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The Four Dimensions of Rail Transit Performance:
How Administration, Finance, Demographics, and Politics Affect Outcomes

DISSERTATION

submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in Urban and Regional Planning

by

Nicholas Shawn Compin

Dissertation Committee:
Professor Marlon Boarnet, Chair
Professor Gordon J. (Pete) Fielding
Professor Lois Takahashi

1999

The Dissertation of Nicholas Shawn Compin is approved
and is acceptable in quality and form
for publication and microfilm:

Committee Chair

University of California, Irvine

1999

DEDICATION

To

my family; especially my parents, and friends

in recognition of their support, sacrifice,

and, most of all,

friendship

TABLE OF CONTENTS

Page

LIST OF FIGURES v

LIST OF TABLES vi

ACKNOWLEDGMENT vii

CURRICULUM VITAE viii

ABSTRACT OF THE DISSERTATION xiv

INTRODUCTION 1

CHAPTER I: THE HISTORY OF GOVERNMENT PARTICIPATION IN MASS TRANSPORTATION 4
- A. Conceptualizing the Government's Role in Public Transportation 5
- B. The Historical Role of Government Participation in Rail Transit Finance 17
- C. Sources of Capital and Operating Funding for Mass Transit (1991-1995) 27
- D. Types of Mass Transportation Funding: Dedicated and General Revenue 31
- E. Conclusion 36

CHAPTER II: MEASURING TRANSIT SYSTEM PERFORMANCE 37
- A. Past Research on Transit System Performance 38
- B. Two Elements of Transit System Performance - Efficiency and Effectiveness 43
- C. Conclusion 54

CHAPTER III: METHODS FOR QUANTITATIVE ANALYSIS 57
- A. Regression Analysis 58
- B. Conclusion 79

CHAPTER IV: REGRESSION RESULTS 81
- A. Regression Results By Type of Rail System: Heavy and Light 81
- B. Discussion of Regression Results 98

CHAPTER V: The Present and Future of Rail Transit Performance Research 110
- A. Major Findings 111
- B. Policy Implications 114
- C. Future Research 115

BIBLIOGRAPHY 118

APPENDIX A: US RAIL TRANSIT AUTHORITIES 125

LIST OF FIGURES

		Page
Figure 4.1	Regression Results: Cost per vehicle hour (COSTVEH)	82
Figure 4.1A	Observed relationship between variables: Heavy Rail	83
Figure 4.1B	Observed relationship between variables: Light Rail	84
Figure 4.2	Regression Results: Cost per passenger (COSTPASS)	86
Figure 4.2A	Observed relationship between variables: Heavy Rail	87
Figure 4.3	Regression Results: Vehicle hour per employee hour (VEHEMP)	88
Figure 4.3A	Observed relationship between variables: Heavy Rail	89
Figure 4.3B	Observed relationship between variables: Light Rail	91
Figure 4.4	Regression Results: Vehicle hour per vehicle max (VEHMAX)	92
Figure 4.4A	Observed relationship between variables: Heavy Rail	93
Figure 4.4B	Observed relationship between variables: Light Rail	95
Figure 4.5	Regression Results: Passengers per vehicle hour (PASSVEH)	95
Figure 4.5A	Observed relationship between variables: Heavy Rail	96
Figure 4.5B	Observed relationship between variables: Light Rail	97

LIST OF TABLES

		Page
Table 1	Sources of Capital Funding 1991-1995	28
Table 2	Sources of Operating Funding 1991-1995	29
Table 3A	Transit Performance Measures Suggested by Various Studies: Efficiency	45
Table 3B	Transit Performance Measures Suggested by Various Studies: Effectiveness	46
Table 3C	Studies including Transit Performance Measures by Author and Year	47
Table 4	Descriptive Statistics for Dependent Variables Used in Regression Models	59
Table 5	Independent Variables for Mode Comparison	60
Table 6	Expected Results of Regression Analyses	63
Table 7	Summary of Regression Results – Heavy Rail Transit	112
Table 8	Summary of Regression Results – Light Rail Transit	113

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ABSTRACT OF THE DISSERTATION

The Four Dimensions of Rail Transit Performance
How Administration, Finance, Demographics, and Politics Affect Outcomes

by

Nicholas Shawn Compin

Doctor of Philosophy in Urban and Regional Planning

University of California, Irvine, 1999

Professor Marlon G. Boarnet, Chair

The rebirth of rail transit in the US over the past two decades has resulted in rail transit's re-emergence as an integral part of both the physical and economic landscapes of many US cities. Currently fifty-four separate rail transit systems are operated in the US (see Appendix A). This re-emergence of rail transit in cities across the US raises an important question. How does society determine if its investment in rail transit is having an impact? More importantly for the current research: how is the impact of rail transit measured across different geographic regions and system types? Performance standards are one way of determining if public investments are reaching established goals. In this research the impact of variables representing four dimensions of transportation performance: administrative, financial, demographic, and political is assessed. Multiple regression analysis is used to assess the impact of important factors representing each of the four dimensions on the performance of all heavy and light rail transit systems in the US.

This study addresses three important gaps in existing research. First, this study is strictly concerned with the performance of rail transit systems; an area of research which is unique and, due to the dearth of information in the past, absent from current literature. Second, existing

research has not adequately addressed the impact of specific sources and types of government subsidies on transit system performance. Sources of subsidies include federal, state, and local funding, while types include dedicated and general revenue funding. Finally, existing research has yet to adequately address the impact of local political relationships on transit system performance.

Results indicate that a significant difference exists between the operation of heavy and light rail transit systems in the US. The main difference is that administrators of heavy rail systems seem to strive to achieve goals more closely associated with standard performance measures, while administrators of light rail systems may target different goals that are not directly associated with or reflected by existing performance measures. The results of this research are extremely useful, not only in terms of determining the impact of important variables on the performance of rail transit systems, but also in helping to focus and redirect performance research.

INTRODUCTION

The rebirth of rail transit in the US over the past two decades has resulted in rail transit's re-emergence as an integral part of both the physical and economic landscapes of many US cities. Currently fifty-four separate rail transit systems are operated in the US (see Appendix A). Every year billions of dollars are spent by federal, state, and local governments on capital and operating expenses associated with rail transit. Cities and regions across the US are building new systems and expanding older systems in the hope of changing both travel and development patterns. The re-emergence of rail transit in cities across the US raises an important question. How does society determine if its investment in rail transit is having an impact? More importantly for the current research how is the impact of rail transit measured across different geographic regions and system types? Performance standards are one way of determining if public investments are reaching established goals. In this research the impact of variables representing four dimensions of transportation performance (administrative, financial, demographic, and political) is assessed. Multiple regression analysis is used to assess the impact of important factors representing each of the four dimensions on the performance of all heavy and light rail transit systems in the US.

