy/ transit voucher
Houston,TX	Met. Transit Auth. (Metro)	RideSponsor	early 1980's	120		bulk sales purchase
Atlanta, GA	Met. Area Rapid Transit Authority (MARTA)	MARTA Partnership	1986	101	14,000	volume discount
Phoenix, AR	City of Phoenix Transit System	Bus Card Plus	1991	270	40,000	electronic billing with discount
Santa Cruz, CA	Santa Cruz Met. Transit District	Aggregate Billing Program	approx. 1987	6		billed per ride volume purchase
Boston, MA	Auth. (MBTA)	Corporate Pass Program	1974	1,400	70,000	consignment
Des Moines, IA	Des Moines Met. Transit Auth. (Metro)	Employer Support Program	1975	54	20,000	consignment
San Diego, CA	Met. Transit Dev. Board (MTDB)	Employee Transit Alt. Program (ETAP)	1993	70	1,000	consignment
San Antonio, TX	VIA Metropolitan Transit	Emloyer Big Pass Program				consignment

APPENDIX TO CHAPTER 7

Appendix 7-1: The Eco Pass -- Boulder, Colorado

Introduction

The Regional Transportation District (RTD) of the Denver Metropolitan Area has instituted one of the oldest, employment-based, deep discount transit pass programs in the country. The community of Boulder, which is located approximately 20 miles to the northwest of the City of Denver, has experimented with various transit programs since 1989 of which the ECO Pass by the RTD is the most notable. As early as 1991, the University of Colorado (CU) students voted to adopt a bus pass program that has been a resounding success and still exists today. In 1998, the Faculty and Staff ECO Pass began initially as a pilot program. Boulder's experiments with transit programs stemmed from the barriers to transit use that were identified in the City's Transit Development plan as follows:

- Paying a fare and the complications of having exact change
- Lack of frequent service
- Indirect routes

The ECO Pass largely addressed the first of these problems. The other problems are being addressed by developing a community transit system with programs referred to as HOP, SKIP, JUMP, LEAP, and BOUND.

Due to the popularity of the program, 35,000 households sought the Boulder City Council's approval in August 2000 to pay between $40 and $100 more a year in property taxes in exchange for ECO Passes.[65] The idea was to make mass transit as much a neighborhood feature as a school or sewer system or even a public library.

Types of Deep Discount Programs

In addition to the regular monthly pass, the RTD offers its full range of deep discount programs in Boulder. One is the employment-based ECO Pass. Another is the CU Student Pass. Their success led to the institution of the residential-based deep discount pass termed, the Neighborhood ECO Pass and most recently the TeenPass.

Goals and Objectives

The primary goal of the ECO Pass was to increase transit ridership. Its secondary goals aimed at improving the quality of life in the region through reductions in traffic congestion, air pollution, vehicle miles traveled and the impact of the automobile on the environment. The objective of the program was to promote transit as an alternative to driving alone through the provision of a low-cost program.

How the Programs Work

The deep discount programs are administered as described for Denver since the same transit agency, the RTD, offers them in Boulder. For all the deep discount programs, the features of universality, unlimited ride, innovative financing and pricing are as described. For example, a regular monthly RTD bus pass can cost from about $21 per adult for the Boulder area to $85 per adult for the entire Denver metropolitan area. By comparison, the ECO Passes are sold to households for between $50 and $100 per year or approximately $4 to $8 per month.[66] Similarly, all Pass cardholders are eligible to use the Guaranteed Ride Home Program.

Participation

Participation rates are among the highest in the metropolitan area and deserve special mention. There is significant evidence that the ECO Pass programs have led to substantial increases in transit ridership in Boulder. Within five years of program inception, travel by transit for work purposes doubled among the employees participating in the downtown business ECO Pass program. By 1998, 13 neighborhoods in Boulder were enrolled in the Neighborhood ECO Pass program.[67] Within six years of the program, the number of students riding the bus jumped from 300,000 trips to 1,500,000 trips annually, a phenomenal fivefold increase.[68] By August 2000, there were 50,000 pass holders (including CU students and staff and faculty) in a city of 100,000 people.[69]

Benefits

The benefits attributed to the ECO Pass program and described for the Denver metropolitan area apply to Boulder. However the following are noteworthy:[70]

- The programs are reported to have helped in significantly alleviating increases in traffic congestion, air pollution and demand for parking throughout the community with special note of downtown and CU campus areas.
- A flip side of the popularity of the programs is that they have become sources of frustration for businesses and neighborhoods that for one reason or another are not able to participate.
- Apart from being a discount bus pass, the ECO Pass is many other things to many people including:
    - An employee benefit
    - A tool for cutting back on traffic growth and air pollution
    - Freer of valuable parking spaces for other paying customers
    - Transportation for the youth
    - An alternative to driving and parking or to riding a bike or walking in foul weather.

Appendix 7-2A: Annual Participant Growth

Denver Regional Transportation District

Annual Growth in Participants - Various Deep Discount Programs

ELIGIBLE INDIVIDUALS

	Eligible Employees[1]	Eligible Residents[2]	Distributed TeenPass[3]	Distributed GradPass[3]	Enrollment CU Boulder[4]	Enrollment AHEC[5]	Total Eligible[6]
1991	3,912						
1992	19,269				25,089		44,358
1993	17,490				25,013		42,503
1994	32,401				24,535		56,936
1995	31,550	266			24,463	31,403	87,682
1996	32,976	1,110			24,636	31,869	90,591
1997	39,640	1,771			25,157	32,595	99,163
1998	46,598	3,269			25,135	32,352	107,354
1999	55,429	3,613			26,349	31,890	117,281
2000	67,673	2,959		3,100	26,739	n/a	*100,471*
2001	77,512	3,727		5,100	27,289	n/a	*113,628*
2002	76,577	3,794		5,630	28,644	n/a	*114,645*

PARTICIPATING GROUPS

	Companies Enrolled[1]	Neighbor-hoods Enrolled[2]	Schools Enrolled TeenPass[3]	Schools Included GradPass[3]	Campuses CU Boulder[4]	Campuses AHEC[5]	Total Groups[6]
1991	47						
1992	365						365
1993	548						548
1994	723						723
1995	1,089	2					1,091
1996	1,178	3			1	3	1,185
1997	1,033	4			1	3	1,041
1998	960	12			1	3	976
1999	1,040	14	5		1	3	1,063
2000	1,035	15	74	177	1	3	1,305
2001	988	17	115	200	1	3	1,324
2002	1,059	17	124	146	1	3	1,350

[1] Employment-based ECO Pass programs

[2] Residential-based ECO Pass programs

[3] Middle and High School Student ECO Pass programs

[4] College ECO Pass program at Colorado University (CU), Boulder (Fall Semesters)

[5] College ECO Pass program at Auraria Higher Education Center (AHEC) -- Fall data
AHEC includes CU-Denver, Metro State and Community College of Denver

[6] Deep Discount Passes includes all ECO Pass programs; exclude regular passes

Appendix 7-2B: Subsidization – Employee Eco Pass Program

Denver Regional Transportation District

Subsidization of the Employment-Based Eco Pass (2002)

2002		SLA				Number of employees			
	Total	A	B	C	D	1 - 24	25-249	250-999	1,000+
Co's that subsidize 100%	88%	90%	100%	86%	86%	93%	84%	77%	100%
Co's that subsidize less than 100%	12%	10%	0%	14%	14%	7%	16%	23%	0%

Base: companies that subsidize Eco Pass

2002		SLA				Number of employees			
	Total	A	B	C	D	1 - 24	25-249	250-999	1,000+
Percent of TOTAL Participating Co's.	74%	74%	84%	75%	60%	78%	71%	62%	100%

Appendix 7-3A: Annual Boardings

Denver Regional Transportation District

ANNUAL SYSTEM-WIDE PASSENGER BOARDINGS (1981 - 2002)

Year	Boardings	Change over Previous Year	% Change over Previous Year	% Change over Base Year (1981)	% Change over Eco Pass Base Year (1991)
1981	25,432,235	--	--	--	--
1982	38,440,267	13,008,032	51.15%	51.15%	--
1983	38,361,395	-78,872	-0.21%	50.84%	--
1984	41,049,735	2,688,340	7.01%	61.41%	--
1985	56,151,519	15,101,784	36.79%	120.79%	--
1986	53,546,971	-2,604,548	-4.64%	110.55%	--
1987	50,671,517	-2,875,454	-5.37%	99.24%	--
1988	51,240,749	569,232	1.12%	101.48%	--
1989	52,470,098	1,229,349	2.40%	106.31%	--
1990	54,617,455	2,147,357	4.09%	114.76%	--
1991	56,687,001	2,069,546	3.79%	122.89%	--
1992	58,374,078	1,687,077	2.98%	129.53%	2.98%
1993	61,435,948	3,061,870	5.25%	141.57%	8.38%
1994	62,323,414	887,466	1.44%	145.06%	9.94%
1995	67,628,196	5,304,782	8.51%	165.92%	19.30%
1996	70,217,783	2,589,587	3.83%	176.10%	23.87%
1997	71,517,108	1,299,325	1.85%	181.21%	26.16%
1998	72,514,988	997,880	1.40%	185.13%	27.92%
1999	74,603,346	2,088,358	2.88%	193.34%	31.61%
2000	77,774,567	3,171,221	4.25%	205.81%	37.20%
2001	82,011,376	4,236,809	5.45%	222.47%	44.67%
2002	81,322,365	-689,011	-0.84%	219.76%	43.46%

THREE MAJOR DEEP DISCOUNT PROGRAMS

	Key 7 Employee ECO Pass	Colorado University Boulder	Auraria Higher Education Center (AHEC)	Total Three Major Programs	Three Majors as % of System-wide Boardings
1991	83,652			83,652	0.15%
1992	779,720	740,137		1,519,857	2.60%
1993	1,247,128	845,208		2,092,336	3.41%
1994	n/a	847,393		847,393	--
1995	n/a	819,968		819,968	--
1996	3,770,449	744,760	1,937,000	6,452,209	9.19%
1997	4,465,559	854,946	1,982,387	7,302,892	10.21%
1998	5,224,896	1,076,904	2,069,316	8,371,116	11.54%
1999	4,916,988	1,096,472	2,143,811	8,157,271	10.93%
2000	5,061,207	1,116,559	2,125,230	8,302,996	10.68%
2001	5,671,434	1,234,057	2,121,203	9,026,694	11.01%
2002	5,999,623	1,427,476	2,399,204	9,826,303	12.08%

Appendix 7-3B: Boardings By Service Type & By Mode

Denver Regional Transportation District

Employee ECO Pass Boardings by Service Type (2002)

Type of Bus Service	System-wide Boardings	% of All Boardings	ECO Pass Boardings[1]	% of ECO Pass Boardings	% of ECO Pass Bus Rides
Local	44,636,216	55%	2,745,709	46%	57%
Express	2,793,112	3%	867,066	14%	18%
Regional	2,602,719	3%	770,725	13%	16%
SkyRide	1,914,067	2%	433,533	7%	9%
Other[2]	1,253,378	2%			--
Subtotal Bus	*53,199,492*	65%	4,817,034	80%	100%

[1] includes key 7 employee boardings

[2] includes: Denver Circulator, Special Services, Call-n-Ride

Employee ECO Pass Boardings by Mode (2002)

Transit Mode	System-wide Boardings	% of All Boardings	ECO Pass Boardings	ECO Pass as % of Mode
All Bus	53,199,492	65%	4,817,034	9.1%
Light Rail	10,429,572	13%	1,182,589	11.3%
Access-a-Ride	454,998	1%	--	--
Van Pool	83,006	0%	--	--
Mall Shuttle	17,155,297	21%	--	--
Total All Modes	81,322,365	100%	5,999,623	7.4%

Key 7 Employment-Based Eco Pass Related Costs

	Annual Sales Revenue	Annual Sales as % of System-wide Revenue	Annual Accounting Revenue[3]	ECO Pass Adminis-tration Cost	ECO Pass Administration Cost as % of Sales
1991	$191,651				
1992	$871,095				
1993	$1,142,660				
1994	$1,580,856	8.84%	$1,563,131	$17,725	1.12%
1995	$1,700,343	8.57%	$1,669,281	$31,061	1.83%
1996	$1,919,011	9.46%	$1,793,047	$125,964	6.56%
1997	$2,229,861	9.74%	$2,075,434	$154,427	6.93%
1998	$2,957,784	11.55%	$2,812,696	$145,088	4.91%
1999	$3,208,235	12.11%	$3,042,740	$165,495	5.16%
2000	$3,496,639	13.24%	$3,230,935	$265,704	7.60%
2001	$3,676,526		$3,533,407	$143,119	3.89%
2002	$4,075,182				

[3] Sales revenue minus cost of production and distribution of ECO Passes

Appendix 7-4A: Annual Fare Revenues In Current Dollars

Denver Regional Transportation District

Annual Revenue - Various Eco Pass Sales ($ Current)

	Employee ECO Pass[1]	Neighborhood ECO Pass[2]	TeenPass[3]	CU Boulder[4]	AHEC[5]	Total Deep Discount Passes[6]
1991	$261,028			$562,238		$823,266
1992	$1,222,146			$641,791		$1,863,937
1993	$1,651,143			$638,928		$2,290,071
1994	$2,342,828			$666,407		$3,009,235
1995	$2,591,322	$10,277		$605,159	$1,572,184	$4,778,942
1996	$3,010,928	$91,932		$618,368	$1,250,980	$4,972,208
1997	$3,578,927	$66,161		$762,639	$1,204,142	$5,611,869
1998	$4,821,188	$123,751		$852,639	$1,100,848	$6,898,426
1999	$5,344,919	$136,834	$100,000	$939,689	$1,167,000	$7,688,442
2000	$6,021,212	$142,722	$500,000	$973,993	$1,234,400	$8,872,327
2001	$6,511,128	$163,367	$800,000	$1,007,244	$1,368,477	$9,850,216
2002	$7,331,252	$172,342	$1,087,568	$1,273,142	$1,558,856	$11,423,160

	System-wide		Deep Discount Programs[6]			
	System-wide Fare Revenue	Change over Previous Year	Annual ECO Pass Sales Revenue	Change over Previous Year	Change in Pass Sales as % of System-wide Change	Total ECO Pass Sales as % of System-wide Change
1991			$823,266			
1992			$1,863,937	$1,040,671		
1993	$19,000,000		$2,290,071	$426,134		
1994	$26,508,526	$7,508,526	$3,009,235	$719,164	10%	40%
1995	$30,246,000	$3,737,474	$4,778,942	$1,769,707	47%	128%
1996	$31,835,376	$1,589,376	$4,972,208	$193,266	12%	313%
1997	$36,746,800	$4,911,424	$5,611,869	$639,661	13%	114%
1998	$41,749,416	$5,002,616	$6,898,426	$1,286,557	26%	138%
1999	$44,140,301	$2,390,885	$7,688,442	$790,016	33%	322%
2000	$45,474,675	$1,334,374	$8,872,327	$1,183,885	89%	665%
2001			$9,850,216	$977,889		
2002			$11,423,160	$1,572,944		

1 Employment-based ECO Pass programs
2 Residential-based ECO Pass programs
3 Middle and High School Student ECO Pass programs
4 College ECO Pass program at Colorado University (CU), Boulder
5 College ECO Pass program at Auraria Higher Education Center (AHEC)
AHEC includes CU-Denver, Metro State and Community College of Denver
6 Deep Discount Passes includes all ECO Pass programs; exclude regular passes

Appendix 7-4B: Annual Fare Revenues In Constant (1983) Dollars

Denver Regional Transportation District

Annual Revenue - Various Eco Pass Sales ($ 1983)

	Employee ECO Pass[1]	Neighborhood ECO Pass[2]	TeenPass[3]	CU Boulder[4]	AHEC[5]	Total Deep Discount Passes[6]
1991	$191,651			$412,803		$604,454
1992	$871,095			$457,442		$1,328,537
1993	$1,142,660			$442,165		$1,584,824
1994	$1,580,856			$449,667		$2,030,523
1995	$1,700,343	$6,743		$397,086	$1,031,617	$3,135,789
1996	$1,919,011	$58,593		$394,116	$797,310	$3,169,030
1997	$2,229,861	$41,222		$475,164	$750,244	$3,496,492
1998	$2,957,784	$75,921		$523,091	$675,367	$4,232,163
1999	$3,208,235	$82,133	$60,024	$564,039	$700,480	$4,614,911
2000	$3,496,639	$82,882	$290,360	$565,617	$716,841	$5,152,339
2001	$3,676,526	$92,246	$451,722	$568,743	$772,714	$5,561,951
2002	$4,075,182	$95,799	$604,540	$707,694	$866,513	$6,349,728