This study addresses three important gaps in existing research. First, this study is strictly concerned with the performance of rail transit systems, an area of research that is unique and, due to the dearth of information in the past, absent from current literature.
Second, existing research has not adequately addressed the impact of specific sources and types of government subsidies on transit system performance. Sources of subsidies include federal, state, and local funding, while types include dedicated and general revenue funding. Finally, existing research has yet to adequately address the impact of local political relationships on transit system performance.

In order to provide a strong basis for analysis, Chapter I addresses the arguments, both pro and con, surrounding the history of government participation in rail transit finance in the US.

Also presented in Chapter I are: a general history of government participation, the sources and amounts of capital and operating funding available for mass transit in the 1990s, and a discussion of funding types; both dedicated and general revenue.

Chapter II is devoted to a review of the literature, especially studies that have addressed the impact, appropriateness and applicability of specific performance measures. Performance measures chosen for inclusion in the current research, the reasons for their inclusion, and the insight provided by each are also discussed. Presented in the final section of Chapter II is a discussion of three important gaps in existing literature that have become apparent through the analysis of past research. These gaps include a determination of the impact of specific types and sources of government subsidies, the concentration of existing performance research on bus transit operations, and the inclusion of data relating to local political relationships and their impact on transit system operating performance.

A new framework for the analysis of the nature of rail transit system performance is developed in Chapter III. Also included in Chapter III is a discussion of the variables used to represent each of the four dimensions of the new framework, with specific attention paid to an explanation of how each affects performance. Finally, Chapter III contains a step-by-step outline of how multiple regression analysis is applied in this research, and an analysis of the expected results.

Presented in Chapter IV are results of regression analyses conducted using data from all heavy and light rail transit properties in the US, 1987 - 1995. Also included in Chapter IV is a discussion concerning whether or not the hypotheses stated in Chapter III were proved or disproved. The final section of Chapter IV is devoted to a discussion of the macro-level understanding gained from the interpretation of regression results, as-well-as suggestions for future research concerning the nature of and factors affecting rail transit performance in the US.

CHAPTER I

The History of Government Participation in Mass Transportation

In order to understand the need for conducting research concerning the performance of rail transit systems in the US, and the impact of specific variables on performance, it is first necessary to frame the issue in such a way as to gain a full understanding of the progression of government involvement, especially financial, in the provision of mass transit. Presented in the first section of this chapter, section A, is a conceptualization of the question of government financing of mass transportation in the US. This includes consideration of the nature of mass transit as a public or private good, which gets at the heart of the issue. The insight gained leads to the consideration of public goals associated with mass transportation and consideration of the arguments in support of and in opposition to government financing of mass transit.

Section B provides a view of the historical progression of government involvement in the provision of rail transit in the US. Rather than a quick transition from private to public ownership and operation, the process of shifting from private to public control of the US rail transit industry was slow and hard fought, taking decades to complete.

Sections C and D contain information concerning recent trends in government financial support of mass transit in general and, more specifically, rail transit. The foci of these sections are the sources and types of government funding available to transit systems for expenditure on capital and operating costs; including federal, state or local government; and dedicated or general revenue.

The final section of this chapter, section E, not only contains a summary of what is presented in this chapter, but an explanation of how past and present government involvement in both the mass transportation industry as a whole and, more specifically, the rail transit industry directs the current research to ask and provide insight into questions that heretofore have not been addressed in existing research.

A. Conceptualizing the Government's Role in Public Transportation

1. Understanding the Goals for and Objectives of Public Transportation.

a. Public Transportation: Public Good or Publicly Provided Private Good?

Public goods have two characteristics. First, they are nonrival: the marginal cost of adding one additional consumer is zero. Second, they are nonexcludable: it is impossible or impractical to exclude a consumer (one who has not paid for the good) from consuming the good (Pindyck and Rubinfeld 1992). The most frequently given example of a pure public good is national defense. Although the cost of providing national defense may vary according to government policies, the cost of adding additional consumers (population increase) is zero. In short, either a country provides national defense, or it does not and that fact does not vary according to changes in population. National defense is also nonexcludable. Again, if a consumer decides not to pay taxes, he or she will still be protected against foreign invasion. To exclude one person, without putting the consumers who paid for the service at risk, would be impossible.

Private goods, on the other hand, are rival: the cost of producing one additional item, no matter how small is positive. Private goods are also excludable; once a commodity is purchased all other consumers are excluded from purchasing that item.

Established transportation systems are often considered to have characteristics of both public and private goods. Highways are examples of what are referred to as impure or congestable public goods, goods that are nonrival when the number of consumers is low, but rival when the number of consumers rises to a point where all who would want to consume the good are unable to (congestion).

Congestion aside, transportation, at its most basic level is a private good. It is true that the cost of operating a public bus is the same whether it is full or empty, but the decision concerning the type of travel offered (e.g. bus vs. train) or the size of the vehicle operated and its service level includes a calculation of the costs related to carrying different numbers of passengers. Public transportation is also easily excludable, especially when tolls or fares are employed. Pricing of transportation results in the exclusion of potential consumers.

Concluding that public transportation is a publicly provided private good is extremely important in that it is with this in mind that one considers the goals for and objectives of public transportation. Goals and objectives not only determine the form, and amount of financial support for public transportation, but ultimately determine whether public investment in mass transportation is desired and warranted. If public transportation is considered to be a publicly provided private good, then the cost of providing the service must be prominently featured in any consideration of goals or objectives. If, on the other hand, public transportation is considered to be a public good, then supply and equity issues must figure most prominently in decisions concerning goals and objectives.

b. Ever-Changing Goals and Objectives for Public Transportation in the US.

The question addressed in this section is what society hopes to accomplish by investing in public transportation. In order to achieve results, what is first necessary is a clear set of goals and objectives. Unfortunately for the American public, clarity of goals and objectives has not been the rule when it comes to public transportation. An extremely convincing argument explaining the lack of clarity of vision in transportation policy in the US has been put forth by Altschuler (1979, p. 13-14).

> "It is highly misleading to think of societies and governments as having goals. And it is particularly misleading to think of the American social and political systems, with their extreme pluralism, as having goals. It is far more useful to think of them as having an enormous number of values and a constantly shifting set of priorities among them."

As a result, it is important to view past and current goals for and objectives of public transportation in the US as being established within a highly politically charged and ever-changing public arena.

Goals for and objectives of public transportation in the US have been characterized as being established in three distinct eras (Cherwony and Ferreri 1981). The social and political attitudes existing in each era have determined the roles that subsidies, fares and level of service (three of the most important factors) have played in transportation decisions.

The first era of mass transportation in the US lasted until 1965. During that time transportation was essentially self-supporting (Fielding 1983). The private market determined the goals and objectives for transit which were based in market economics; either a system realized a profit, or service was discontinued. By the late 1950s private transportation providers could no longer compete with the private automobile which had been receiving financial assistance since the early 1900s in the form of highway expenditures (Wachs 1989). As ridership levels during the first era plummeted, fares increased, and service levels and farebox revenues decreased (Fielding 1983). This cycle continued until the mid-1960s when government assumed control of many private transportation companies. In 1961 (Housing Act) federal assistance was made available in the form of loans and grants and in 1964 (UMTA Act) capital grants were made available.

The second era of transportation in the US lasted for approximately fifteen years, from mid 1960s to the early 1980s. This era witnessed a shift in the goals for and objectives of what had become an almost exclusively public transportation system. Transportation was thought of as a way to address many of society's social ills, including: problems with the supply of oil (energy), air pollution, traffic congestion, urban sprawl, and mobility requirements of the elderly and disabled. Transit's perceived ability to address such a wide variety of urban problems, coupled with its relatively minor price tag, gained broad political support for transportation. Increased political interest resulted in federal operating assistance (UMTA Act 1974) and an increase in federal spending for transportation during the mid-1970s from $540 million to $5.2 billion (Pucher 1980). An important consideration is that the redistribution of transportation funding, from the federal level to state and local transit agencies, was based on politically determined criteria, in stark contrast to the economic, profit-based criteria in effect prior to the government takeover in the 1960s. Transit was viewed as a political tool, used by politicians to insure support from voters in areas targeted for service expansion (DeAlessi 1973; Meyer and Gomez-Ibanez 1981; Ortner and Wachs 1979). Success for transit was being measured in terms of fare stabilization and compliance with federal government labor laws, vehicle procurement and service to elderly and disabled populations (Fielding 1983).

The third era of transportation in the US began when Ronald Reagan took office in 1981. Once again, the goals and objectives of transit were primarily based on political ideology as the new administration set its sights on federal cost cutting, including a total phasing out of federal operating subsidies for transit. A second primary goal of the new administration was to return control and responsibility for government projects such as transportation to local government. This was to be accomplished by offering federal assistance in the form of block grants which state and local governments would then distribute according to their own criteria.

Today there are still no overarching national goals or objectives for the public provision of transportation in the US. In the first era, the search for profit by private companies, coupled with nearly total government neglect, nearly ran mass transit into the ground. During the second era, public transit was considered a near panacea for solving many of society's problems. With federal funding came federal regulation and control and a tenfold increase in the federal budget for mass transportation. In the third era, political backlash against monumental budget increases and federal control of local policy-making threatened once again to cripple mass transportation.

The problem identified by Altschuler (1979) continues today as each political era brings with it a shifting set of priorities and goals for transit. Today the lack of goals for and objectives of public transportation is compounded as the goals and objectives set forth in eras past vie for superiority over the others creating an increasingly difficult and confusing atmosphere in which to operate public transportation systems. Possibly we have entered into yet a fourth era of transportation in the US where the goals of the first era – (cost efficiency), must be incorporated with the goals of the second era – (public service), within the framework of the third era – (local control and responsibility).

If the US has entered into a fourth era of transportation and local governments are to be held responsible for the performance of rail transit systems, then it is extremely important to determine exactly what goals rail transit must meet and, possibly more important, who has established the goals to be met and why. Presented in the following section of this paper are the major arguments and counterpoints both in support of and opposition to mass transportation on the whole and, more specifically, publicly provided mass transportation. This section further assists in providing an outline of political viewpoints that shape the discussion of rail transit performance.

2. Arguments in Support of Mass Transit Subsidies

Support for public assistance in mass transportation has been expressed through two major avenues, economic and social, with each containing a myriad of permutations. Claims associated with each type of argument and evidence from research are presented in the following sections.

Economic

The most fundamental economic arguments in support of mass transit are those concerning scale economies. Economies of scale arise whenever the cost of production less than doubles when output is doubled (Pindyck and Rubinfeld 1992). For mass transit this means that the cost per extra unit of output (e.g. cost per passenger mile) declines as service volume increases. Expanding a system to take advantage of scale economies, while efficiently pricing services at marginal cost, results in deficit spending, thus subsidies are necessary for public transit to take advantage of returns to scale (Meyer, Kain and Wohl 1965).

A second important economic argument in support of public mass transit employs the concept of utility maximization. Utility is the level of satisfaction that a person or group gets from consuming a good or undertaking an activity (Pindyck and Rubinfeld 1992), and utility maximization is the highest satisfaction a person or group can get. In transportation the most commonly referred to area for utility maximization is in the use of existing infrastructure. Supporters often associate mass transportation with enabling the most efficient use of space in an urban area. That is, there are fewer resulting negative externalities in an urban area when growth is compact and transportation needs are met by mass transportation. In this way urban sprawl, which is often viewed as a negative externality and as leading to the inefficient use of existing infrastructure and services, can be avoided.

Economic - Counter Point

Economies of scale depend on declining marginal cost; that is, as scale increases cost per additional unit of output must decrease. Actually, nearly the exact opposite has been viewed with respect to the relationship between system size and the marginal costs of providing public transportation. For example, Lave (1991), in a study of the productivity of 62 transit firms from 1950-1985, found that the average cost per bus hour increased with firm size. This means that larger firms actually incur greater costs as a result of their being large, which also indicates that diseconomies of scale are present. Several hypotheses have been proposed to help explain this phenomenon (Cervero 1983; Lave 1991). Hypotheses are primarily centered on the idea that large systems also have large workers' unions. In addition, large cities tend to be older and more dense, thus mass transit's mode share is greater and a transit worker strike has a greater impact. As a result of the vulnerability of large transit systems to worker strikes, labor negotiations in large cities tend to favor the unions more than in smaller cities. This causes the costs associated with providing public transportation in large cities to increase at a greater rate than operations costs in smaller cities.

Social

Over the years social justifications for public transportation have taken many forms. Above all, public transit has been put forth as a way of addressing many of society's ills. The argument is that if society can "internalize" transit's external benefits, or the effects of production and consumption activities not directly reflected in the market (Pindyck and Rubinfeld 1992), then an investment in public transportation results in much more than improved transportation. Public transit has not only been seen as part of the solution to increasing the mobility of the disabled, the poor, the young, and the aged (Saltzman 1979), but also as a way for society to clean-up the environment primarily by reducing air pollution (Cervero 1989). Along these lines, one main way to reduce air pollution is to reduce the total number of vehicle miles traveled (VMT) by auto. One concept that has been presented to accomplish the goal of reduced VMT is to locate jobs and housing within the same community, thereby increasing the ratio of jobs to housing or, what is commonly known as, the jobs-housing balance (Levine 1996; Giuliano 1991; Cervero 1989). Finally, public transit is often presented as a means of influencing land use by concentrating development near highway interchanges and corridors and near rail lines and stations. It is hypothesized that by concentrating on increasing the density of urban land use the nationwide trend of urban decay can be reversed and investment encouraged in inner-city areas (Calthorpe 1993).