	System-wide		Deep Discount Programs[6]			
	System-wide Fare Revenue	Change over Previous Year	Annual ECO Pass Sales Revenue	Change over Previous Year	Change in Pass Sales as % of System-wide Change	Total ECO Pass Sales as % of System-wide Change
1991			$604,454			
1992			$1,328,537	$724,083		
1993	$13,148,789		$1,584,824	$256,288		
1994	$17,886,995	$4,738,206	$2,030,523	$445,699	9%	43%
1995	$19,846,457	$1,959,462	$3,135,789	$1,105,266	56%	160%
1996	$20,290,233	$443,777	$3,169,030	$33,241	7%	714%
1997	$22,895,202	$2,604,969	$3,496,492	$327,462	13%	134%
1998	$25,613,139	$2,717,936	$4,232,163	$735,672	27%	156%
1999	$26,494,779	$881,640	$4,614,911	$382,748	43%	523%
2000	$26,408,057	-$86,721	$5,152,339	$537,427	-620%	-5941%
2001			$5,561,951	$409,613		
2002			$6,349,728	$787,776		

1 Employment-based ECO Pass programs
2 Residential-based ECO Pass programs
3 Middle and High School Student ECO Pass programs
4 College ECO Pass program at Colorado University (CU), Boulder
5 College ECO Pass program at Auraria Higher Education Center (AHEC)
AHEC includes CU-Denver, Metro State and Community College of Denver
6 Deep Discount Passes includes all ECO Pass programs; exclude regular passes

Appendix 7-4C: Fare Per Boarding

Denver Regional Transportation District

Annual Revenue per Boarding

REVENUE PER BOARDING ($ CURRENT)

	System-wide	Key 7 Employee ECO Pass	CU Boulder	AHEC	Combined Three Major Programs	Three Majors as % of System-wide
1991	n/a	$3.12	--		--	--
1992	n/a	$1.57	$0.87		$1.23	--
1993	$0.31	$1.32	$0.76		$1.09	354%
1994	$0.43	n/a	$0.79		--	--
1995	$0.45	n/a	$0.74	--	--	--
1996	$0.45	$0.80	$0.83	$0.65	$0.77	170%
1997	$0.51	$0.80	$0.89	$0.61	$0.77	150%
1998	$0.58	$0.92	$0.79	$0.53	$0.82	143%
1999	$0.59	$1.09	$0.86	$0.54	$0.94	159%
2000	$0.58	$1.19	$0.87	$0.58	$1.07	183%
2001	n/a	$1.15	$0.82	$0.65	$1.09	--
2002	n/a	$1.22	$0.89	$0.65	$1.16	--

REVENUE PER BOARDING ($ 1983)

	System-wide	Key 7 Employee ECO Pass	CU Boulder	AHEC	Combined Three Major Programs	Three Majors as % of System-wide
1991	n/a	$2.29	--		--	--
1992	n/a	$1.12	$0.62		$0.87	
1993	$0.21	$0.92	$0.52		$0.76	354%
1994	$0.29	n/a	n/a		--	--
1995	$0.29	n/a	n/a	--	--	--
1996	$0.29	$0.51	$0.53	$0.41	$0.49	170%
1997	$0.32	$0.50	$0.56	$0.38	$0.48	150%
1998	$0.35	$0.57	$0.49	$0.33	$0.51	143%
1999	$0.36	$0.65	$0.51	$0.33	$0.57	159%
2000	$0.34	$0.69	$0.51	$0.34	$0.62	183%
2001	n/a		$0.46	$0.36	$0.62	--
2002	n/a		$0.50	$0.36	$0.65	--

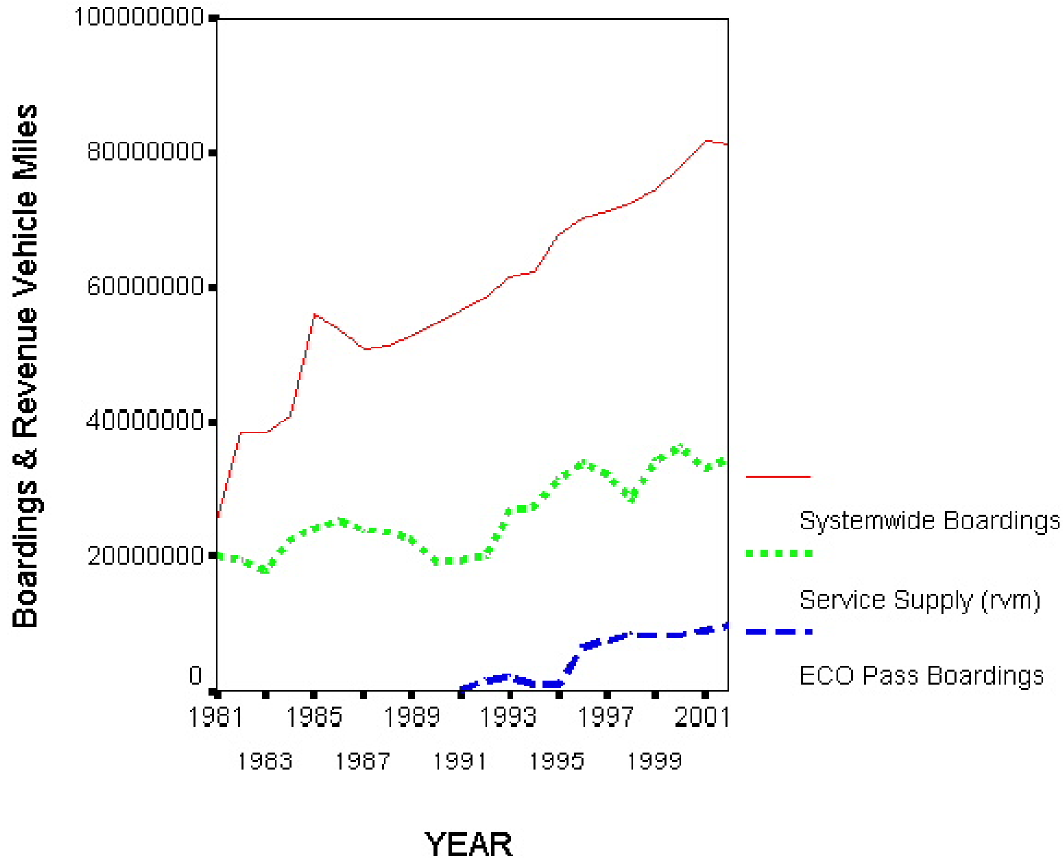
Appendix 7-4D: Consumer Price Indices & APTA Data

U.S. DEPT. OF LABOR		APTA TRANSIT FACT BOOK, 2000 All Transit Agencies in the U.S.				
		OBJECT CLASS			FUNCTION CLASS	
	Average CPI[1]	Total Operating Expenses ($m)	(M&S) Materials & Supplies ($m)	M&S as % of Total	(GA) General Administration ($m)	GA as % of Total
1981	90.9	--	--	--	--	--
1982	96.5	--	--	--	--	--
1983	**99.6** **base year**	--	--	--	--	--
1984	103.9	11574.0	1462.2	12.6%	2914.7	25.2%
1985	107.6	12380.9	1561.2	12.6%	2505.3	20.2%
1986	109.6	12951.7	1524.3	11.8%	2748.0	21.2%
1987	113.6	13472.1	1421.0	10.5%	2869.4	21.3%
1988	118.3	14287.3	1446.2	10.1%	3077.8	21.5%
1989	124.0	14972.3	1507.6	10.1%	3251.0	21.7%
1990	130.7	15742.1	1608.4	10.2%	3449.9	21.9%
1991	136.2	16541.4	1559.7	9.4%	3584.5	21.7%
1992	140.3	16781.4	1529.1	9.1%	2674.2	15.9%
1993	144.5	17349.8	1536.1	8.9%	2714.0	15.6%
1994	148.2	17919.9	1593.9	8.9%	2752.0	15.4%
1995	152.4	17848.7	1613.4	9.0%	2589.5	14.5%
1996	156.9	18340.7	1677.0	9.1%	2744.3	15.0%
1997	160.5	18936.1	1734.1	9.2%	2919.9	15.4%
1998	163.0	19249.1	1818.1	9.4%	3013.1	15.7%
1999	166.6	--	--	--	--	--
2000	172.2	--	--	--	--	--
2001	177.1	--	--	--	--	--
2002	179.9	--	--	--	--	--

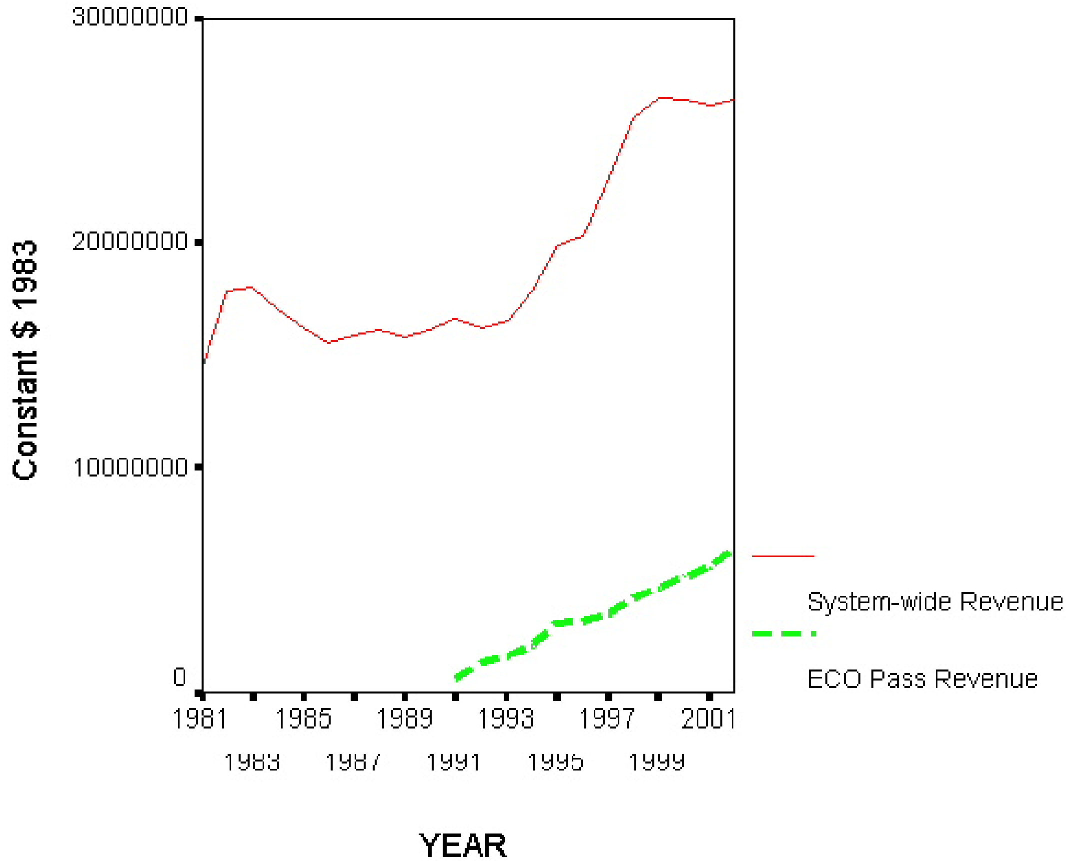
[1] U.S. city average for all items by all urban consumers

Appendix 7-5: Autocorrelation Plots & OLS Results

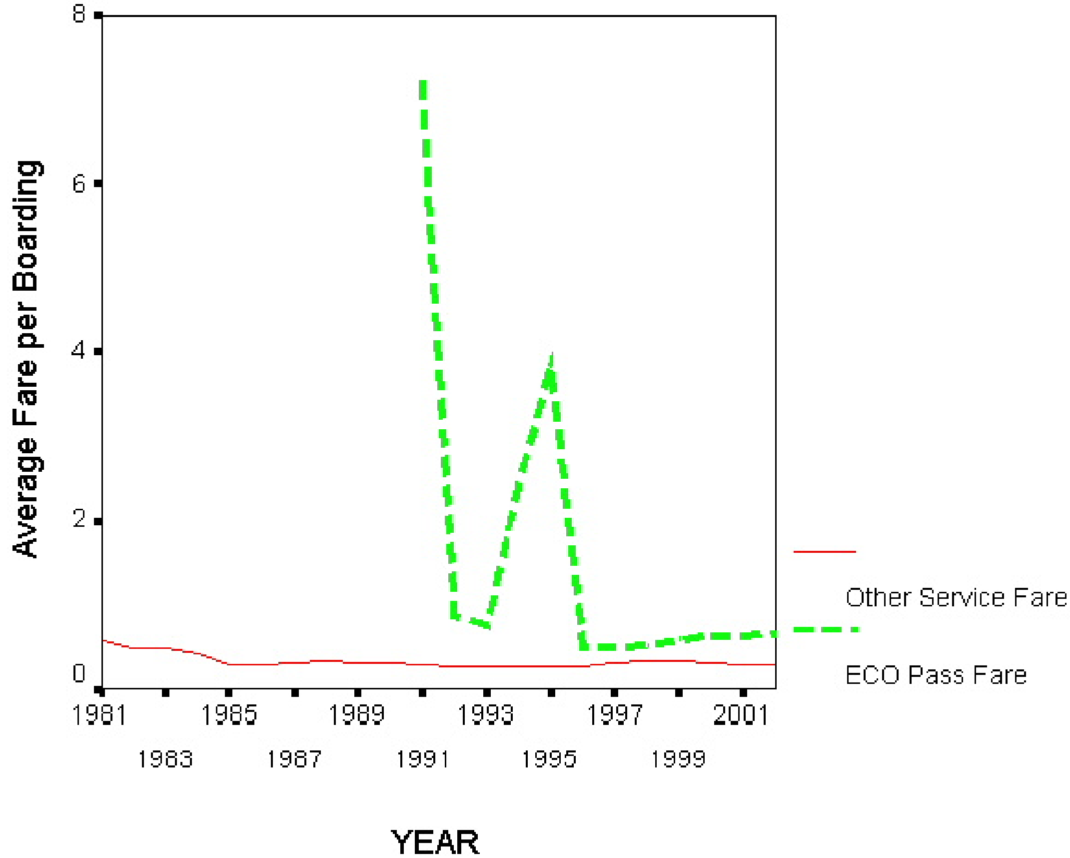
DESCRIPTIVES



(a) Trends in Service Supply and Ridership



(b) Trends in Revenue (constant 1983 Dollars)

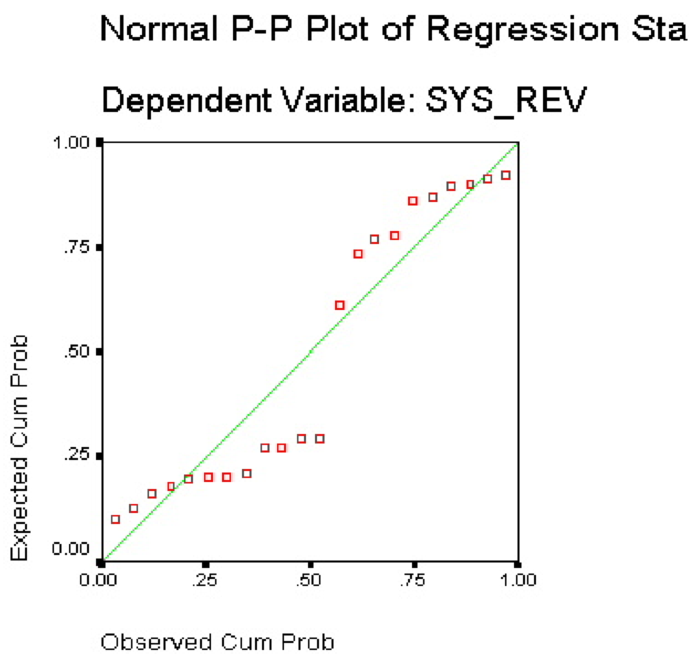


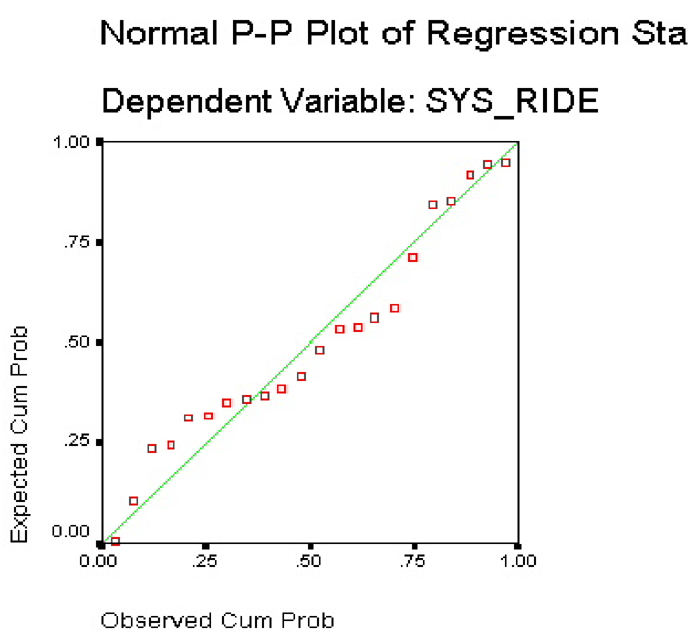
(c) Trends in Fare per Boarding (constant 1983 Dollars)

PLOTS OF STANDARDIZED RESIDUALS

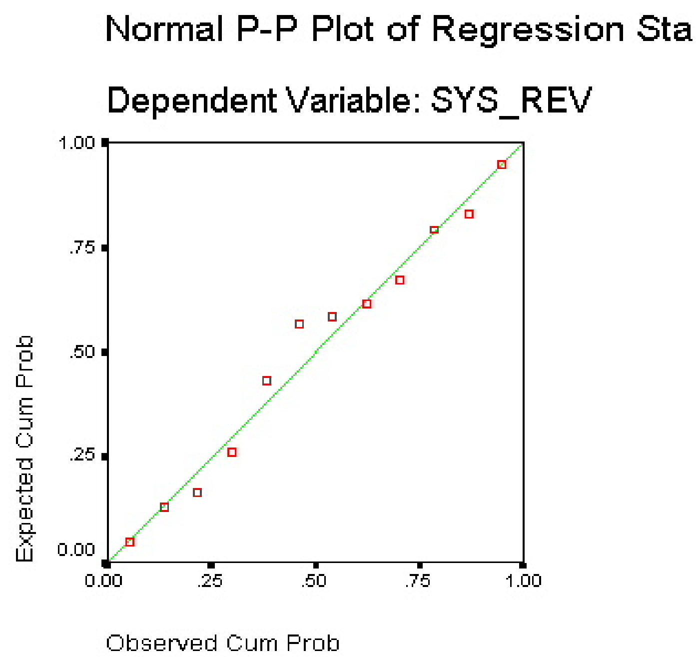
Residual plots show positive serial correlation whereby clusters of positive and clusters of negative errors alternatively follow each other.