Social - Counter Point

Few would argue with transit's ability to increase mobility for the disabled, poor, young, and elderly, but on the other three points research has shown public transportation as having little impact.

With respect to air quality improvements and energy savings associated with public transit systems, transit's mode share is too small to have much of an impact. In 1990, the national average of transit's mode share for journey to work was 5.1% (Federal Highway Administration 1992) and was closer to 3% for all trips. Research on the air quality impacts of public transportation has concluded that technological solutions for auto emissions have a greater impact on air quality than measures aimed at reducing vehicle miles traveled to increase transit's mode split (Bae 1993).

With respect to the impact of transportation on land use, the general conclusion of research is that transportation improvements in established urban areas have little impact on local land use (Boarnet and Compin 1999; Giuliano and Small 1993; Giuliano 1989; Knight and Trygg 1977). Transportation may serve as a vehicle for public investment in areas served by transit, but it is the promise of reductions in development-related costs that entice developers, not the existence of transit.

Other Arguments

Countervailing Subsidy

Supporters of public transit often cite uneven distribution of government subsidies as a justification for public transit's inability to compete with the private automobile. The gist of the argument is that the government heavily subsidizes automobile through the construction and maintenance of roadways and the maintenance of low fuel prices. Auto users are not required to pay the full cost related to driving such as increased air pollution and roadway congestion. The argument continues that if public transit were subsidized at the same level as automobiles, public transit would become more attractive to potential riders and be able to compete with the auto for passengers (Pucher 1990; Vickrey 1973).

Countervailing Subsidy - Counter Point

Few would argue that automobile users pay the full costs associated with operating a vehicle. The costs of operating an automobile are much greater than what drivers actually pay, primarily due to government investment in roadways and social costs of driving which automobile users do not directly pay (Meyer, Kain, and Wohl 1965; Bly, Webster, and Pounds 1980). The problem with the countervailing subsidy argument is that raising the subsidies offered to public transit is not the most direct way to address the issue. Many argue that the way to rectify the situation is to increase the cost of auto usage (Vickrey 1980; Downs 1992). Rather than having society pay for inefficiencies in both forms of transportation, the costs of those inefficiencies would be borne by the individual users. From a purely economic standpoint user fees are preferable. From a social welfare standpoint the preferable option is to apply scarce public resources toward solving other societal problems instead of compounding inefficiencies in transportation (Meyer, Kain, and Wohl 1965, pg. 349).

Infant Industry

The main impetus for the 1964 UMTA capital subsidy program for mass transit was that after years of neglect, mass transit in the US was in need of a financial "inoculation" to help it gain strength to counteract decreasing ridership and service levels (Lave 1994). Under the program, a one-time injection of public funds would be used by mass transit to help it become more competitive with other forms of transportation, primarily the automobile. Extended service levels and new vehicles would allow mass transit to become more attractive to potential riders.

Infant Industry - Counterpoint

The best evidence against this argument is the history of government funding of mass transit in the US. The "one-shot injection" soon became an intravenous lifeline as operating subsidies were made available to public transit in 1975 and have continued to increase to the present day. All the while transit's mode share has declined or remained relatively constant (Altschuler, Womack, and Pucher 1979).

Option (Alternative) Value

Supporters of public transit argue that public transportation is necessary in that it can serve as a transportation option in cases of personal necessity or natural disaster (Yoshpe 1961). An example of personal necessity might be a temporary, unforeseen need such as a medical condition that prevents a person from driving as they normally would. The 1994

Northridge earthquake is a prime example of a regional emergency caused by a natural disaster. The earthquake damaged four major freeways in the Los Angeles area and thousands of commuters were cut off from their jobs. Although the most serious delays were taken care of within a month after the quake (Caltrans 1994) public transit, especially the Metrolink which carries passengers from outlying cities to downtown Los Angeles, was available to carry a large portion of the city's workers who had no other way to reach downtown Los Angeles.

Option (Alternative) Value - Counterpoint

Natural disasters occur every year in the United States. Whether it is earthquakes in the West, blizzards in the Midwest or Northeast, or hurricanes in the Southeast, hundreds of millions of dollars are lost when cities and their transportation systems are damaged. During such times, the availability of mass transportation plays an important role in the rapid recovery of affected regions, especially when it comes to getting workers back to their jobs. Fortunately, temporary conditions such as natural disasters, although serious, are usually short-lived (Giuliano 1996) and are not a justification for long-term public investment in expensive transportation systems.

Income Redistribution

One final argument in support of public transportation subsidies is in their redistributive qualities. The concept is based on the argument that simple, or flat fare structures, are inequitable as inner-city riders, mostly poor, pay more per mile of service than suburban riders, mostly middle-class. Thus increases in average fares would hurt those riders most who could afford it least (Government Accounting Office 1981).

Income Redistribution - Counter

The main disagreement with the argument that transit subsidies are a form of income redistribution is that transportation subsidies must be spent on transportation. This implies that the transfer is for a purpose which society finds compelling, but is unknown to the transit user (Kolsen and Docwra 1977, p. 11-12). Again, if such subsidies are to serve as equity instruments, applying them directly to the inequality rather than a secondary target would result in a more beneficial impact on income redistribution.

3. Arguments in Opposition to Transportation Subsidies

One of the most important arguments against subsidies in terms of the current research is that subsidies remove incentives for transit planners and managers to act in an efficient manner. Past research has shown that if a large amount of capital funding is available transportation planners often have an incentive to overestimate ridership and underestimate costs of potential systems (Kain 1990; Pickrell 1992). Research has also shown that a steady stream of operating funding often results in decreasing system productivity and increased costs (Anderson 1983; Lave 1991; Pucher, Markstadt, and Hirshman 1983).

In addition to the counters to arguments in support of transit subsidies that were covered in the previous section arguments in opposition to transit subsidies include:

* Subsidies inhibit free-market competition and either force private firms out of the market or prohibit their entry into the transit market. Market inefficiencies result in which transit costs are higher than they would be in a free market.
* Subsidies create a dependency on outside funding sources that are subject to withdrawal. A major shift in funding policies can cause chaos at the local level.
* Subsidies undermine revenue income (farebox return rate) as they are applied toward fare reduction even as operating costs continue to escalate.
* Subsidies result in excessive service expansion (generally in terms of route miles) into low-density suburban areas. This results in systems that operate far below capacity and increases in operating costs per passenger (Pucher 1995; Wachs 1989).