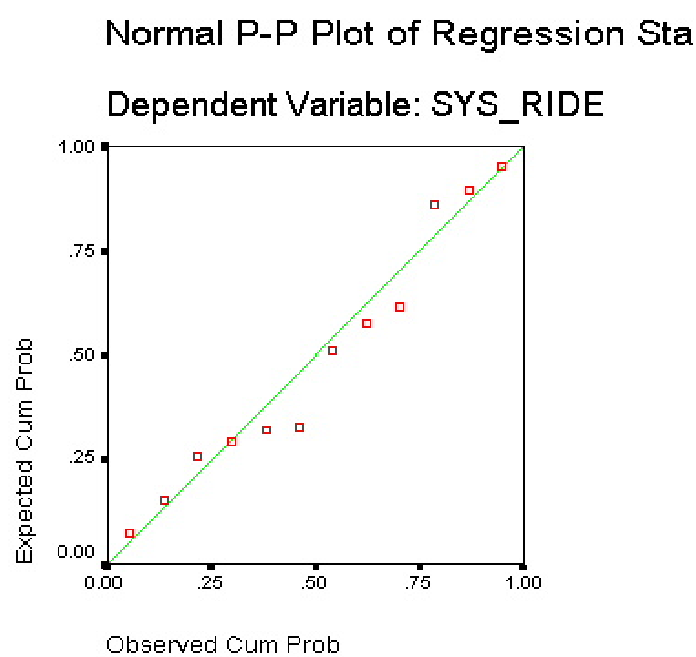
(a) Two Decades for System-wide Revenues and Ridership





(b) One Decade with Eco Pass for System-wide Revenues and Ridership





CHECKS FOR SERIAL CORRELATION WITH DURBIN-WATSON STATISTICS

Hypothesis	DW_stat[1]	rho[2]	d_L	d_U	Serial Correlation
	d = 2(1-ρ)	ρ = (2-d)/2	1 predictor; 22 or 12 data points		d significant @ 5% level?
1. supply → system-wide rides	0.833	0.5835	1.24	1.43	Yes
2. system rides → system revenue	0.292	0.854	1.24	1.43	Yes
3. supply → system revenue	0.81	0.595	1.24	1.43	Yes
4. Eco Pass rides → system rides	1.252	0.374	1.08	1.36	inconclusive
5. Eco Pass revenue → system revenue	0.743	0.6285	1.08	1.36	Yes
6. Eco Pass rides → system revenue	1.888	0.056	1.08	1.36	No
7. Eco Pass revenue → system rides	2.275	-0.1375	1.08	1.36	No

NOTES:

[1] DW = $\{\Sigma_{t=2..T} (\varepsilon_t - \varepsilon_{t-1})^2\} / \{\Sigma_{t=1..T} (\varepsilon_t)^2\}$
Pindyck and Rubinfeld -- Equation 6.22, p165

The plots of residuals indicate the possibility of **positive serial correlation**

(a) Values of d below d_L allow us to reject the null hypothesis of "no serial correlation"

(b) If d is greater than d_U, we retain the null hypothesis

(c) Where d lies between d_L and d_U, the results are inconclusive.

In the majority of cases, where d is less than d_L, d is significant at the 5% level
Therefore, serial correlation is present

[2] Rho (ρ) measures the strength of correlation between variables.
The closer it is to 1, the stronger the correlation.

PLOTS OF SERIAL CORRELATION COEFFICIENTS

Plots of serial correlation coefficients indicate that the 1-year lag is dominant.

Autocorrelations: SUPPLY

```
     Auto- Stand.
Lag  Corr.   Err. -1   -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòòú
  1   .812   .199              .       ó*******.********          16.574   .000
  2   .619   .195              .       ó*******.****              26.679   .000
  3   .402   .190              .       ó********                  31.163   .000
  4   .242   .185               .      ó***** .                   32.884   .000
  5   .161   .179               .      ó***   .                   33.690   .000
  6   .120   .174               .      ó**    .                   34.169   .000
  7   .059   .169               .      ó*     .                   34.292   .000
  8  -.029   .163               .     *ó      .                   34.324   .000
  9  -.093   .157                .   **ó     .                    34.673   .000
 10  -.217   .151                . ****ó     .                    36.736   .000
 11  -.250   .144                .*****ó     .                    39.735   .000
 12  -.305   .138                ******ó     .                    44.637   .000
 13  -.284   .131                *.****ó    .                     49.379   .000
 14  -.273   .123                 *****ó    .                     54.297   .000
 15  -.244   .115                 *****ó    .                     58.798   .000
 16  -.239   .107                 *.***ó   .                      63.843   .000
```

Partial Autocorrelations: SUPPLY

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1   -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòòú
  1   .812   .213             .        ó********.*******
  2  -.119   .213             .      **ó        .
  3  -.190   .213             .    ****ó        .
  4   .023   .213             .        *        .
  5   .111   .213             .        ó**      .
  6   .009   .213             .        *        .
  7  -.151   .213             .     ***ó        .
  8  -.134   .213             .     ***ó        .
  9   .057   .213             .        ó*       .
 10  -.250   .213             .   *****ó        .
 11   .101   .213             .        ó**      .
 12  -.157   .213             .     ***ó        .
 13   .103   .213             .        ó**      .
 14  -.102   .213             .      **ó        .
 15   .000   .213             .        *        .
 16  -.079   .213             .      **ó        .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  21
```

Autocorrelations: Unstandardized Residual -- SUPPLY

```
     Auto- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .408   .199            .       ó*********                  4.189   .041
  2   .160   .195            .       ó***     .                  4.867   .088
  3   .164   .190            .       ó***     .                  5.612   .132
  4  -.105   .185             .    **ó       .                   5.937   .204
  5  -.107   .179             .    **ó       .                   6.296   .278
  6  -.059   .174             .     *ó       .                   6.412   .379
  7  -.033   .169             .     *ó       .                   6.450   .488
  8  -.160   .163             .   ***ó       .                   7.420   .492
  9  -.191   .157              . ****ó      .                    8.905   .446
 10  -.172   .151              .  ***ó      .                   10.202   .423
 11  -.107   .144              .   **ó      .                   10.757   .464
 12   .071   .138              .     ó*     .                   11.025   .527
 13   .031   .131               .    ó*    .                    11.083   .604
 14  -.018   .123               .    *     .                    11.105   .678
 15   .045   .115               .    ó*    .                    11.258   .734
 16  -.008   .107                .   *    .                     11.264   .793
```

Partial Autocorrelations: Unstandardized Residual -- SUPPLY

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .408   .213           .        ó*********.
  2  -.008   .213           .        *         .
  3   .121   .213           .        ó**       .
  4  -.259   .213           .   *****ó         .
  5   .027   .213           .        ó*        .
  6  -.032   .213           .       *ó         .
  7   .079   .213           .        ó**       .
  8  -.241   .213           .   *****ó         .
  9  -.066   .213           .       *ó         .
 10  -.111   .213           .      **ó         .
 11   .115   .213           .        ó**       .
 12   .108   .213           .        ó**       .
 13  -.086   .213           .      **ó         .
 14  -.118   .213           .      **ó         .
 15   .053   .213           .        ó*        .
 16   .014   .213           .        *         .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  21
```

Autocorrelations: SYS_RIDE

```
     Auto- Stand.
Lag  Corr.   Err. -1   -.75   -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .773   .199              .       ó*******.*******           15.026   .000
  2   .621   .195              .       ó*******.****              25.215   .000
  3   .482   .190              .       ó*******.**                31.664   .000
  4   .326   .185               .      ó*******                   34.788   .000
  5   .283   .179               .      ó******.                   37.277   .000
  6   .217   .174               .      ó****  .                   38.831   .000
  7   .120   .169               .      ó**    .                   39.340   .000
  8   .027   .163               .      ó*     .                   39.367   .000
  9  -.052   .157                .    *ó     .                    39.475   .000
 10  -.120   .151                .   **ó     .                    40.108   .000
 11  -.183   .144                . ****ó     .                    41.712   .000
 12  -.247   .138                .*****ó     .                    44.925   .000
 13  -.286   .131                *.****ó    .                     49.735   .000
 14  -.325   .123               **.****ó    .                     56.718   .000
 15  -.331   .115               **.****ó    .                     64.960   .000
 16  -.328   .107               ***.***ó   .                      74.410   .000
```

Partial Autocorrelations: SYS_RIDE

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1   -.75   -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .773   .213             .        ó********.******
  2   .059   .213             .        ó*       .
  3  -.039   .213             .       *ó        .
  4  -.123   .213             .      **ó        .
  5   .159   .213             .        ó***     .
  6  -.039   .213             .       *ó        .
  7  -.134   .213             .     ***ó        .
  8  -.114   .213             .      **ó        .
  9  -.001   .213             .        *        .
 10  -.051   .213             .       *ó        .
 11  -.104   .213             .      **ó        .
 12  -.109   .213             .      **ó        .
 13  -.009   .213             .        *        .
 14  -.062   .213             .       *ó        .
 15  -.016   .213             .        *        .
 16  -.048   .213             .       *ó        .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  21
```

Autocorrelations: Unstandardized Residual -- SYS_RIDE

```
     Auto- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .807   .199              .       ó*******.********          16.373   .000
  2   .502   .195              .       ó*******.**                23.017   .000
  3   .231   .190              .       ó*****  .                  24.504   .000
  4   .016   .185               .      *      .                   24.511   .000
  5  -.124   .179               .    **ó      .                   24.990   .000
  6  -.212   .174               .  ****ó      .                   26.475   .000
  7  -.253   .169               . *****ó      .                   28.735   .000
  8  -.323   .163               .******ó      .                   32.677   .000
  9  -.390   .157              **.*****ó     .                    38.844   .000
 10  -.399   .151              **.*****ó     .                    45.848   .000
 11  -.390   .144              **.*****ó     .                    53.142   .000
 12  -.392   .138              **.*****ó     .                    61.246   .000
 13  -.322   .131                *.****ó    .                     67.329   .000
 14  -.163   .123                 . ***ó    .                     69.090   .000
 15   .017   .115                 .    *    .                     69.111   .000
 16   .168   .107                  .   ó***.                      71.586   .000
```

Partial Autocorrelations: Unstandardized Residual -- SYS_RIDE

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .807   .213             .        ó********.*******
  2  -.429   .213             *********ó        .
  3  -.004   .213             .        *        .
  4  -.122   .213             .      **ó        .
  5  -.008   .213             .        *        .
  6  -.106   .213             .      **ó        .
  7  -.023   .213             .        *        .
  8  -.291   .213             .  ******ó        .
  9  -.043   .213             .       *ó        .
 10  -.043   .213             .       *ó        .
 11  -.169   .213             .     ***ó        .
 12  -.226   .213             .   *****ó        .
 13   .137   .213             .        ó***     .
 14   .050   .213             .        ó*       .
 15   .022   .213             .        *        .
 16  -.015   .213             .        *        .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  21
```

Autocorrelations: SYS_REV

```
     Auto- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .858   .199             .       ó*******.*********          18.495   .000
  2   .720   .195             .       ó*******.******             32.186   .000
  3   .565   .190             .       ó*******.***                41.060   .000
  4   .380   .185              .      ó******.*                   45.306   .000
  5   .190   .179              .      ó****  .                    46.431   .000
  6   .035   .174              .      ó*     .                    46.471   .000
  7  -.069   .169              .     *ó      .                    46.641   .000
  8  -.165   .163              .   ***ó      .                    47.669   .000
  9  -.234   .157               .*****ó     .                     49.890   .000
 10  -.271   .151               .*****ó     .                     53.123   .000
 11  -.286   .144               ******ó     .                     57.050   .000
 12  -.309   .138               ******ó     .                     62.092   .000
 13  -.320   .131               *.****ó    .                      68.085   .000
 14  -.310   .123               *.****ó    .                      74.419   .000
 15  -.278   .115               *.****ó    .                      80.267   .000
 16  -.259   .107                *.***ó   .                       86.162   .000
```

Partial Autocorrelations: SYS_REV

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .858   .213            .        ó********.********
  2  -.058   .213            .       *ó        .
  3  -.146   .213            .     ***ó        .
  4  -.216   .213            .    ****ó        .
  5  -.163   .213            .     ***ó        .
  6  -.011   .213            .        *        .
  7   .086   .213            .        ó**      .
  8  -.072   .213            .       *ó        .
  9  -.066   .213            .       *ó        .
 10  -.043   .213            .       *ó        .
 11  -.021   .213            .        *        .
 12  -.107   .213            .      **ó        .
 13  -.058   .213            .       *ó        .
 14  -.012   .213            .        *        .
 15   .053   .213            .        ó*       .
 16  -.070   .213            .       *ó        .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  21
```

Autocorrelations: Unstandardized Residual -- SYS_REV

```
     Auto- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòú
  1   .807   .199             .       ó*******.********          16.373   .000
  2   .502   .195             .       ó*******.**                23.017   .000
  3   .231   .190             .       ó*****  .                  24.504   .000
  4   .016   .185              .      *      .                   24.511   .000
  5  -.124   .179              .    **ó      .                   24.990   .000
  6  -.212   .174              .  ****ó      .                   26.475   .000
  7  -.253   .169              . *****ó      .                   28.735   .000
  8  -.323   .163              .******ó      .                   32.677   .000
  9  -.390   .157             **.*****ó     .                    38.844   .000
 10  -.399   .151             **.*****ó     .                    45.848   .000
 11  -.390   .144             **.*****ó     .                    53.142   .000
 12  -.392   .138             **.*****ó     .                    61.246   .000
 13  -.322   .131               *.****ó    .                     67.329   .000
 14  -.163   .123                . ***ó    .                     69.090   .000
 15   .017   .115                .    *    .                     69.111   .000
 16   .168   .107                 .   ó***.                      71.586   .000
```

Partial Autocorrelations: Unstandardized Residual -- SYS_REV

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòú
  1   .807   .213            .        ó********.*******
  2  -.429   .213            *********ó        .
  3  -.004   .213            .        *        .
  4  -.122   .213            .      **ó        .
  5  -.008   .213            .        *        .
  6  -.106   .213            .      **ó        .
  7  -.023   .213            .        *        .
  8  -.291   .213            .  ******ó        .
  9  -.043   .213            .       *ó        .
 10  -.043   .213            .       *ó        .
 11  -.169   .213            .     ***ó        .
 12  -.226   .213            .   *****ó        .
 13   .137   .213            .        ó***     .
 14   .050   .213            .        ó*       .
 15   .022   .213            .        *        .
 16  -.015   .213            .        *        .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  21
```

Autocorrelations: Unstandardized Residual -- Eco-Ride

```
     Auto- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .337   .256            .         ó*******  .                 1.731   .188
  2  -.264   .244            .    *****ó         .                 2.900   .235
  3  -.611   .231          ***.********ó        .                   9.879   .020
  4  -.329   .218             . *******ó        .                 12.152   .016
  5   .125   .204              .       ó**     .                  12.526   .028
  6   .404   .189              .       ó********                  17.101   .009
  7   .254   .173               .      ó***** .                   19.273   .007
  8  -.058   .154                .    *ó     .                    19.412   .013
  9  -.183   .134                 .****ó    .                     21.289   .011
 10  -.138   .109                  .***ó   .                      22.884   .011
```

Partial Autocorrelations: Unstandardized Residual -- Eco-Ride

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòôòòòòú
  1   .337   .289          .           ó*******    .
  2  -.425   .289          .  *********ó           .
  3  -.471   .289          .  *********ó           .
  4  -.092   .289          .         **ó           .
  5  -.030   .289          .          *ó           .
  6   .019   .289          .           *           .
  7  -.040   .289          .          *ó           .
  8  -.012   .289          .           *           .
  9   .135   .289          .           ó***        .
 10   .030   .289          .           ó*          .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  11
```

Autocorrelations: Unstandardized Residual -- Eco-Revenue

```
     Auto- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1   Box-Ljung  Prob.
                   ùòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòú
  1   .486   .256            .         ó**********                  3.611   .057
  2  -.037   .244            .        *ó         .                  3.635   .162
  3  -.414   .231             .********ó        .                   6.841   .077
  4  -.548   .218           **.********ó        .                  13.151   .011
  5  -.391   .204              ********ó       .                   16.817   .005
  6  -.028   .189              .      *ó       .                   16.839   .010
  7   .153   .173               .      ó***   .                    17.628   .014
  8   .192   .154                .     ó**** .                     19.178   .014
  9   .164   .134                 .    ó*** .                      20.682   .014
 10   .051   .109                  .   ó*  .                       20.902   .022
```

Partial Autocorrelations:Unstandardized Residual - Eco-Revenue

```
   Pr-Aut- Stand.
Lag  Corr.   Err. -1  -.75  -.5 -.25   0   .25  .5   .75   1
                   ùòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòôòòòòòú
  1   .486   .289          .           ó********** .
  2  -.358   .289          .    *******ó           .
  3  -.324   .289          .     ******ó           .
  4  -.286   .289          .     ******ó           .
  5  -.160   .289          .        ***ó           .
  6   .003   .289          .           *           .
  7  -.229   .289          .      *****ó           .
  8  -.172   .289          .        ***ó           .
  9  -.072   .289          .          *ó           .
 10  -.120   .289          .         **ó           .