4. Discussing the Arguments

Of the arguments presented in support of public transit subsidies, those based in economics are the easiest to counter, while social arguments are the most difficult to counter. The reason for this is that the economic impacts of transit subsidies on transit system operations are more easily quantifiable and measured. Social impacts are far more difficult to quantify and even more difficult is the task of measuring direct impacts on society given the vast number of potentially significant variables that are outside the influence of transportation.

B. The Historical Role of Government Participation in Rail Transit Finance

The economic and social arguments presented in the previous section assist in framing the question of public involvement in the operation of rail transit systems in the US. These arguments, both pro and con, have not only helped to inform the public about rail transit, they have also helped shape public policy. Presented in this section is the history of federal government involvement in the public provision of rail transportation in the US. From its earliest beginnings federal financial policy, which has been and continues to be shaped by economic and social arguments, has been the driving force behind the construction and expansion of rail transit systems.

1. Before the 1960s

The federal government's role in the provision of rail transit has changed dramatically over the past 100 years. It was the federal government, which in the late 1800s spurred the construction of railroad lines across the Western portion of the US. The transcontinental railroads were heavily supported by the federal government and were used as a way to hasten the settlement of the Western United States. In this way, through widespread settlement, the federal government insured that the lands in the West would remain part of the United States, in effect protecting previously established borders. Once the system of rail lines were in place and the settlement of the West was well underway, the federal government in effect stepped out of the picture. They did not assist, and were not involved in the construction, financing or regulation of local interurban rail lines that criss-crossed many cites in the US in the 1920s. In fact, two of the only steps that the federal government took in relation to rail transit between the late 1800s and the early 1960s actually assisted in the demise of rail transit in many regions throughout the US.

The Holding Company Act of 1935 and The Federal Transportation Act of 1958

First, the Holding Company Act of 1935 was passed as an attempt to break-up the monopolies of power companies in the US. This Act forced power companies to begin to divest themselves of their transit subsidiaries (Smerk 1991, p. 43). Without the financial support of such large companies, the interurban railways continued to weaken. Second, the Federal Transportation Act of 1958 was an attempt at strengthening existing rail transit companies by escalating the process of discontinuing unprofitable routes. Prior to the Act of 1958, a rail company either had to go through a process that could take many years to discontinue service on a particular route or abandon an entire line if they wished act quickly. "The 1958 Act was the first major step in moving railroads away from passenger service" (Smerk 1991, p. 60). This Federal Act, combined with the financial weakness of urban rail transit finally resulted in the abandonment of nearly all of the commuter rail lines in the US.

2. A Changing Federal Role - The 1960s

The presidential election of 1960 was the first step toward government involvement in urban rail transit in the US. "First, under Presidents Kennedy and Johnson, there was an increased attention to urban problems" (Salzman 1992, p. 40). As I have mentioned before, the leadership of the US before the 1960’s concentrated on what they were most familiar with rural policies. The Kennedy administration began considering the problems of urban areas, of which transportation was an integral factor.

The Federal Housing Act of 1961

The Federal Housing Act of 1961, signed on June 28, 1961, addressed the problem of urban mobility by including three provisions specifically aimed at financing urban rail transit. First, the Act authorized $25 million for rail transit demonstration projects. Second, as a provision for planning grants, the Act required that mass transit planning be included as an integral part of comprehensive urban planning. Finally, the Act authorized $50 million in loans for capital improvement for rail transit from the Housing and Home Finance Agency.

Of the three provisions, the one with the greatest effect on establishing a national rail transit program was the first (Smerk 1991, p. 81). Through a small number of demonstration projects (e.g., Philadelphia, PA) it was shown that if improved, rail transit could attract riders. One major precedent that was established by the Act was that no funds were to be given directly to private companies (which owned 95% of the rail transit lines before 1964) but would be channeled through state or local governments or other government agencies. Thus rail transit gained a foothold in federal governmental policy.

The Federal Highway Act of 1962 and the Urban Mass Transportation Act of 1964

The Federal Highway Act of 1962, which became effective on July 1, 1965, "was the first piece of federal legislation to mandate urban transportation planning as a condition for receiving federal funds in urbanized areas" (Weiner 1992, p. 46). Under the Act, transportation funding would not be appropriated to urban areas of 50,000 or more, unless proposed expenditures were based on comprehensive and continuing planning efforts. The Act also required the consideration of alternatives to highway expansion, of which rail transit was principal.

The Urban Mass Transportation Act of 1964, signed on July 9, 1964 by President Lyndon Johnson, continued both the demonstration and low-interest rate loan programs begun under the Housing Act of 1961 and strengthened the requirement of an in-depth planning process contained in the Federal Highway Act of 1962.

The 1964 Act provided for federal grants of two-thirds of net project costs (gross costs minus operating revenues) associated with construction, reconstruction or acquisition of mass transportation facilities and equipment. Additionally, the Act required that in areas where a comprehensive planning process was incomplete, only 50% of total funding would be released (Urban Mass Transportation Administration 1964).

Thus both Acts not only strengthened rail transit's position in federal transportation policymaking, but insured long-term, continuing aid for rail transit in the US.

The UMTA and the Newly Created DOT 1966 - 1970

On April 1, 1967 the Department of Transportation became a cabinet-level agency, but the Urban Mass Transportation Administration (UMTA) was still under the Department of Housing and Urban Development, which in effect prohibited it from gaining access to the real cash cow, the National Highway Trust Fund. Fortunately for transit, in early 1968, and without fanfare, President Johnson proposed switching the UMTA from HUD to DOT and by late 1968 the process was completed.

From 1968 until 1970 the federal transit program slowed to a crawl as officials moved from one department to another. The chaotic organization of the departments and their officials was also in response to an uncertain future and an impending change of presidential administrations (Smerk 1991, p. 106).

3. The Growth Years of Mass Transit - The 1970s

The early 1970s witnessed an occurrence that made the transportation industry hold its collective breath, a republican was elected president for the first time in nearly 10 years, but

Richard Nixon was not what transit supporters had expected. During the first three fiscal years of the Nixon Administration, mass transportation was to receive nearly seven times more funding per year than it had received per year in the mid to late 1960s.

The Urban Mass Transportation Assistance Act of 1970 and the Highway Act of 1973

"Even though the Nixon and Ford administrations de-emphasized the urban programs of the previous administrations, they still embraced transit problems in an attempt to accommodate all perspectives on the urban problem" (Saltzman 1992, p. 40). The passage of the Urban Mass Transportation Assistance Act of 1970 on October 15, 1970, demonstrated Nixon's dedication to mass transit as the Act allocated $3.1 billion in capital grants to urban mass transportation over the next three fiscal years, until July 1, 1974.