Plot Symbols:      Autocorrelations *     Two Standard Error Limits .

Total cases:  22     Computable first lags:  11
```

Appendix 7-6: Granger Causality Test Results

Denver Regional Transportation District

Granger Causality Tests

	Original Statement		Reverse of Statement	
	Reduced Model (RM)	**Full Model (FM)**	**Reduced Model (RM)**	**Full Model (FM)**
Statement	*supply changes do not cause ridership changes*		*ridership changes do not cause supply changes*	
Hypothesis Test	1a	1b	1aR	1bR
dependent variable (**effect**)	$rides_t$	$rides_t$	$supply_t$	$supply_t$
explanatory variable (**cause**)	$rides_{t-1}$	$rides_{t-1}$, $supply_{t-1}$*	$supply_{t-1}$	$supply_{t-1}$, $rides_{t-1}$*
standardized beta weights	0.956	0.782, 0.206,	0.881	0.598, 0.335
Adjusted R-square	0.91	0.918	0.765	0.788
F-statistic	203.015	113.552	66.138	38.126
sum of squared residuals (**SSE**)	3.0221E+14	2.59334E+14	1.55973E+14	1.33474E+14
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	21	21	21	21
k-q	1		1	
SSE(FM) / (k-q)	2.59334E+14		1.33474E+14	
SSE(RM) - SSE(FM) / (k-q)	4.28749E+13		2.24989E+13	
T-k-1	18		18	
SSE(FM) / (T-k-1)	1.44074E+13		7.4152E+12	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	2.975882385		3.034153253	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1} = F_{crit}$	4.41		4.41	
Accept/Reject Hypothesis Statement	Accept		Accept	

* Variable not significant (p-value greater than 5%)

Denver Regional Transportation District

Granger Causality Tests

Statement	Original Statement: Reduced Model (RM)	Original Statement: Full Model (FM)	Reverse of Statement: Reduced Model (RM)	Reverse of Statement: Full Model (FM)
	ridership changes do not cause revenue changes		*revenue changes do not cause ridership changes*	
Hypothesis Test	2a	2b	2aR	2bR
dependent variable (**effect**)	$revenue_t$	$revenue_t$	$rides_t$	$rides_t$
explanatory variable (**cause**)	$revenue_{t-1}$	$revenue_{t-1}$, $rides_{t-1}$*	$rides_{t-1}$	$rides_{t-1}$, $revenue_{t-1}$*
standardized beta weights	0.959	0.935, 0.031	0.956	0.818, 0.177
Adjusted R-square	0.915	0.911	0.91	0.919
F-statistic	217.122	103.375	203.015	113.728
sum of squared residuals (**SSE**)	2.8624E+13	2.84895E+13	3.02209E+14	2.58961E+14
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	21	21	21	21
k-q	1		1	
SSE(FM) / (k-q)	2.84895E+13		2.58961E+14	
SSE(RM) - SSE(FM) / (k-q)	1.34522E+11		4.3248E+13	
T-k-1	18		18	
SSE(FM) / (T-k-1)	1.58275E+12		1.43867E+13	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	0.084992367		3.006106981	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1}$ = F_{crit}	4.41		4.41	
Accept/Reject Hypothesis Statement	Accept		Accept	

* Variable not significant (p-value greater than 5%)

Denver Regional Transportation District

Granger Causality Tests

	Original Statement		Reverse of Statement	
	Reduced Model (RM)	**Full Model (FM)**	**Reduced Model (RM)**	**Full Model (FM)**
Statement Hypothesis	*supply changes do not cause revenue changes*		*revenue changes do not cause supply changes*	
Test	3a	3b	3aR	3bR
dependent variable (**effect**)	$revenue_t$	$revenue_t$	$supply_t$	$supply_t$
explanatory variable (**cause**)	$revenue_{t-1}$	$revenue_{t-1}$, $supply_{t-1}$*	$supply_{t-1}$	$supply_{t-1}$, $revenue_{t-1}$*
standardized beta weights	0.959	0.811, 0.186	0.881	0.663, 0.274
Adjusted R-square	0.915	0.925	0.765	0.783
F-statistic	217.122	123.841	66.138	37.049
sum of squared residuals (**SSE**)	2.8624E+13	2.41004E+13	1.55973E+14	1.36597E+14
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	21	21	21	21
k-q	1		1	
SSE(FM) / (k-q)	2.41004E+13		1.36597E+14	
SSE(RM) - SSE(FM) / (k-q)	4.52361E+12		1.9376E+13	
T-k-1	18		18	
SSE(FM) / (T-k-1)	1.33891E+12		7.5887E+12	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	3.378574674		2.553267277	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1} = F_{crit}$	4.41		4.41	
Accept/Reject Hypothesis Statement	Accept		Accept	

* Variable not significant (p-value greater than 5%)

Denver Regional Transportation District

Granger Causality Tests

	Original Statement		Reverse of Statement	
	Reduced Model (RM)	**Full Model (FM)**	**Reduced Model (RM)**	**Full Model (FM)**
Statement	*ECO ride changes do not cause system ride changes*		*system ride changes do not cause ECO ride changes*	
Hypothesis Test	4a	4b	4aR	4bR
dependent variable (**effect**)	system-rides$_t$	system-rides$_t$	ECO-rides$_t$	ECO-rides$_t$
explanatory variable (**cause**)	system-rides$_{t-1}$	system-rides$_{t-1}$, ECO-ride$_{t-1}$*	ECO-rides$_{t-1}$	ECO-rides$_{t-1}$*, system-rides$_{t-1}$
standardized beta weights	0.983	1.047, -0.076	0.886	0.240, 0.715
Adjusted R-square	0.963	0.948	0.761	0.848
F-statistic	289.341	92.752	32.89	28.943
sum of squared residuals (**SSE**)	2.71263E+13	2.59322E+13	2.77214E+13	1.56669E+13
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	11	11	11	11
k-q	1		1	
SSE(FM) / (k-q)	2.59322E+13		1.56669E+13	
SSE(RM) - SSE(FM) / (k-q)	1.19411E+12		1.20545E+13	
T-k-1	8		8	
SSE(FM) / (T-k-1)	3.24152E+12		1.95836E+12	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	0.368379773		6.155388505	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1} = F_{crit}$	5.32		5.32	
Accept/Reject Hypothesis Statement	Accept		Reject	

* Variable not significant (p-value greater than 5%)

Denver Regional Transportation District

Granger Causality Tests

	Original Statement		**Reverse of Statement**	
	Reduced Model (RM)	**Full Model (FM)**	**Reduced Model (RM)**	**Full Model (FM)**
Statement	*ECO revenue changes do not cause system revenue changes*		*system revenue changes do not cause ECO revenue changes*	
Hypothesis Test	5a	5b	5aR	5bR
dependent variable (**effect**)	sys-revenue$_t$	sys-revenue$_t$	ECO-revenue$_t$	ECO-revenue$_t$
explanatory variable (**cause**)	sys-revenue$_{t-1}$	sys-revenue$_{t-1}$, ECO-revenue$_{t-1}$*	ECO-revenue$_{t-1}$	ECO-revenue$_{t-1}$, sys-revenue$_{t-1}$*
standardized beta weights	0.97	0.763, 0.211	0.984	0.856, 0.133
Adjusted R-square	0.934	0.919	0.964	0.961
F-statistic	156.706	58	269.231	125.078
sum of squared residuals (**SSE**)	1.23394E+13	1.13946E+13	8.81266E+11	8.44266E+11
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	11	11	11	11
k-q	1		1	
SSE(FM) / (k-q)	1.13946E+13		8.44266E+11	
SSE(RM) - SSE(FM) / (k-q)	9.44821E+11		37000185579	
T-k-1	8		8	
SSE(FM) / (T-k-1)	1.42432E+12		1.05533E+11	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	0.66334668		0.35060234	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1} = F_{crit}$	5.32		5.32	
Accept/Reject Hypothesis Statement	Accept		Accept	

* Variable not significant (p-value greater than 5%)

Denver Regional Transportation District

Granger Causality Tests

Statement	Original Statement: Reduced Model (RM)	Original Statement: Full Model (FM)	Reverse of Statement: Reduced Model (RM)	Reverse of Statement: Full Model (FM)
Statement	*ECO ride changes do not cause system revenue changes*		*system revenue changes do not cause ECO ride changes*	
Hypothesis Test	6a	6b	6aR	6bR
dependent variable (**effect**)	system-revenue$_t$	system-revenue$_t$	ECO-rides$_t$	ECO-rides$_t$
explanatory variable (**cause**)	system-revenue$_{t-1}$	syst-revenue$_{t-1}$, ECO-ride$_{t-1}$*	ECO-rides$_{t-1}$	ECO-rides$_{t-1}$*, system-revenue$_{t-1}$*
standardized beta weights	0.97	0.624, 0.371	0.886	0.299, 0.639
Adjusted R-square	0.934	0.942	0.761	0.81
F-statistic	156.706	81.524	32.89	22.304
sum of squared residuals (**SSE**)	1.23394E+13	8.26049E+12	2.77214E+13	1.96215E+13
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	11	11	11	11
k-q	1		1	
SSE(FM) / (k-q)	8.26049E+12		1.96215E+13	
SSE(RM) - SSE(FM) / (k-q)	4.07892E+12		8.0999E+12	
T-k-1	8		8	
SSE(FM) / (T-k-1)	1.03256E+12		2.45268E+12	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	3.950288805		3.302466204	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1} = F_{crit}$	5.32		5.32	
Accept/Reject Hypothesis Statement	Accept		Accept	

* Variable not significant (p-value greater than 5%)

Denver Regional Transportation District

Granger Causality Tests

	Original Statement		Reverse of Statement	
	Reduced Model (RM)	**Full Model (FM)**	**Reduced Model (RM)**	**Full Model (FM)**
Statement	*ECO revenue changes do not cause system ride changes*		*system revenue changes do not cause ECO ride changes*	
Hypothesis Test	7a	7b	7aR	7bR
dependent variable (**effect**)	system-ride$_t$	system-ride$_t$	ECO-revenue$_t$	ECO-revenue$_t$
explanatory variable (**cause**)	system-ride$_{t-1}$	system-ride$_{t-1}$*, ECO-revenue$_{t-1}$*	ECO-revenue$_{t-1}$	ECO-revenue$_{t-1}$*, system-ride$_{t-1}$*
standardized beta weights	0.983	-0.058, 1.048	0.984	0.612, 0.376
Adjusted R-square	0.963	0.975	0.964	0.963
F-statistic	289.341	198.013	269.231	131.861
sum of squared residuals (**SSE**)	2.71263E+13	1.24199E+13	8.81266E+11	8.02113E+11
explanatory variables in RM (**q**)	1	--	1	--
explanatory variables in FM (**k**)	--	2	--	2
number of time series data points (**T**)	11	11	11	11
k-q	1		1	
SSE(FM) / (k-q)	1.24199E+13		8.02113E+11	
SSE(RM) - SSE(FM) / (k-q)	1.47064E+13		79152938258	
T-k-1	8		8	
SSE(FM) / (T-k-1)	1.55248E+12		1.00264E+11	
{SSE(RM) - SSE(FM) / (k-q)}/{SSE(FM) / (T-k-1)} = F_{calc}	9.472807365		0.789444442	
$F_{table\ \alpha=0.5,\ df=q,\ T-k-1} = F_{crit}$	5.32		5.32	
Accept/Reject Hypothesis Statement	Reject		Accept	

* Variable not significant (p-value greater than 5%)

APPENDIX TO CHAPTER 8

Appendix 8-1: Primary Mode from Residence to Central Campus

Primary Mode from Residence to Central Campus (Percentages)

	BEFORE		AFTER	
	1996	1997	1999	2000
Summary				
Walk	42.88%	53.51%	42.31%	51.57%
Auto Drive Alone	8.50%	12.46%	9.13%	11.51%
Transit	9.07%	12.24%	15.37%	21.71%
All Others	39.55%	21.79%	33.19%	15.22%
Details				
Walk	42.88%	53.51%	42.31%	51.57%
Bike	10.42%	13.56%	7.62%	8.66%
Drive Alone	8.50%	12.46%	9.13%	11.51%
Share Ride	3.06%	4.48%	1.19%	1.97%
Motorcycle	0.89%	1.00%	0.51%	0.65%
AC Transit	3.93%	5.65%	8.71%	14.09%
BART	4.94%	6.32%	5.57%	6.32%
Other Transit	0.20%	0.27%	1.09%	1.30%
Shuttles	0.73%	1.17%	1.49%	2.32%
Not enrolled	24.45%	1.58%	22.38%	1.62%
Total	100%	100%	100%	100%

Primary Mode from Residence to Central Campus (Students)

	BEFORE		AFTER	
	1996	1997	1999	2000
Summary				
Walk	12953	16162	13232	16127
Auto Drive Alone	2567	3765	2855	3600
Transit	2740	3698	4806	6789
All Others	11949	6581	10380	4759
Details				
Walk	12953	16162	13232	16127
Bike	3148	4095	2382	2707
Drive Alone	2567	3765	2855	3600
Share Ride	924	1352	373	615
Motorcycle	270	303	160	204
AC Transit	1187	1706	2725	4406
BART	1492	1910	1741	1977
Other Transit	61	82	340	406
Shuttles	222	354	467	726
Not enrolled	7385	477	6998	507
Total	30209	30206	31273	31275

Appendix 8-2: Reasons for Change in Primary Mode

Reasons for Change in Primary Mode from Residence to Central Campus (Between Last Year and This Year)

	1997	Frequency	Valid Percent	Cumulative Percent	
No change in primary mode	0	23600	78.1	78.1	
❑ Change in employment	1	243	0.8	78.9	
❑ Change in residential location	2	3261	10.8	89.7	1
❑ Child care changes	3	49	0.2	89.9	
❑ Increased parking costs	4	159	0.5	90.4	
❑ Increased traffic congestion	5	130	0.4	90.8	
❑ Change in class or work schedule	6	418	1.4	92.2	3
❑ Change in AC Transit routes or service	7	61	0.2	92.4	
❑ Discounted BART, Muni or BART Plus pass	8	37	0.1	92.6	
❑ Student Carpool Program	9	28	0.1	92.6	
❑ Increased transit fares	10	91	0.3	92.9	
❑ Safety factors	11	119	0.4	93.3	
❑ AC Transit Class Pass	12	224	0.7	94.1	
❑ City parking restrictions	13	35	0.1	94.2	
❑ Other	14	1753	5.8	100	2
	Total	30207	100		

	2000	Frequency	Valid Percent	Cumulative Percent	
No change in primary mode	0	19315	61.8	61.8	
❑ Not enrolled at UC Berkeley	1	3589	11.5	73.2	A 1
❑ Change in employment	2	62	0.2	73.4	
❑ Change in residential location	3	3093	9.9	83.3	1
❑ Child care changes	4	9	0	83.4	
❑ Increased parking costs	5	179	0.6	83.9	
❑ Increased traffic congestion	6	178	0.6	84.5	
❑ Change in class or work schedule	7	722	2.3	86.8	
❑ Change in AC Transit routes or service	8	85	0.3	87.1	
❑ Discounted BART, Muni or BART Plus pass	9	87	0.3	87.4	
❑ Student Carpool Program	10				
❑ Increased transit fares	11	19	0.1	87.4	
❑ Safety factors	12	169	0.5	88	
❑ AC Transit Class Pass	13	1130	3.6	91.6	3
❑ City parking restrictions	14	182	0.6	92.1	
❑ Other	15	2456	7.9	100	2
	Total	31274	100		

Appendix 8-3: Distribution of Distances from Residence to Central Campus