During the years of 1971 and 1972, the mass transportation industry launched an intense lobbying effort in order to reach two goals. First, they wanted federal aid for operating expenses. This goal was vehemently opposed by President Nixon primarily because one of the main beneficiaries of such funding would be the organized labor groups of the transit industry who were not Nixon supporters (Smerk 1991, p. 117). Thus provisions for operating expenses were not included in the Highway Act of 1973.

Second, the transportation industry and its supporters wanted to gain access to the Highway Trust Fund, which it did on August 13, 1973, when the Highway Act was signed into law. The Act not only provided an increase of $3 billion in contract authority for mass transportation purposes for fiscal years 1974-1976, it authorized an additional $985,500,000 from the Department of Transportation (i.e. the Highway Trust Fund) to be used for mass transportation. Thus the transit industry gained access to a continual and seemingly limitless source of funding.

The National Mass Transportation Assistance Act of 1974

The Act of 1974, which was signed into law by President Gerald Ford on November 26, 1974, had a profound effect on the provision of mass transportation in several major areas. The Act amended the Urban Mass Transportation Act of 1964 in three major areas. First, the 1974 Act provide a substantial increase in funding - a total of $11.8 billion over six years. Second, the Act required the participation of state and local government in the distribution of federal transit funding. Third, and most important, the Act allowed federal funding to be spent for transit system operating costs for cities with a population over 50,000 (NMTA 1974).

The provisions of the 1974 Act are much more complicated than is presented here. Suffice it to say the Act was extremely beneficial for mass transit, especially with respect to providing local systems federal funds for certain operating purposes.

The Surface Transportation Assistance Act of 1978

The years of the Carter administration were difficult for the transit industry. The major culprit was the uncertainty of the Carter administration with the finer points associated with the operation of government programs. The Carter administration was not prepared to adequately address the major changes taking place in urbanized growth and mass transportation across the country and thus was unable to build upon the long-term vision of the Nixon administration (Smerk 1991, p. 163). Although the process of creating transit legislation and then getting it passed by Congress was long and often times confusing, the Surface Transportation Act of 1978 ultimately contained more funding for mass transportation than had previously been authorized. The transit portion of the joint highway transit bill totaled $15.16 billion divided over the fiscal years 1979-1983. The Act made several basic changes in the mass transportation program including the provision of funding for rail transit operations, operating aid for mass transportation systems in non-urbanized areas and a requirement that a public hearing be held prior to implementation of general fare increases or major service changes by a transit operating agency. The Act also required consideration of environmental and economic impacts of any service changes.

4. A Holding Pattern for Transit - The Decade of the 1980s

In the 1970s the process of transferring control of the mass transit industry from private to public sector was all but completed. With nearly all of its major goals met in the 1970s, the transit industry was able concentrate on just one major goal in the 80s: increased funding. That would be much easier said than done for in 1981 the new presidential administration of Ronald Reagan took control of Washington with tax and federal spending cuts on its agenda. Once the Reagan administration's agenda was identified, the best the transit industry could hope for was a holding pattern in terms of federal funding and programs (Smerk 1991, p. 215) and in terms of funding, that is what it received. With the passage of the Surface Transportation Assistance Act of 1982 initial funding from the Mass Transportation Account of the Highway Trust Fund was increased and funding from the General Fund was decreased.

The Reagan Administration sought to "...strengthen Federalism by relying on state and local processes for intergovernmental coordination and review of federal financial assistance and direct federal development" (Weiner 1992, p. 63). Using the 1982 Act, the Reagan Administration changed the manner in which transportation projects in the US were funded in three important ways. The first change was a \$.05 cent raise in the national gasoline tax (\$.01 to the Mass Transit Account) to guarantee a source of federal funding from the newly created Mass Transit Account of the Highway Trust Fund (a guaranteed source which the transit industry had been coveting for years)[1]. The second change was a shift in the federal funding apportionment formula from 2/3 discretionary and 1/3 non-discretionary to 1/3 discretionary and 2/3. This gave control over how transportation funds were spent to state and local officials.

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[1] It is important to note that this change in effect linked the fortunes of mass transit and highways, thereby creating an extremely strong political coalition.

Finally, a funding cap based on a percentage of the fiscal 1982 appropriations to operating assistance provided to urban areas.

The Federal Mass Transportation Act of 1987

Although many voters saw Ronald Reagan's presidential re-election as a mandate for the Reagan administration, it was not a mandate to make sweeping changes in the nation's mass transportation program. Over the years transit had gained in stature, counting among its supporters, Congress, many urban governments and a majority of the public. Thus changes in the mass transportation program in 1987 "really amounted to fine-tuning, not a radical departure from previous practices" (Smerk 1991, p. 258). The Act did authorize a transit program for five years, much longer than past acts and as a result of large-scale lobbying efforts; the Act also authorized an increase in federal aid for fiscal year 1988 of 2.8 percent over that for fiscal year 1987.

Although the 1987 Act offered relatively few major changes over prior years, certain important trends were continued, including: the application of more stringent guidelines and criterion associated with new transit projects, an increase in comprehensive planning, including long-range financial planning, initiation of a "Buy American" policy which required that at least 60% of new rolling stock purchased for transit systems in the US be manufactured or assembled in the US, finally, increased funding for start-up projects in cities such as Los Angeles, Fort Lauderdale-Miami, Philadelphia, the Virgin Islands, and Santa Clara County.

Although not an extreme departure from past requirements, rules governing the distribution of federal funding for new rail transit starts were solidified and adjusted. Instead of basing eligibility for federal funding solely on an established formula (roughly half according to population and population density, and half according to service and ridership levels) (Pucher 1988, p. 384), the new process required alternative analyses and preliminary engineering studies in order to assist decision-makers in gauging the cost-effectiveness of proposed rail systems or extensions. In addition, the amount of local funding available for the new project was also taken into consideration. The result of changes in the determination of eligibility was that urban areas that wanted new rail transit or to expand existing systems were required to outline exactly where the funding for such projects would come; including federal, state and local government sources and predictions for farebox recovery rates. In essence, transit authorities were required to show the existence of local support and take more financial responsibility for new rail projects.

5. Transit Stabilizes and Grows - The Early 1990s

In the early 1990s mass transit in the US gained greater access to federal funding and increased flexibility of expenditure decisions. Under the Omnibus Budget Reconciliation Acts of 1990 and 1993 the portion of the Highway Trust Fund tax on motor fuels deposited into the Mass Transit Account was raised to \$0.015 in 1991 and raised again to \$0.02 in 1993. In addition, in 1991, the Surface Transportation Assistance Act was reauthorized as the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the transit law was renamed the Federal Transit Act and the UMTA was renamed the Federal Transit Administration (FTA). Aside from the name changes, several main goals were to be addressed by ISTEA. The first goal was to increase federal funding for transportation-related projects. The second was to promote a more regional approach toward transportation projects. The third was to strengthen the emphasis on the environmental aspects of transportation decisions.