Distribution of Distances from Residence to Central Campus

Distance (miles)			1997	Frequency	Percent	Dist x freq	Cum %	
less than		0.5	1	11865	39.3	2966.25	39.3	0.25
0.5	-	0.9	2	5086	16.8	3560.2	56.1	0.70
1.0	-	1.9	3	3480	11.5	5046	67.6	1.45
2.0	-	2.9	4	1664	5.5	4076.8	73.1	2.45
3.0	-	4.9	5	2070	6.9	8176.5	80	3.95
5.0	-	9.9	6	1572	5.2	11711.4	85.2	7.45
10.0	-	19.9	7	1610	5.3	24069.5	90.5	14.95
20.0	-	29.9	8	1032	3.4	25748.4	93.9	24.95
30.0	-	39.9	9	552	1.8	19292.4	95.7	34.95
40.0	-	49.9	10	199	0.7	8945.05	96.4	44.95
50.0		or more	11	311	1	15550	97.4	50.00
		NA	0	765	2.5		99.9	
			Total	30207	100	129142.5	**4.28**	**Avg.**

Distance (miles)			2000	Frequency	Percent	Dist x freq	Cum %		% Change from 1997
less than		0.5	1	7971	25.5	1992.75	25.5	0.25	-35.11%
0.5	-	0.9	2	8485	27.1	5939.5	52.6	0.70	-6.24%
1.0	-	1.9	3	4751	15.2	6888.95	67.8	1.45	0.30%
2.0	-	2.9	4	2169	6.9	5314.05	74.7	2.45	2.19%
3.0	-	4.9	5	1822	5.8	7196.9	80.5	3.95	0.63%
5.0	-	9.9	6	1683	5.4	12538.35	85.9	7.45	0.82%
10.0	-	19.9	7	1375	4.4	20556.25	90.3	14.95	-0.22%
20.0	-	29.9	8	746	2.4	18612.7	92.7	24.95	-1.28%
30.0	-	39.9	9	537	1.7	18768.15	94.4	34.95	-1.36%
40.0	-	49.9	10	182	0.6	8180.9	95	44.95	-1.45%
50.0		or more	11	306	1	15300	96	50.00	-1.44%
		NA	0	1246	4		100		0.10%
			Total	31274	100	121288.5	**3.88**	**Avg.**	-9.29%

Appendix 8-4: Student Travel Distances (Home to Campus) by Primary Mode

Student Travel Distances (Home to Campus) by Primary Mode

	1997	Q3												Total
		0	1	2	3	4	5	6	7	8	9	10	11	
N/A	Distance (miles)		< 0.5	0.5 - 0.9	1.0 - 1.9	2.0 - 2.9	3.0 - 4.9	5.0 - 9.9	10.0 - 19.9	20.0 - 29.9	30.0 - 39.9	40.0 - 49.9	50.0+	
Walk	1		10338	3722	1500	265	70	32	37	17	27	12	5	16025
Auto - driver	2		114	173	377	330	737	871	885	531	229	101	157	4505
Auto passenger	4		30	14	21	25	54	46	36	13	15	10	15	279
Carpool	5				12		37	5	43	29	29			155
Motorcycle	6		63	46	42	42	12	38	44					287
Bicycle	7		967	877	1042	592	436	74	37	7	6			4038
AC Transit	8		43	39	355	324	577	122	89	23		7	12	1591
BART	9		24	29	39	70	119	329	400	392	227	67	86	1782
Campus Shuttle	10		123	123	17			10	15				15	303
LBL or RFS bus	11		12	21	7					3	9			52
Other transit	12		23		38					2			20	83
Not enrolled	13													
	Total		1255	1135	1540	1028	1144	573	585	427	242	74	133	29100

Auto - drive alone		2		53	127	287	261	649	702	715	498	169	75	131	3667
Drive with 1 passenger		3		61	46	90	69	88	169	170	33	60	26	26	838

Student Travel Distances (Home to Campus) by Primary Mode

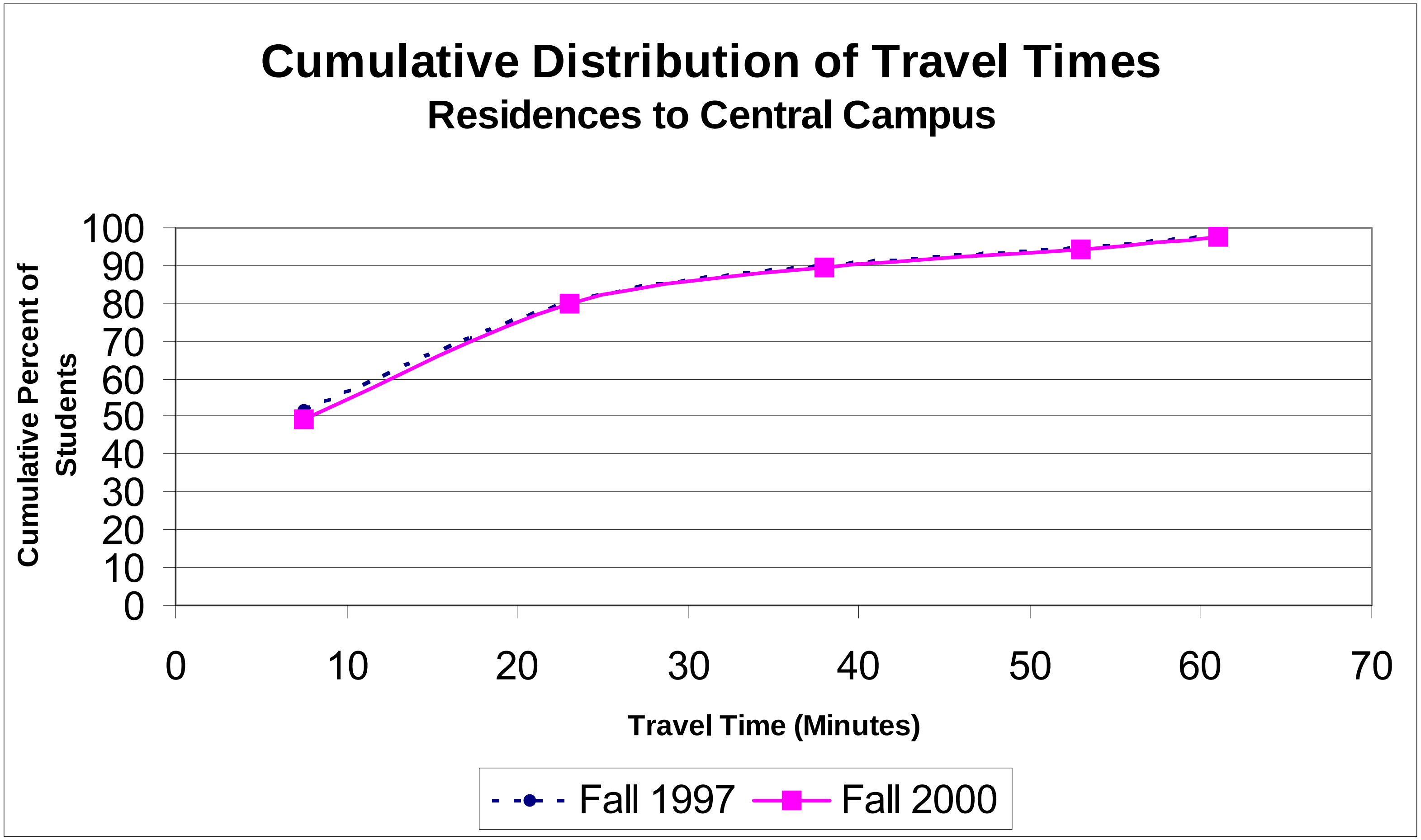
	2000		Q3A												Total
			0	1	2	3	4	5	6	7	8	9	10	11	
N/A		Distance (miles)		< 0.5	0.5 - 0.9	1.0 - 1.9	2.0 - 2.9	3.0 - 4.9	5.0 - 9.9	10.0 - 19.9	20.0 - 29.9	30.0 - 39.9	40.0 - 49.9	50.0+	
Walk		12		6807	6541	1887	254	55	72	35			13	16	15680
Auto - driver		3		172	188	222	271	458	756	637	312	258	88	112	3474
Auto passenger		4		28	29	36	110	88	55	85	22	20			473
Carpool		8		13	15	9	16		11	10	16	16		5	111
Motorcycle		10		6	6	62	50	26	23	11					184
Bicycle		6		417	581	833	542	274	43	5					2695
AC Transit		2		259	630	1232	739	754	289	160	35	18			4116
BART		5		31	110	24	29	80	364	391	343	201	82	132	1787
Campus Shuttle		7		154	204	154	25	19	5	13				10	584
LBL or RFS bus		9		20	8	70	34		9						141
Other transit		11		35	38	87	78	67	16	16	18	19		11	385
Not enrolled		1													
		Total		7942	8350	4616	2148	1821	1643	1363	746	532	183	286	29630

Appendix 8-5: Distribution of Travel Times from Residence to Central Campus

Distribution of Travel Times from Residence to Central Campus

Travel Time (min.)	1997		Frequency	Percent	Time x freq	Cum %	
15.0 or less	Valid	1	15601	51.6	117007.5	51.6	7.5
16.0 - 30.0		2	8702	28.8	200146	80.4	23.0
31 - 45		3	2828	9.4	107464	89.8	38.0
46 - 60		4	1450	4.8	76850	94.6	53.0
61.0 or more		5	1000	3.3	61000	97.9	61.0
N/A		0	626	2.1		100	
		Total	30207	100	562467.5	**18.62**	**Avg.**

Travel Time (min.)	2000		Frequency	Percent	Time x freq	Cum %	
15.0 or less		1	15441	49.4	115807.5	49.4	7.5
16.0 - 30.0		2	9520	30.4	218960	79.8	23.0
31 - 45		3	3029	9.7	115102	89.5	38.0
46 - 60		4	1483	4.7	78599	94.2	53.0
61.0 or more		5	1081	3.5	65941	97.7	61.0
N/A		0	720	2.3		100	
	Valid	Total	31274	100	594409.5	**19.01**	**Avg.**


Cumulative Distribution of Travel Times
Residences to Central Campus
Cumulative Percent of Students
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
Travel Time (Minutes)
Fall 1997
Fall 2000

Appendix 8-6: Distribution of Travel Times by Primary Mode

Student Travel Times (Home to Campus) by Primary Mode

1997		Q25						Total
		0	1	2	3	4	5	
N/A	Travel Time		up to 15 minutes	16 - 30 minutes	31 - 45 minutes	46 - 60 minutes	over 60 minutes	
Walk	1		11377	4110	314	25	45	15871
Auto – driver	2		887	1789	1077	605	257	4615
Auto passenger	4		80	106	30	51	15	282
Carpool	5		42	56	28	31	19	176
Motorcycle	6		159	104	25			288
Bicycle	7		2592	1236	165	31		4024
AC Transit	8		123	712	676	127	42	1680
BART	9		80	304	409	555	554	1902
Campus Shuttle	10		122	120	31	6	15	294
LBL or RFS bus	11		3	28	9		12	52
Other transit	12		48	12			22	82
Not enrolled								
Total			15513	8577	2764	1431	981	29266

Auto - drive alone	2		663	1479	850	550	178	3720
Drive with 1 passenger	3		224	310	227	55	79	895

2000		Q20A						Total
		0	1	2	3	4	5	
N/A	Travel Time		up to 15 minutes	16 - 30 minutes	31 - 45 minutes	46 - 60 minutes	over 60 minutes	
Walk	12		11555	3989	203	57		15804
Auto – driver	3		668	1417	983	253	236	3557
Auto passenger	4		153	172	70	97		492
Carpool	8		37	17	48	16	5	123
Motorcycle	10		137	41	26			204
Bicycle	6		1669	875	102	15		2661
AC Transit	2		669	2104	1038	402	136	4349
BART	5		46	223	388	613	648	1918
Campus Shuttle	7		217	276	43		23	559
LBL or RFS bus	9		16	77	30		5	128
Other transit	11		102	170	51	30	29	382
Not enrolled								
Total			15269	9361	2982	1483	1082	30177

Appendix 8-7: Distribution of Typical Student Arrival and Departure Times

Distribution of Typical Student Arrival and Departure Times (1997)							
Arrival	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
No Response	1151	1262	1210	1266	2468	10898	11257
Before 7:30 am	864	879	911	766	764	193	58
7:30am - 8:29am	6522	7050	6735	6783	5830	356	238
8:30am - 9:29am	8556	7741	8911	7952	7295	1009	661
9:30am - 10:29am	6007	5607	6025	5585	5737	1364	1138
10:30am - 12:59pm	4553	5367	4217	5573	4736	2512	2285
1:00pm - 3:29pm	1417	1323	1405	1258	1515	1762	2231
3:30pm - 4:29pm	221	178	158	205	168	264	281
4:30pm - 5:29pm	43	84	76	95	45	182	202
5:30pm - 7:29pm	117	169	81	188	50	135	219
7:30pm - 10:00pm	26	23	30	57	39	80	196
After 10:00pm		7	16	7	38	94	69
No Trip to Campus	731	516	431	473	1521	11359	11372
Total	30207	30207	30207	30207	30207	30207	30207
Departure	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
No Response	7141	7065	6976	7107	9194	24249	24361
Before 7:30 am							
7:30am - 8:29am	8	44	12	9	8		
8:30am - 9:29am	67	55	43	61	93	12	
9:30am - 10:29am	278	245	284	267	533	38	38
10:30am - 12:59pm	1272	1166	1201	1208	2156	119	83
1:00pm - 3:29pm	3929	2881	4023	3231	4470	382	282
3:30pm - 4:29pm	3602	4277	3560	3913	2934	516	440
4:30pm - 5:29pm	4808	4975	5007	4968	4191	1754	1252
5:30pm - 7:29pm	5283	5622	5186	5584	4161	1314	1191
7:30pm - 10:00pm	2370	2288	2288	2211	1356	789	881
After 10:00pm	1448	1589	1622	1633	1073	893	1583
No Trip to Campus			5	14	38	141	96
Total	30207	30207	30207	30207	30207	30207	30207

Distribution of Typical Student Arrival and Departure Times (1997)							
2-way travel	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
No Response	8292	8327	8186	8373	11662	35147	35618
Before 7:30 am	864	879	911	766	764	193	58
7:30am - 8:29am	6530	7094	6747	6792	5838	356	238
8:30am - 9:29am	8623	7796	8954	8013	7388	1021	661
9:30am - 10:29am	6285	5852	6309	5852	6270	1402	1176
10:30am - 12:59pm	5825	6533	5418	6781	6892	2631	2368
1:00pm - 3:29pm	5346	4204	5428	4489	5985	2144	2513
3:30pm - 4:29pm	3823	4455	3718	4118	3102	780	721
4:30pm - 5:29pm	4851	5059	5083	5063	4236	1936	1454
5:30pm - 7:29pm	5400	5791	5267	5772	4211	1449	1410
7:30pm - 10:00pm	2396	2311	2318	2268	1395	869	1077
After 10:00pm	1448	1596	1638	1640	1111	987	1652
No Trip to Campus	731	516	436	487	1559	11500	11468
Total	60414	60414	60414	60414	60414	60414	60414

Distribution of Typical Student Arrival and Departure Times (2000)							
2-way travel	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
No Trip to Campus	903	1010	989	929	928	343	159
Before 7:30 am	6643	7297	6668	6884	5674	372	285
7:30am - 8:29am	8307	8474	8684	8527	7833	874	629
8:30am - 9:29am	6355	5705	6210	5722	5985	1048	803
9:30am - 10:29am	6408	6661	6069	6828	6499	2252	1936
10:30am - 12:59pm	5559	4491	5288	4165	6515	2004	2268
1:00pm - 3:29pm	4115	4358	4153	4089	3447	890	794
3:30pm - 4:29pm	4029	4948	4251	4866	3555	1232	1054
4:30pm - 5:29pm	5576	5339	5449	5520	3218	1461	1451
5:30pm - 7:29pm	2543	2470	2504	2239	1417	707	986
7:30pm - 10:00pm	1416	1574	1621	1569	1113	835	1425
After 10:00pm	1259	901	1113	1335	3649	17038	16885
Total	53113	53228	52999	52673	49833	29056	28675
No Response	9435	9320	9549	9875	12715	33492	33873
Total	62548	62548	62548	62548	62548	62548	62548

Average Distribution of Arrival & Departure Times					
		Weekdays		Weekends	
Hours of Day		Weekday 1997	Weekday 2000	Weekend 1997	Weekend 2000
Weighted Trips					
Before 7:30 am		837	6633	126	329
7:30am - 8:29am		6600	8365	297	752
8:30am - 9:29am		8155	5995	841	926
9:30am - 10:29am		6114	6493	1289	2094
10:30am - 12:59pm		6290	5204	2500	2136
1:00pm - 3:29pm		5090	4032	2329	842
3:30pm - 4:29pm		3843	4330	751	1143
4:30pm - 5:29pm		4858	5020	1695	1456
5:30pm - 7:29pm		5288	2235	1430	847
7:30pm - 10:00pm		2138	1459	973	1130
After 10:00pm		1487	1651	1320	16962
Average Daily		50700	51417	13548	28615
Percentages					
Before 7:30 am		1.65%	12.90%	0.93%	1.15%
7:30am - 8:29am		13.02%	16.27%	2.19%	2.63%
8:30am - 9:29am		16.08%	11.66%	6.21%	3.23%
9:30am - 10:29am		12.06%	12.63%	9.51%	7.32%
10:30am - 12:59pm		12.41%	10.12%	18.45%	7.46%
1:00pm - 3:29pm		10.04%	7.84%	17.19%	2.94%
3:30pm - 4:29pm		7.58%	8.42%	5.54%	3.99%
4:30pm - 5:29pm		9.58%	9.76%	12.51%	5.09%
5:30pm - 7:29pm		10.43%	4.35%	10.55%	2.96%
7:30pm - 10:00pm		4.22%	2.84%	7.18%	3.95%
After 10:00pm		2.93%	3.21%	9.74%	59.28%
Average Daily		100.00%	100.00%	100.00%	100.00%

1997	Distribution of Typical Student Arrival and Departure Times							
Period of Day	**Hours of Day**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
AM Peak	Before 8:30 a.m.	7394	7973	7658	7558	6602	549	296
Midday	8:30 a.m. – 3:30 p.m.	26079	24385	26109	25135	26535	7198	6718
PM Peak	3:30 p.m. – 7:30 p.m.	14074	15305	14068	14953	11549	4165	3585
Evening	After 7:30 p.m.	3844	3907	3956	3908	2506	1856	2729
	Total to/from Campus	51391	51570	51791	51554	47192	13768	13328
AM Peak	Before 8:30 a.m.	14.39%	15.46%	14.79%	14.66%	13.99%	3.99%	2.22%
Midday	8:30 a.m. – 3:30 p.m.	50.75%	47.29%	50.41%	48.75%	56.23%	52.28%	50.41%
PM Peak	3:30 p.m. – 7:30 p.m.	27.39%	29.68%	27.16%	29.00%	24.47%	30.25%	26.90%
Evening	After 7:30 p.m.	7.48%	7.58%	7.64%	7.58%	5.31%	13.48%	20.48%
	Total to/from Campus	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

2000	Distribution of Typical Student Arrival and Departure Times							
Period of Day	**Hours of Day**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
AM Peak	Before 8:30 a.m.	14950	15771	15352	15411	13507	1246	914
Midday	8:30 a.m. – 3:30 p.m.	22437	21215	21720	20804	22446	6194	5801
PM Peak	3:30 p.m. – 7:30 p.m.	12148	12757	12204	12625	8190	3400	3491
Evening	After 7:30 p.m.	2675	2475	2734	2904	4762	17873	18310
	Total to/from Campus	52210	52218	52010	51744	48905	28713	28516
AM Peak	Before 8:30 a.m.	28.63%	30.20%	29.52%	29.78%	27.62%	4.34%	3.21%
Midday	8:30 a.m. – 3:30 p.m.	42.97%	40.63%	41.76%	40.21%	45.90%	21.57%	20.34%
PM Peak	3:30 p.m. – 7:30 p.m.	23.27%	24.43%	23.46%	24.40%	16.75%	11.84%	12.24%
Evening	After 7:30 p.m.	5.12%	4.74%	5.26%	5.61%	9.74%	62.25%	64.21%
	Total to/from Campus	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Averages of the Distribution of Arrival & Departure Times					
		Weekdays		Weekends	
Period of Day	**Hours of Day**	**1997**	**2000**	**1997**	**2000**
AM Peak	Before 8:30 a.m.	7437	**14998**	423	1080
Midday	8:30 a.m. – 3:30 p.m.	25649	21724	6958	5998
PM Peak	3:30 p.m. – 7:30 p.m.	13990	11585	3875	3446
Evening	After 7:30 p.m.	3624	3110	2293	**18092**
	Total to/from Campus	50700	51417	13548	28615
AM Peak	Before 8:30 a.m.	14.67%	**29.17%**	3.12%	3.77%
Midday	8:30 a.m. – 3:30 p.m.	50.59%	42.25%	51.36%	20.96%
PM Peak	3:30 p.m. – 7:30 p.m.	27.59%	22.53%	28.60%	12.04%
Evening	After 7:30 p.m.	7.15%	6.05%	16.92%	**63.22%**
	Total to/from Campus	100.00%	100.00%	100.00%	100.00%

Appendix 8-8: Test of "Before" and "After" Proportions

Test of Proportions[1]

For a pair of samples, say one for "before" and the other for "after" conditions; let

P_{s1} = proportional attribute of sample 1

P_{s2} = proportional attribute of sample 2

N_1 = size of sample 1

N_2 = size of sample 2

P_u = the population proportion

σ_{p-p} = the standard deviation of the sampling distribution of the differences in sample proportions

The null hypothesis is that there is no difference between the pair of proportions, that is:

Ho: $P_{u1} = P_{u2}$ (say, P_{u1} for "before" and P_{u2} for "after" conditions)

1. Estimate the population proportion as the weighted average of the two samples:

$$P_u = \frac{N_1 P_{s1} + N_2 P_{s2}}{N_1 + N_2}$$

2. Estimate the standard deviation of the sampling distribution

$$\sigma_{p-p} = \sqrt{\{P_u(1 - P_u)\}}\ \sqrt{\{(N_1 + N_2) / (N_1 N_2)\}}$$

3. Calculate the test statistic, Z:

$$Z_{calc} = \frac{P_{s1} - P_{s2}}{\sigma_{p-p}}$$

Reject the null hypothesis if Z_{calc} is greater than ±1.96 corresponding to the alpha level of 0.05. Rejection means there is a statistically significant difference between the two proportional attributes.

[1] Joseph F. Healey, Statistics: A Tool for Social Research, 5th Ed., Wadsworth Publishing Company, 1999, pp 213-217.

Choice of Travel Mode Before & After Introduction of the UCB ClassPass Program

Test of Proportions

INPUT:

0.056	=	P_{s1}	proportional attribute of sample 1 (BEFORE)
0.141	=	P_{s2}	proportional attribute of sample 2 (AFTER)
3357	=	N_1	size of sample 1
3008	=	N_2	size of sample 2
0.0962	=	P_u	the population proportion
0.0074	=	$\sigma_{p\text{-}p}$	standard deviation of the sampling distribution of the differences in sample proportions

Estimate the population proportion as the weighted average of the two samples

0.0962 = P_u $(N_1P_{s1} + N_2P_{s2}) / (N_1 + N_2)$

Estimate the standard deviation of the sampling distribution

0.0074 = $\sigma_{p\text{-}p}$ $\sqrt{\{P_u(1 - P_u)\}}\ \sqrt{\{(N_1 + N_2) / (N_1N_2)\}}$

Calculate the test statistic, Z:

-11.4834 = Z_{calc} $(P_{s1} - P_{s2}) \;/ (\sigma_{p\text{-}p})$

		Walk	**Auto Drive Alone**	**All Transit**	**AC Transit**	**BART**	**Other Transit**
INPUT:							
P_{s1}	=	53.50%	12.50%	12.20%	5.60%	6.30%	0.30%
P_{s2}	=	51.60%	11.50%	21.70%	14.10%	6.30%	1.30%
N_1	=	3357	3357	3357	3357	3357	3357
N_2	=	3008	3008	3008	3008	3008	3008
P_u	=	**0.5260**	**0.1203**	**0.1669**	**0.0962**	**0.0630**	**0.0077**
$\sigma_{p\text{-}p}$	=	**0.0125**	**0.0082**	**0.0094**	**0.0074**	**0.0061**	**0.0022**
CALCULATE:							
P_u	=	**0.5260**	**0.1203**	**0.1669**	**0.0962**	**0.0630**	**0.0077**
$\sigma_{p\text{-}p}$	=	**0.0125**	**0.0082**	**0.0094**	**0.0074**	**0.0061**	**0.0022**
Z_{calc}	=	**1.5156**	**1.2245**	**-10.1477**	**-11.4834**	**0.0000**	**-4.5491**
RESULTS:							
Z_{calc} within critical region ±1.96		Y	Y	N	N	Y	N
Reject null hypothesis: $P_{s1}=P_{s2}$?		N	N	Y	Y	N	Y
Stat. significant difference?		N	N	Y	Y	N	Y

Distribution of Travel Distances Before & After the UCB ClassPass Program

Test of Proportions

INPUT:

0.393	=	P_{s1}	proportional attribute of sample 1 (BEFORE)
0.255	=	P_{s2}	proportional attribute of sample 2 (AFTER)
3357	=	N_1	size of sample 1
3008	=	N_2	size of sample 2
0.3278	=	P_u	the population proportion
0.0118	=	σ_{p-p}	standard deviation of the sampling distribution of the differences in sample proportions

Estimate the population proportion as the weighted average of the two samples

0.3278 = P_u $(N_1P_{s1} + N_2P_{s2}) / (N_1 + N_2)$

Estimate the standard deviation of the sampling distribution

0.0118 = σ_{p-p} $\sqrt{\{P_u(1 - P_u)\}}\ \sqrt{\{(N_1 + N_2) / (N_1N_2)\}}$

Calculate the test statistic, Z:

11.7097 = Z_{calc} $(P_{s1} - P_{s2})$ $/(\sigma_{p-p})$

INPUT:		**Within 0.5 mile**	**Within 1.0 mile**	**Within 2.0 miles**	**Within 5.0 miles**
P_{s1}	=	39.30%	56.10%	67.60%	80.00%
P_{s2}	=	25.50%	52.60%	67.80%	80.50%
N_1	=	3357	3357	3357	3357
N_2	=	3008	3008	3008	3008
P_u	=	**0.3278**	**0.5445**	**0.6769**	**0.8024**
σ_{p-p}	=	**0.0118**	**0.0125**	**0.0117**	**0.0100**
CALCULATE:					
P_u	=	**0.3278**	**0.5445**	**0.6769**	**0.8024**
σ_{p-p}	=	**0.0118**	**0.0125**	**0.0117**	**0.0100**
Z_{calc}	=	**11.7097**	**2.7992**	**-0.1703**	**-0.5001**
RESULTS:					
Z_{calc} within critical region ± 1.96		N	N	Y	Y
Reject null hypothesis: $P_{s1}=P_{s2}$?		Y	Y	N	N
Stat. significant difference?		Y	Y	N	N

Distribution of Travel Times Before & After the UCB ClassPass Program

Test of Proportions

INPUT:

0.516	=	P_{s1}	proportional attribute of sample 1 (BEFORE)
0.494	=	P_{s2}	proportional attribute of sample 2 (AFTER)
3357	=	N_1	size of sample 1
3008	=	N_2	size of sample 2
0.5056	=	P_u	the population proportion
0.0126	=	σ_{p-p}	standard deviation of the sampling distribution of the differences in sample proportions

Estimate the population proportion as the weighted average of the two samples

0.5056 = P_u $(N_1P_{s1} + N_2P_{s2}) / (N_1 + N_2)$

Estimate the standard deviation of the sampling distribution

0.0126 = σ_{p-p} $\sqrt{\{P_u(1 - P_u)\}}\ \sqrt{\{(N_1 + N_2) / (N_1N_2)\}}$

Calculate the test statistic, Z:

1.7527 = Z_{calc} $(P_{s1} - P_{s2})$ $/(\sigma_{p-p})$

INPUT:		**Within 15 minutes**	**16 to 30 minutes**	**31 to 45 minutes**	**46 to 60 minutes**	**Over 60 minutes**
P_{s1}	=	51.60%	28.80%	9.40%	4.80%	3.30%
P_{s2}	=	49.40%	30.40%	9.70%	4.70%	3.50%
N_1	=	3357	3357	3357	3357	3357
N_2	=	3008	3008	3008	3008	3008
P_u	=	**0.5056**	**0.2956**	**0.0954**	**0.0475**	**0.0339**
σ_{p-p}	=	**0.0126**	**0.0115**	**0.0074**	**0.0053**	**0.0045**
CALCULATE:						
P_u	=	**0.5056**	**0.2956**	**0.0954**	**0.0475**	**0.0339**
σ_{p-p}	=	**0.0126**	**0.0115**	**0.0074**	**0.0053**	**0.0045**
Z_{calc}	=	**1.7527**	**-1.3967**	**-0.4067**	**0.1872**	**-0.4399**
RESULTS:						
Z_{calc} within critical region ±1.96		Y	Y	Y	Y	Y
Reject null hypothesis: $P_{s1}=P_{s2}$?		N	N	N	N	N
Stat. significant difference?		N	N	N	N	N

Distribution of Weekday Travel Periods Before & After the UCB ClassPass Program

Test of Proportions

INPUT:

0.1467	=	P_{s1}	proportional attribute of sample 1 (BEFORE)
0.2917	=	P_{s2}	proportional attribute of sample 2 (AFTER)
3357	=	N_1	size of sample 1
3008	=	N_2	size of sample 2
0.2152	=	P_u	the population proportion
0.0103	=	$\sigma_{p\text{-}p}$	standard deviation of the sampling distribution of the differences in sample proportions

Estimate the population proportion as the weighted average of the two samples

0.2152 = P_u $(N_1 P_{s1} + N_2 P_{s2}) / (N_1 + N_2)$

Estimate the standard deviation of the sampling distribution

0.0103 = $\sigma_{p\text{-}p}$ $\sqrt{\{P_u(1 - P_u)\}}\ \sqrt{\{(N_1 + N_2) / (N_1 N_2)\}}$

Calculate the test statistic, Z:

-14.0529 = Z_{calc} $(P_{s1} - P_{s2})$ $/(\sigma_{p\text{-}p})$

INPUT:		**Before 8:30 a.m.**	**8:30 a.m. – 3:30 p.m.**	**3:30 p.m. – 7:30 p.m.**	**After 7:30 p.m.**
P_{s1}	=	14.67%	50.59%	27.59%	7.15%
P_{s2}	=	29.17%	42.25%	22.53%	6.05%
N_1	=	3357	3357	3357	3357
N_2	=	3008	3008	3008	3008
P_u	=	**0.2152**	**0.4665**	**0.2520**	**0.0663**
$\sigma_{p\text{-}p}$	=	**0.0103**	**0.0125**	**0.0109**	**0.0062**
CALCULATE:					
P_u	=	**0.2152**	**0.4665**	**0.2520**	**0.0663**
$\sigma_{p\text{-}p}$	=	**0.0103**	**0.0125**	**0.0109**	**0.0062**
Z_{calc}	=	**-14.0538**	**6.6573**	**4.6444**	**1.7609**
RESULTS:					
Z_{calc} within critical region ±1.96		N	N	N	Y
Reject null hypothesis: $P_{s1}=P_{s2}$?		Y	Y	Y	N
Stat. significant difference?		Y	Y	Y	N

Distribution of Weekend Travel Periods Before & After the UCB ClassPass Program

Test of Proportions

INPUT:

0.0312	=	P_{s1}	proportional attribute of sample 1 (BEFORE)
0.0377	=	P_{s2}	proportional attribute of sample 2 (AFTER)
3357	=	N_1	size of sample 1
3008	=	N_2	size of sample 2
0.0343	=	P_u	the population proportion
0.0046	=	$\sigma_{p\text{-}p}$	standard deviation of the sampling distribution of the differences in sample proportions

Estimate the population proportion as the weighted average of the two samples

0.0343 = P_u $(N_1P_{s1} + N_2P_{s2}) / (N_1 + N_2)$

Estimate the standard deviation of the sampling distribution

0.0046 = $\sigma_{p\text{-}p}$ $\sqrt{\{P_u(1 - P_u)\}}\ \sqrt{\{(N_1 + N_2) / (N_1N_2)\}}$

Calculate the test statistic, Z:

-1.4231 = Z_{calc} $(P_{s1} - P_{s2})$ $/(\sigma_{p\text{-}p})$

INPUT:		**Before 8:30 a.m.**	**8:30 a.m. – 3:30 p.m.**	**3:30 p.m. – 7:30 p.m.**	**After 7:30 p.m.**
P_{s1}	=	3.12%	51.36%	28.60%	16.92%
P_{s2}	=	3.77%	20.96%	12.04%	63.22%
N_1	=	3357	3357	3357	3357
N_2	=	3008	3008	3008	3008
P_u	=	**0.0343**	**0.3699**	**0.2078**	**0.3880**
$\sigma_{p\text{-}p}$	=	**0.0046**	**0.0121**	**0.0102**	**0.0122**
CALCULATE:					
P_u	=	**0.0343**	**0.3699**	**0.2078**	**0.3880**
$\sigma_{p\text{-}p}$	=	**0.0046**	**0.0121**	**0.0102**	**0.0122**
Z_{calc}	=	**-1.4355**	**25.0793**	**16.2590**	**-37.8470**
RESULTS:					
Z_{calc} within critical region ±1.96		Y	N	N	N
Reject null hypothesis: P_{s1}=P_{s2}?		N	Y	Y	Y
Stat. significant difference?		N	Y	Y	Y

APPENDIX TO CHAPTER 9

Appendix 9-1: Monthly Averages

City of Berkeley ECO Pass

Magnetic Dip Data Tracking (Jan - Nov, 2002)

		Monthly Average	**Stan Dev**	**Variance**	**Min**	**Max**
	Passes Used	*194*	12.7	160.5	173	208
	Total Monthly	*3094*	246.4	60723.2	2670	3394
	Avg Weekday	*125*	8.8	77.5	112	138
Total Boardings	**Avg Weekend Day**	*44*	4.7	22.3	35	50
Frequency Ranges of Riders	**1 - 10 times**	*108*	11.3	127.7	91	124
	11 - 20 times	*34*	3.8	14.3	27	40
	21 - 40 times	*33*	4.8	23.1	27	43
	>40 times	*20*	4.0	16.4	12	25
Top 5 bus boardings by time of day	**AM Pk (6a-10a)**	*558*	52.9	2796.2	468	639
	MD (10a-3p)	*463*	31.4	989.1	416	514
	PM Pk (3p-7p)	*600*	53.4	2853.1	524	686
	Eve (7p-12mn)	*149*	12.0	143.5	132	165
	Revenue per boarding	*$2.15*	$0.16	0.02	2.01	2.47

Frequency of Riders by Number of Days (2002)

	Number of Riders			**Mean**	**Median**	**Mode**	**St-Dev**
1 day		23		23			
2 days	70	82	80	74	75		
	64						
3 days	103	89		96	96		
4 days	114	105		110	110		
5 days	93	113	119	116	119		
	128	129					
6 days	130	120	120	123	120		
7 days	118	114	111	**127**	**128**	**135**	**8**
	118	117	131				
	135	124	124				
	133	131	129				
	133	135	142				
	134	133	135				
	117	124	119				
	122	133	125				
	126	119	126				
	131	136	142				
	136	135	122				
	139	121	122				
	132	118					

Appendix 9-2: Monthly Data

City of Berkeley ECO Pass
Magnetic Dip Data Tracking (Jan - Nov, 2002)

		Jan	Feb	Mar	Apr	May	Jun
	Passes Used	173	176	185	204	203	190
Total Boardings	**Total Monthly**	2,848	2,670	3,257	3,260	3,290	2,950
	Avg Weekday	113	119	133	132	127	124
	Avg Weekend Day	35	36	47	43	45	48
Frequency Ranges of Riders	**1 - 10 times**	--	93	91	111	108	102
	11 - 20 times	--	35	40	34	36	35
	21 - 40 times	--	36	30	28	43	36
	>40 times	--	12	24	21	16	17
Top 5 bus boardings by time of day	**AM Pk (6a-10a)**	510	479	570	594	601	557
	MD (10a-3p)	439	416	500	500	467	454
	PM Pk (3p-7p)	571	524	598	629	628	540
	Eve (7p-12mn)	143	165	147	165	161	152
	Revenue per boarding	$2.32	$2.47	$2.03	$2.03	$2.01	$2.24

		Jul	Aug	Sep	Oct	Nov
	Passes Used	207	204	198	208	185
Total Boardings	**Total Monthly**	2,945	3,267	3,312	3,394	2,841
	Avg Weekday	112	128	138	132	116
	Avg Weekend Day	46	50	46	46	46
Frequency Ranges of Riders	**1 - 10 times**	124	118	105	123	107
	11 - 20 times	36	31	37	30	27
	21 - 40 times	27	31	35	30	31
	>40 times	19	24	20	25	20
Top 5 bus boardings by time of day	**AM Pk (6a-10a)**	554	593	573	639	468
	MD (10a-3p)	434	514	435	469	466
	PM Pk (3p-7p)	589	612	686	676	543
	Eve (7p-12mn)	141	159	140	132	135
	Revenue per boarding	$2.24	$2.24	$2.03	$2.03	$2.03

Appendix 9-3: Test of AC Transit Choice Proportions

Change in Choice of AC Transit due to City of Berkeley ECO Pass

Test of Proportions

INPUT:

0.062	=	P_{s1}	proportional attribute of sample 1 (BEFORE)
0.107	=	P_{s2}	proportional attribute of sample 2 (AFTER)
428	=	N_1	size of sample 1
703	=	N_2	size of sample 2
0.089971	=	P_u	the population proportion
0.017543	=	σ_{p-p}	the standard deviation of the sampling distribution of the differences in sample proportions

Estimate the population proportion as the weighted average of the two samples

0.089971 = P_u $\quad (N_1 P_{s1} + N_2 P_{s2}) / (N_1 + N_2)$