With regards to the first goal, ISTEA represented a plan for nearly a 50% increase in yearly funding over the late 1980s: \$5 billion/year vs. 3.3 billion/year (Pucher 1995, p. 217). The second goal of a more regional approach toward transportation was to be accomplished by providing state and local governments and local transportation authorities a greater amount of flexibility in how they chose to use federal funding. Specifically ISTEA allowed states the option to use a total of \$28 billion, or 50% of their federal highway funds and 40% of their federal bridge funds for projects to improve public transport, carpooling, and bicycle or pedestrian facilities.

The third goal of increased emphasis on the environment was included primarily to assist state and local governments to meet the requirements of the Clean Air Act; restore and preserve wetlands; and finance transportation enhancements (US DOT 1992). In order to reach the third goal, the Congestion and Air Quality Improvement Program of ISTEA authorized $6 billion over 6 years for use in projects that can be shown to improve air quality and reduce roadway congestion.

6. Summary of Federal Involvement in Transportation Finance

What has been documented in this section is an increasing federal role in the provision of rail transit service in the US, including increased funding and control. Federal monies were first made available for capital expenses, then operating expenses. As the federal role increased, so too did the amount of regulation connected to federal funding. Finally, in the 1980s and 1990s, state and local officials gained control over the distribution of funding, but the federal government maintained a certain level of control by associating federal transportation funding with other federal policies such as the Federal Clean Air Act of 1990. The result has been a massive increase in both the amount of available funding and requirements associated with short and long-term planning of rail projects.

The days of a single entity having control over the design, funding and operation of a rail system are long gone. Many different entities are now involved including federal, state, regional and local governments and private sector developers. Each group has its own set of criteria by which it gauges rail transit system performance. The integration of funding and policy requirements at all levels of government has resulted in an immense industry with a nearly ad-hoc establishment of goals and methods to reach goals. Thus it is necessary for research to begin to address the question of the impact of a set of important factors on rail transit performance in order for rail transit operators to both set and meet long-term goals and increase rail transit's operating performance in urban areas throughout the US. That is what this study strives for: a bit of clarification in an otherwise hazy and confusing mesh of interconnected values and intersecting priorities that are associated with the operation of rail transit in the US.

C. Sources of Capital and Operating Funding for Mass Transit (1991-1995)

Where does the funding for transit system capital and operating expenses come from? This is the first piece of data that is necessary to begin to understand the impact that funding source and type have on the performance of transit systems in general, and, more specifically, rail transit systems in the US. This information is necessary because different levels of government have different goals with respect to public investment in transportation. If the US has entered into a fourth era of transportation that requires the incorporation of the goals of the first era – (cost efficiency), the goals of the second era – (public services), and the framework of the third era – (local control and responsibility), then not only is the level of government from where funding comes important, but also whether the funding is dedicated[2] or not. In order to answer these questions data from the Federal Transit Administration's (FTA) "Data Tables" report for the 1991 - 1995 National Transit Database Report Years were analyzed.[3]

1. Recent Trends in Total Available[4] Capital and Operating Funding (1991-1995)

a. Available Capital Funding

Capital funding for mass transit reached its highest level in history in 1995, the latest year for which data is readily accessible, as over $7 billion was made available from federal, state and local sources (See Table 1). From 1991-1995 the total amount of capital funding for transit from government sources increased approximately 35%: 12.5% from 1991-1993, a 2.4% decrease in 1994, and finally, a 25.1% increase from 1994-1995.

Table 1
Sources of Capital Funding 1991 - 1995 (Millions)

Source	1991	1992	1993	1994	1995
Federal	$ 2,545.0 (49.9%)	$ 2,598.7 (49.2%)	$ 2,383.5 (41.6%)	$ 2,518.1 (45.0%)	$ 3,313.7 (47.3%)

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[2] Dedicated funding refers to funding that is collected and dispersed for a specific purpose.

[3] 1995 was the most recent year for which comprehensive data on this subject was readily available.

[4] The term "available" refers to funding from all sources that could have been spent during the time period.

State	638.1 (12.5%)	777.7 (14.7%)	1,316.7 (23.0%)	1,005.5 (18.0%)	989.2 (14.1%)
Local	1,914.2 (37.6%)	1,906.2 (36.1%)	2,003.4 (34.9%)	2,074.8 (37.1%)	2,705.5 (38.6%)
Total	$ 5,097.3 (100%)	$ 5,282.6 (100%)	$ 5,733.6 (100%)	$ 5,598.4 (100%)	$ 7,008.4 (100%)

Source: National Transit Summaries and Trends 1995, Exhibit 2-1, pg. 21.

Federal capital assistance has continually represented the greatest source of available funding, with a high of 49.9% of total capital funds available to transit in 1991, a low of 41.6% in 1993, and 47.3% in 1995. Trends in state capital assistance were opposite of federal funds, increasing from 12.5% of the total in 1991 to 23% in 1993, the year federal percentages were at their lowest, and falling to 14.1% in 1995. Local sources of capital funds mirrored the percentage trends of federal funds, decreasing from 37.6% in 1991 to 35.4% in 1993, then increasing to 38.6% in 1995. Thus, for capital assistance in the 1990s, federal and local funding have followed similar trends, while state funding has had an opposite response to trends in federal funding.

b. Available Operating Funding

Overall operating funding for mass transit reached the highest level in history in 1994 with over $17.3 billion available from all sources (See Table 2). The level of operating funding then dropped less than 1% in 1995, but remained over the $17 billion level.

Table 2
Sources of Operating Funding 1991-1995 (Millions)

Source	1991	1992	1993	1994	1995
Government Subsidies					
Fed.	$ 850.0 (5.3%)	$ 849.1 (5.3%)	$ 913.0 (5.4%)	$ 861.5 (5.0%)	$ 767.8 (4.5%)
State	3,173.5 (19.9%)	3,680.6 (23.1%)	3,475.1 (20.7%)	3,626.7 (20.9%)	3,598.6 (21.0%)
Local	5,391.7 (33.8%)	4,832.6 (30.4%)	5,165.5 (30.8%)	5,815.4 (33.5%)	5,677.7 (33.1%)
Total	$ 9,415.2 (59.1%)	$ 9,362.3 (58.9%)	$ 9,553.6 (57.0%)	$ 10,303.6 (59.4%)	$ 10,044.1 (58.5%)
Directly Generated					
Pass. Fares	5,599.4 (35.1%)	5,697.3 (35.8%)	6,117.1 (36.5%)	6,466.4 (37.3%)	6,478.9 (37.7%)

Other	929.1 (5.8%)	848.2 (5.3%)	1,087.2 (6.5%)	574.7 (3.3%)	651.2 (3.8%)
Total	$ 6,528.5 (40.9%)	$ 6,545.5 (41.2%)	$ 7,204.3 (43%)	$ 7,041.1 (40.6%)	$ 7,130.1 (41.5%)
Operating Funding					
Total	$ 15,943.7(100%)	$ 15,907.8(100%)	$ 16,757.9(100%)	$ 17,344.7(100%)	$ 17,174.3(100)

Source: National Transit Summaries and Trends 1995, Exhibit 3-5, pg. 35.