Estimate the standard deviation of the sampling distribution

0.017543 = σ_{p-p} $\quad \sqrt{\{P_u(1 - P_u)\}} \sqrt{\{(N_1 + N_2) / (N_1 N_2)\}}$

Calculate the test statistic, Z:

-2.56509 = Z_{calc} $\quad (P_{s1} - P_{s2}) \quad /(\sigma_{p-p})$

Reject the null hypothesis if Z_{calc} is greater than ±1.96
corresponding to the alpha level of 0.05.
significant difference between the two proportional attributes ?

RESULT:

Z_{calc} is outside the critical region at alpha level of 0.05
Reject the null hypothesis
Statistically significant difference between "before" and "after" proportions

APPENDIX TO CHAPTER 10

Appendix 10-1: The Federal Law on Employer-Provided Transit Benefits

Federal laws (**Internal Revenue Code 132(f)**), provide significant tax savings to both employers and employees for the use of public transit. By the simplest interpretation, the laws allow employers the flexibility to do any of the following:

An employee benefit ~ each employee can receive up to $100 a month ($1200 a year) as a tax-free benefit toward the purchase of public transit tickets. Such a benefit is a fully deductible business expense at the federal level, which means an employer pays less than the full face value. Assuming a 30 percent company tax rate, for instance, a $35 voucher would cost about $24 after tax deductions. Issued as a voucher, a commuter check, or other instrument for purchase of transit services, it is a tax-free employee benefit that avoids all payroll-related taxes. For example, the after-tax value of a $35 transit voucher would require a raise of more than $55, which would cost the employer $60 when all payroll taxes are included.

A pre-tax salary deduction ~ employees can ask their employers to withhold up to $100 a month ($1200 a year) of their pre-tax salary to purchase public transit tickets. When transit services are purchased with employees' pre-tax salary, employers save money from reduced payroll taxes, which include employer-paid FICA, unemployment, workers compensation, disability, pension and other payroll-driven costs that amount to approximately 10 percent of the salary. Employees can save approximately 40 percent of their commuting costs by avoiding federal and state income taxes and employee-paid FICA. For example, if an employee's gross salary is reduced by $35 a month for buying a transit voucher, the employee's take-home pay is reduced only $21 resulting in a $14 saving in taxes.

A combination of benefit and deduction ~ employers may offer a combination of both tax-free benefit and pre-tax deduction to a combined total of $100 a month ($1200 a year). For example, an employer can provide $50 as an employee benefit and the employee can request an additional $50 from pre-tax salary.

It is apparent that irrespective of how the employer-sponsored transit benefit is issued, it is likely to yield benefits for and from both employers and employees. With its administration, employers can enhance compensation packages, save costs of employee parking, help reduce traffic congestion, enhance company image and improve employee morale. By riding transit, employees can reduce the stress of driving and lessen air pollution.

In the San Francisco Bay Area, for instance, over 3,200 employers of all sizes have enrolled in the "Commuter Check" program. "Commuter Check" is a special voucher used to purchase Bay Area transit tickets or pay for qualified vanpool costs. It comes in six denominations: \$20, \$25, \$30, \$35, \$45 and \$50. A 1994 survey of Bay Area employees receiving Commuter Checks found that about a third (31 percent) of the recipients increased their use of transit. The survey also showed that a large majority (79 percent) of respondents noted improved opinions of their employer as a result of receiving Commuter Checks, a third (35 percent) noted reduced stress from not driving to work or driving less often, and a third (33 percent) said job satisfaction had improved. Improvements in on-time arrival and productivity were also noted.[71]

APPENDIX TO CHAPTER 11

Appendix 11-1: Annual ECO Pass Prices and Multipliers – Denver RTD

Eco Pass Pricing 2003 -- Denver RTD

EMPLOYEES	Service Level Area (SLA)			
	A	B	C	D
	Suburban	CBD Fringe	Downtown	Airport
ECO Pass Price (per employee/per year)				
1 - 24	$44	$95	$242	$247
25 - 249	$39	$85	$225	$236
250-999	$34	$78	$213	$219
1,000 - 1,999	$29	$73	$208	$213
2,000+	$27	$69	$197	$202
ECO Pass Price as % of Annual Monthly Regular Pass				
1 - 24	10.5%	22.6%	57.6%	58.8%
25 - 249	9.3%	20.2%	53.6%	56.2%
250-999	8.1%	18.6%	50.7%	52.1%
1,000 - 1,999	6.9%	17.4%	49.5%	50.7%
2,000+	6.4%	16.4%	46.9%	48.1%
Mean	*8.2%*	*19.0%*	*51.7%*	*53.2%*
Area Multiplier Implicit in ECO Pass Price				
1 - 24	1.0	2.2	5.5	5.6
25 - 249	1.0	2.2	5.8	6.1
250-999	1.0	2.3	6.3	6.4
1,000 - 1,999	1.0	2.5	7.2	7.3
2,000+	1.0	2.6	7.3	7.5
Mean	*1.0*	*2.3*	*6.4*	*6.6*
ECO Pass Contract Minima				
1 - 10	$420	$900	$1,260	$1,260
11 - 20	$840	$1,800	$2,520	$2,520
21 +	$1,260	$2,700	$3,780	$3,780

Notes:

1. Employees added during the year are pro-rated based upon the above pricing
2. Regular Bus & LRT fares: $1.15 base per trip; $35 per month; $420 per year
3. Definitions of Service Level Area (SLA):

A ~ Outer suburban and major employment centers outside CBD*

B ~ Downtown Boulder CBD* and fringe Denver CBD*

C ~ Downtown Denver CBD*

D ~ Denver International Airport (DIA) and home businesses

*CBD = Central Business District

Appendix 11-2: AC Transit Operating Costs & Revenues

AC Transit -- Recent (2000) Unit Operating Costs[1]

Operating Expenses (Dollars in 000's)

Vehicle Operating Cost	Vehicle Mtnce Cost	Non-Veh Mtnce Cost	General Admin Cost	Total Operating Cost
α	β	χ	δ	ε
$103,283.43	$37,564.74	$3,880.48	$33,690.92	$178,419.56

Service Supply

Revenue Vehicle Miles[2]

Vehicles in Max Service	Annual Veh Revenue Mls per Max Svc Veh	Total Veh Revenue Mls	Vehicle Operating Cost per Rev Ml	Vehicle Mtnce Cost per Rev Ml	Non-Veh Mtnce Cost per Rev Ml	General Admin Cost per Rev Ml	Total Operating Cost per Rev Ml
1	2	$3 = 1 * 2$	$\alpha / 3$	$\beta / 3$	$\chi / 3$	$\delta / 3$	$\varepsilon / 3$
606	35,150	21,300,898	$4.85	$1.76	$0.18	$1.58	$8.38

Revenue Vehicle Hours[3]

Vehicles in Max Service	Annual Veh Revenue Hrs per Max Svc Veh	Total Veh Revenue Hrs	Vehicle Operating Cost per Rev Hr	Vehicle Mtnce Cost per Rev Hr	Non-Veh Mtnce Cost per Rev Hr	General Admin Cost per Rev Hr	Total Operating Cost per Rev Hr
4	5	$6 = 4 * 5$	$\alpha / 6$	$\beta / 6$	$\chi / 6$	$\delta / 6$	$\varepsilon / 6$
606	2,970.68	1,800,234	$57.37	$20.87	$2.16	$18.71	$99.11

Annual Vehicle Revenue Miles per Vehicle Revenue Hour = 11.8

[1] All data for publicly operated transit service; privately operated, purchased transportation excluded

[2] Source: Table 30, FTA Section 15 Data, National Transit Database

[3] Source: Table 11, FTA Section 15 Data, National Transit Database

Fare Revenue

	2000	1999	1998
Fare Revenues Earned			
Directly Operated	$44,183,065	$40,371,863	
Purchased Transportation	$1,141,229	1,049,029	
Total Fare Revenues Earned	$45,324,294	$41,420,892	$45,230,439
Annual Unlinked Trips	67,632,612	65,897,176	65,667,960
Revenue per boarding	***$0.67***	***$0.63***	***$0.69***

Appendix 11-3: Program-Specific Operating Costs – Example Application

Program-Specific Operating Costs						
unit cost per revenue vehicle mile			$TOC_{um} = SOE_a / vrm_a$		**$8.38**	
unit cost per revenue vehicle hour			$TOC_{uh} = SOE_a / vrh_a$		**$99.11**	
Route Extensions			$L_r = m_d * r_m$	$* TOC_{um}$		
additional directional miles of service ($\mathbf{m_d}$),					0.25	
number of service runs affected per month ($\mathbf{r_m}$)					1512	
operating costs per revenue mile ($\mathbf{TOC_{um}}$)					$8.38	
monthly program cost due to route extensions ($\mathbf{L_x}$),						**$3,166**
Increase in service runs			$L_f = r * h_m$	$* TOC_{uh}$		
additional directional runs of service (**r**)					8	
average directional run time in hours per month ($\mathbf{h_m}$)					0.5	
operating costs per revenue hour ($\mathbf{TOC_{uh}}$)					$99.11	
monthly program cost due to increased service runs ($\mathbf{L_f}$)						**$396**
Additional "tripper" operators			$L_t = t_{nd} * t_{cd}$	$* t_m$		
additional tripper operators per day ($\mathbf{t_{nd}}$),					1	
the average unit tripper cost per day ($\mathbf{t_{cd}}$)					60	
number of tripper service days per month ($\mathbf{t_m}$)					22	
monthly program cost of tripper operators ($\mathbf{L_t}$),						**$1,320**
Guaranteed rides home (GRH)			$E(L_g) = \Sigma_N\ P_g * X_g$			
probability of service use a month ($\mathbf{P_g}$)					0.0075188	
average cost of GRH per month ($\mathbf{X_g}$)					$300	
probability of "no use" a month					0.9924812	
monthly cost of GRH service per participant ($\mathbf{L_g}$)						**$2.26**
Production cost of pass instrument						
	$5 to $6 per participant per year					
monthly cost of the pass instrument per participant ($\mathbf{P_p}$)						**$0.50**
Administrative assistance						
	1% to 3% of program costs					
multiplier for additional administrative assistance ($\mathbf{Aa_c}$)						**1.03**

Appendix 11-4: Example Applications of Alternative Objective Functions

Linear Program #1: Maximize Net Revenue

Cost Factors	**Optimization**
Number of participants	1330
Location and accessibility multiplier	1
	0
Decision Variables	
P_g = base monthly unit pass cost [default = 1]	\$2.68
Revenue increase target [default =0]	1.53
Maximum number of participants	1330
Obj Func: max $I_n = I_c - I_o - C_a = \Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a$	
P_{ret} = base monthly retail price per participant (cost+L_g + P_p) & Aa_c	\$7.50
P_s = regular price or weighted average price of monthly passes	\$20.10
N_g = number of persons passes are purchased for in a group	1330
R_b = number of transit riders in the group before pass implementation	120
R_a = number of transit riders in the group after pass implementation	
I_o = revenue from passes sold to the group before pass implementation	\$2,412.00
I_c = revenue from passes sold to the group after pass implementation	\$9,975.00
I_m = minimum revenue defined by agency policy to warrant program inception	\$2,412.00
T_m = targeted revenue goal, that is, proportional increase	1.533424452
C_a = additional operating cost necessitated by the program.	\$0.00
L_x = additional costs related to route extensions	\$0.00
L_f = additional costs related to increase in service runs	\$0.00
L_t = additional costs related to tripper operators	\$0.00
L_g = additional costs related to guaranteed ride home service	\$0.00
Aa_c = multiplier for additional administrative assistance to the group	1.03
P_p = additional costs related to production cost of pass instrument	\$0.50
AI_m = pass price multiplier related to location accessibility.	1
P_{AI} = location-based monthly pass price per participant.	\$7.50
Objective Function	
maximize: $I_n = I_c - I_o - C_a = \Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a$	\$7,563.00
Constraints	
$I_n = I_c - I_o - C_a = \Sigma_{Ng} P_g - \Sigma_{Rb} P_s - C_a$	\$7,563.00
$I_c \geq (1+T_m) * \max (I_o, I_m)$	\$6,110.62
$I_c \geq I_o + C_a$	\$2,412.00
$P_{AI} \leq (0.15, 0.30, 0.45, 0.60)*P_s$ for AI_m = 1, 2, 3, 4	7.5
decision variables are non-negative: b7, b8, b9, b32 > 0	
P_s = regular price of monthly passes	\$50.00

Linear Program #2: Maximize Net Revenue Plus Improvements

Cost Factors	**Optimization**
Number of participants	1330
Location and accessibility multiplier	1
	0
Decision Variables	
P_g = base monthly unit pass cost [default = 1]	\$2.41
Revenue increase target [default =0]	1.03
Maximum number of participants	1330
Obj Func: max $I_n = I_c - I_o - C_a = \Sigma_{Ng}\, P_g - \Sigma_{Rb}\, P_s - C_a$	
P_{ret} = base monthly retail price per participant (cost+L_g + P_p) & Aa_c	\$7.87
P_s = regular price or weighted average price of monthly passes	\$20.10
N_g = number of persons passes are purchased for in a group	1330
R_b = number of transit riders in the group before pass implementation	120
R_a = number of transit riders in the group after pass implementation	
I_o = revenue from passes sold to the group before pass implementation	\$2,412.00
I_c = revenue from passes sold to the group after pass implementation	\$10,460.81
I_m = minimum revenue defined by agency policy to warrant program inception	\$2,412.00
T_m = targeted revenue goal, that is, proportional increase	1.026323887
C_a = additional operating cost necessitated by the program.	\$8,048.81
L_x = additional costs related to route extensions	\$6,332.37
L_f = additional costs related to increase in service runs	\$396.44
L_t = additional costs related to tripper operators	\$1,320.00
L_g = additional costs related to guaranteed ride home service	\$2.26
Aa_c = multiplier for additional administrative assistance to the group	1.03
P_p = additional costs related to production cost of pass instrument	\$0.50
AI_m = pass price multiplier related to location accessibility.	1
P_{AI} = location-based monthly pass price per participant.	\$7.87
Objective Function	
maximize: $I_n = I_c - I_o - C_a = \Sigma_{Ng}\, P_g - \Sigma_{Rb}\, P_s - C_a$	\$0.00
Constraints	
$I_n = I_c - I_o - C_a = \Sigma_{Ng}\, P_g - \Sigma_{Rb}\, P_s - C_a$	\$0.00
$I_c \geq (1+T_m) * \max(I_o, I_m)$	\$4,887.49
$I_c \geq I_o + C_a$	\$10,460.81
$P_{AI} \leq (0.15, 0.30, 0.45, 0.60)*P_s$ for AI_m = 1, 2, 3, 4	7.5
decision variables are non-negative: b7, b8, b9, b32 > 0	
P_s = regular price of monthly passes	\$50.00

Comparative Analysis of LP Results

(a) LP Solution	Base Pass Cost	Retail Pass Price	Number of Participants	Revenue Margin
Maximize net revenue	$2.68	$7.50	1330	274%
Max net revenue + improvements		$7.50	1330	71%
Min. base cost of pass	$1.26	$3.76	1330	74%
Min. participants	$6.78	$7.50	360	1%
As Implemented		*$5.00*	*1330*	*140%*

(b) LP-based Revenue		
Maximize net revenue	$3,564.40	$9,975.00
Max net revenue + improvements	$0.00	$9,975.00
Min. base cost of pass	$1,675.80	$5,000.80
Min. participants	$2,440.80	$2,700.00
As Implemented		*$6,650.00*
(c) Less 3% admin mark-up		
Maximize net revenue	$3,457.47	$9,675.75
Max net revenue + improvements	$0.00	$9,675.75
Min. base cost of pass	$1,625.53	$4,850.78
Min. participants	$2,367.58	$2,619.00
As Implemented		*$6,450.50*
(d) Less pass production cost ($0.50 ea.)		
Maximize net revenue	$2,792.47	$9,010.75
Max net revenue + improvements	-$665.00	$9,010.75
Min. base cost of pass	$960.53	$4,185.78
Min. participants	$2,187.58	$2,439.00
As Implemented		*$5,785.50*
(e) Less lost fare revenue ($)		
Maximize net revenue	$380.47	$6,598.75
Max net revenue + improvements	-$3,077.00	$6,598.75
Min. base cost of pass	-$1,451.47	$1,773.78
Min. participants	-$224.42	$27.00
As Implemented		*$3,373.50*
(f) Service Expansion cost		
Maximize net revenue	0	0
Max net revenue + improvements	$4,882.62	$4,882.62
Min. base cost of pass	0	0
Min. participants	0	0
As Implemented		*0*
(g) Net revenue [(e) - (f)]		
Maximize net revenue	$380.47	$6,598.75
Max net revenue + improvements	-$7,959.62	$1,716.13
Min. base cost of pass	-$1,451.47	$1,773.78
Min. participants	-$224.42	$27.00
As Implemented		*$3,373.50*
(h) Margin over original revenue ($)		
Maximize net revenue	15.77%	273.58%
Max net revenue + improvements	-330.00%	71.15%
Min. base cost of pass	-60.18%	73.54%
Min. participants	-9.30%	1.12%
As Implemented		*139.86%*

$2,412

ENDNOTES

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[1] Public Use Microdata Sample, U.S. Census 2000, State of California analyzed in: Cornelius Nuworsoo, Measuring Accessibility of Low-Income, Central-City Residents to Suburban Job Opportunities: A Case Study of the San Francisco Bay Area, A Professional Report to the California Department of Transportation, Submitted in Partial Satisfaction of the Requirements for Master of City Planning, Department of City and Regional Planning, University of California, Berkeley, 2002
[2] Jose Gomez-Ibanez, 1996, p30

[3] Friedman, p58
[4] Brown, Jeffrey, Daniel Baldwin Hess, and Donald Shoup, Unlimited Access 1999 & Transit Fact Book, 1997. Brown, Hess, and Shoup estimated the seat occupancy as follows:

> "See Bureau of Transportation Statistics (1998, 23) for data on the number of transit passengers. See Federal Transit Administration (1998) for data on annual passenger miles and annual vehicle revenue miles for public transit systems in the U.S. Dividing the 17.5 billion passenger miles traveled on bus transit in 1997 by the 1.6 billion vehicle revenue miles of service on bus transit gives an average occupancy of **10.94** passenger miles per bus mile (17.5 ÷ 1.6 = **10.94** passengers per bus). Dividing the average bus occupancy of **10.94** passengers by the average bus capacity of 40 seats gives an average seat occupancy of 27 percent (**10.94** ÷ 40 = 27%). That is, if all passengers are seated during their trips, only 27 percent of bus seats are occupied. This calculation overestimates the number of bus seats that are occupied because some passengers stand rather than sit. The 1995 Nationwide Personal Transportation Survey asked respondents who rode the bus whether they (1) sat only; (2) stood only; or (3) some of both. The survey revealed that 65 percent of bus passengers sat for the entire trip, 10 percent stood for the entire trip, and 25 percent both sat and stood; thus, 35 percent of bus riders stood for at least part of their trip. Because we assumed that all bus riders were seated during their trips when we estimated that 27 percent of bus seats are occupied, we have overestimated the average seat occupancy of a bus. Therefore, *at least* 73 percent of bus seats are empty."

[5] Cornelius Nuworsoo, Types of Transit Operations and Operating Ratios in California (Unpublished Report) May, 2001
[6] Don Pickrell, 1992
[7] Jose Gomez-Ibanez, 1996 p44
[8] Savage and Schupp, 1997, p93
[9] Thomas Rubin, ITS seminar, 2000
[10] Mayworm, Lago and McEnroe, 1980, Ecosometrics, Inc., p 83
[11] Brown, Hess, and Shoup, 1999
[12] Brown, Hess, and Shoup, Unlimited Access, 1999
[13] Brown, Hess, and Shoup, BruinGO: An Evaluation, 2002
[14] Fay Lewis, RTD, in TransAct, www.transact.org/Reports/5yrs/ecopass.htm
[15] King County News Release, May 23, 2001: http://www.metrokc.gov/exec/news/2001/0523012.html
[16] Brown, Hess, and Shoup, Unlimited Access, 1999
[17] ECO Pass programs were introduced at the RTD under the management of Peter Cipolla, who later joined VTA as general manager
[18] Santa Clara Valley Authority website: http://www.vta.org/ecopass/ecopas_resi/index.html
[19] Gomez-Ibanez, p99
[20] Gomez-Ibanez, p100
[21] Baumol and Bradford, p265
[22] Baumol and Bradford, p267
[23] Baumol and Bradford, p274
[24] Baumol and Bradford, p280
[25] See reference

[26] William B. Tye (1983), p250, 260

[27] Prest, A. R. Transport Economics in Developing Countries, New York: Praeger, 1969, pp. 7-21

[28] Dalrymple, Dana, Evaluating Fertilizer Subsidies in Developing Countries, Office of Policy Development and Analysis, Bureau for Program and Policy Coordination, Washington, D.C.: US Agency for International Development, July 1975, pp. 4

[29] Friedman, p 339

[30] Adapted from Lee S. Friedman, **The Microeconomics of Public Policy Analysis**, Princeton University Press, 2002

[31] Friedman, p238

[32] Friedman, p238

[33] Friedman, p235

[34] Friedman, p235

[35] For definitions, see: (a) Walter Nicholson, **Microeconomic Theory**, 3rd Ed. The Dryden Press, 1985, p 172; (b) Lee S. Friedman, **The Microeconomics of Public Policy Analysis**, Princeton University Press, 2002, p 86; (c) Dominick Salvatore, **Microeconomic Theory**, 3rd Ed. McGraw-Hill, 1992, p 46

[36] Eugene E. Slutsky (1880-1948), referenced in Friedman, Lee, S. (2002), p 122

[37] Mayworm, Patrick, Armando M. Lago and J. Matthew McEnroe. 1980. *Patronage Impacts of Changes in Transit Fares and Services*. Prepared by Ecosometrics, Inc., for U.S. Department of Transportation, Urban Mass Transportation Administration.

[38] Savage, Ian. 2002. Management Objectives and the Causes of Mass Transit Deficits. Submitted to *Transportation Research.* April 2002

[39] Brown, Jeffrey, Daniel Baldwin Hess, and Donald Shoup. 1999 **Unlimited Access.** Institute of Transportation Studies, School of Public Policy and Social Research University of California, Los Angeles Los Angeles

[40] Details as follows:

Estimated Arc Elasticities

	Monthly Fare (F)			Percent Transit Rides (R)			$e_{R,F}$	$e_{R,F}$
	Before[5]	**After**	**Change**	**Before**	**After**	**Change**	**"B-A" Arc**	**mid-Arc**
Univ. of California, Berkeley Students[1] AC Transit	50	6.84	-43.16	5.6	14.1	8.5	-1.758407	-0.568232
City of Berkeley Employees[2] AC Transit	50	5	-45	6.2	10.7	4.5	-0.806452	-0.325444
Silicon Valley Commuters[3] Santa Clara VTA	45	9	-36	11	27	16	-1.818182	-0.631579
Univ. of Washington, Seattle Sudents[4] Metro Transit	90	5	-85	21	35	14	-0.705882	-0.279412
Univ. of Washington, Faculty & Staff[4] Metro Transit	90	6.75	-83.25	21	28	7	-0.36036	-0.166023

Data Sources:

[1] "Before" & "After" data from 1997 & 2000 Student Transportation Surveys, U.C. Berkeley

[2] "Before" & "After" data from 2001 & 2002 Employee Transportation Surveys, City of Berkeley

[3] Ca 1997 Commuter Survey, reported in Shoup et al 1999.

[4] "Before" & "After" data from 1991 & 1992 surveys of faculty, staff and students, Univ. Washington

[5] Monthly Bus Pass fare data from APTA Fare Summary CD, 2003.

41 http://www.rtd-denver.com/FaresAndPasses/
42 http://www.rtd-denver.com/FaresAndPasses/Passes/Eco_Pass/index.html
43 http://www.rtd-denver.com/FaresAndPasses/Passes/NeighborhoodPass/index.html
44 http://www.colorado.edu/ecenter/projects/alt_trans/new_way_history.html
45 http://www.colorado.edu/ecenter/projects/alt_trans/new_way_history.html
46 1997 RTD ECO Pass Denver CBD Employee Survey
47 2001 RTD Boarding Statistics and SkyRide Customer Satisfaction Survey
48 Brown, Hess, and Shoup, Unlimited Access, 1999
49 Robert S Pindyck and Daniel L. Rubinfeld, Econometric Models and Economic Forecasts, 4th Ed., McGraw Hill, pp 242-246, 1998
50 C. W. J. Granger, "investigating Causal Relations by Econometric Models and Cross-Spectral Methods" Econometrica, vol. 37, pp 424-438, 1969 and C. A. Sims, "Money, Income and Causality", American Economic Review, vol. 62, pp 540-552, 1972 referenced in Pindyck and Rubinfeld, p 242
51 See equation 24-4 in Thomas H. Wonnacott and Ronald J. Wonnacott, Introductory Statistics for Business and Economics, 4th Ed., John Wiley & Sons, 1990, p 698
52 Berkeley City Council Member Kriss Worthington
53 http://www.accma.ca.gov/grh/
54 Mayworm, Patrick, Armando M. Lago and J. Matthew McEnroe. 1980. *Patronage Impacts of Changes in Transit Fares and Services*. Prepared by Ecosometrics, Inc., for U.S. Department of Transportation, Urban Mass Transportation Administration.

55 Savage, Ian. 2002. Management Objectives and the Causes of Mass Transit Deficits. Submitted to *Transportation Research.* April 2002

56 Brown, Jeffrey, Daniel Baldwin Hess, and Donald Shoup. 1999 **Unlimited Access.** Institute of Transportation Studies, School of Public Policy and Social Research University of California, Los Angeles Los Angeles

57 Details as follows:

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3 Ca 1997 Commuter Survey, reported in Shoup et al 1999.

4 "Before" & "After" data from 1991 & 1992 surveys of faculty, staff and students, Univ. Washington

5 Monthly Bus Pass fare data from APTA Fare Summary CD, 2003.

[58] Brown, Hess, and Shoup, Unlimited Access, 1999
[59] Brown, Hess, and Shoup, BruinGO: An Evaluation, 2002, p8
[60] Brown, Hess, and Shoup, BruinGO: An Evaluation, 2002, p31
[61] Fay Lewis, RTD, in TransAct, www.transact.org/Reports/5yrs/ecopass.htm
[62] Brown, Hess, and Shoup, BruinGO: An Evaluation, 2002, p18
[63] As data allows, unit or average costs should be determined by location type (e.g. CBD, central city, urban fringe, suburban, rural, etc.)
[64] The parameter, y, has a typical value of 0.3. See Cervero, Rood and Appleyard, Environment and Planning, 31: 1259-1278
[65] Monte Whaley in The Denver Post, August 15, 2000; http://www.denverpost.com/news/election/po10815.htm
[66] The Boulder County Business Report, October, 1998; http://www.bcbr.com/oct98/ecobrf.htm
[67] http://www.go.boulder.co.us/pubs/transit/ctp_cee.html
[68] http://www.colorado.edu/ecenter/projects/alt_trans/new_way_history.html
[69] Monte Whaley in The Denver Post, August 15, 2000; http://www.denverpost.com/news/election/po10815.htm
[70] http://www.go.boulder.co.us/pubs/transit/ctp_cee.html

[71] Metropolitan Transportation Commission website: http://www.mtc.ca.gov/projects/commuter_check/ccheck.html