State and local outlays for transit operations increased 13.4% and 5.3% respectively, from 1991-1995, while their percentages of total operating funds experienced a less than 1% change, leveling off in 1995 at 20.9% for state and 33.1% for local. Total federal outlays increased 10.7% over the same period, but the federal share of total operating funding decreased from 5.3% in 1991 to 4.5% in 1995.

Another main source of operating funding presented in the 1995 *National Transit Summaries and Trends* is "other" which represents approximately 43% of the total operating funds available to transit systems. "Other" includes funding collected directly by transit agencies such as revenue from passenger fares and advertising. Although the "other" category's overall share of total operating funds increased less than one percent between 1991 and 1995, for passenger fares, the main component of the category, revenue increased 15.7% from 1991-1995. The share of total operating funding generated by passenger fares also rose steadily from 35.1% in 1991 to 37.7% in 1995.

Thus, with respect to operating funding, total outlays continue to increase. Meanwhile state and local sources of funding are becoming increasingly more important as the federal government's role in providing direct funding for transit system operations diminishes. This declining federal role in rail transit finance is in accord with the relatively conservative policies pursued by republican administrations that held the presidency during the decade of the 1980s and into the early 1990s and whose policies have been continued by a republican-dominated Congress to the mid-1990s.

2. Government and Individual Sources of Applied Capital and Operating Funding - 1995[5]

a. Applied Capital Funding

In 1995 the largest governmental source of capital funds applied by all rail systems in the US was the federal government (47.3%), followed by directly generated (26.3%), state (14.1%), and local (12.3%). The largest individual sources of federal transit capital funds were the Capital Program (55.8%) and the Urbanized Area Formula Grant (42.7%).

b. Applied Operating Funding

In 1995, directly generated (transit agency) funds were the largest government source of operating funds applied (53%), followed by local (21.6%), state (21.0%) and federal (4.5%). The largest individual source of transit operating funds applied was passenger fares (35.4%).

3. Summary

Given that the trends of increased government subsidy of mass transit and increased financing of transit operations by state and local government in the US will continue, it has become increasingly necessary to assess the impact that source of government subsidies has on the performance of rail transit systems in the US. Only in this way will those involved in the planning and operation of rail transit systems be able to establish and reach long-term goals they have set for system operations.

D. Types of Mass Transportation Funding: Dedicated and General Revenue

The information in this section will assist in highlighting the importance of two funding types: dedicated and general revenue. The information is presented here in order to establish a basis for the argument presented in Chapter III that funding type - dedicated or general revenue, should be included in any analysis of the factors that affect rail transit system performance in the US if a greater understanding is to be gained.

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[5] The term "applied" means spent. In this instance capital and operating funding "applied" is used in that data for only one year, the most recent, was observed. When data for only one year is observed it is more accurate to consider "applied" rather than "available" funding as funding that is available in one year may be applied in subsequent years.

1. Definitions

Dedicated funding refers to funding that is both raised and then, by law, appropriated for a specific purpose. Dedicated funding sources for transportation are often supplied by specifically earmarked taxes. Taxes may be raised at the state, regional or local level. State taxes applied to dedicated funding sources for transit-related purposes often involve increases in sales, income, and property taxes. Regional and local sources of dedicated funding are often supplied by increases in sales taxes or bridge and tunnel tolls. Regional tax increases are often made possible by the passage of countywide initiatives and often result in sales tax increases (Pucher 1980). Other common sources of local, dedicated funding for transportation include payroll taxes, joint development fees, public/private partnerships, special assessments, and parking fees (McGillivray and Kirby 1979).

General revenue funding refers to funding that is not specifically raised or appropriated for a specific purpose. General revenue funding is most commonly supplied by property taxes and state grants (Fisher 1988). General revenue funding is flexible in that it may not have been allocated to a specific purpose prior to its being raised. Outlays from general revenue funds are usually subject to yearly budget negotiations conducted by elected officials and therefore are not guaranteed sources of transportation funding.

2. Sources of Dedicated and General Revenue Funding - 1995

This section provides a breakdown of the percentage of all rail transit capital and operating funding in the US that has been provided by state and local dedicated and general revenue sources. This section provides a framework from which to begin to understand the relationship between dedicated funding, public goals, and their impact on the performance of rail transit systems in the US.

* Applied Capital Funding

For capital funding in 1995, approximately 66.8% of state funds were from dedicated sources while 33.2% were from general revenue sources. For local funds, approximately 59.9% were from dedicated sources and 40.1% from general revenue sources

* Applied Operating Funding

In 1995 local sources of operating funds were split roughly in half with 50.8% from dedicated sources and 49.2% from general revenue sources. For state sources of operating funds, approximately 55.1% were from dedicated sources and 44.9% from general revenue sources.

a. Dedicated and General Revenue Funding Provided by Taxes

Presented in this section are the percentages of state and local taxes (by type of tax) dedicated to transit operating and capital funds. It is important to make a distinction between types of taxes in that, as will be argued in Chapter III, the competition for sales tax receipts is an important factor affecting the performance of mass transit systems throughout the US.

* Applied Capital Funding

In 1995 local taxes accounted for 37.8% of total dedicated taxes for mass transit capital funds, with directly generated (35%) and state (27%). The largest portion of local taxes was generated by sales tax (88.6%), while the largest potion of directly generated tax was also sales tax (98%). For state taxes, the largest contributor was the gas tax at (26.4%), next was "other" (25.1%), property tax (25%), and finally sales tax (23.5%).

* Applied Operating Funding

Of the total funds dedicated for mass transit operating funds in 1995, local taxes accounted for 35.5%, directly generated taxes (34.6%) and state taxes (29.9%). The largest portion of local taxes was provided by sales tax (80%). For directly generated taxes, "other" taxes[6] provided the largest portion (50%). The largest portion of state taxes was also generated by "other" taxes[7] (36.4%) while sales and gas taxes generated 24% and 23.5% respectively.

3. Advantages and Disadvantages of Dedicated and General Revenue Funding

a. Dedicated Funding

Dedicated sources of transportation funding offer one primary advantage; funding at a specific level is guaranteed for a specific amount of time. Guaranteed funding makes it possible for transit agencies to develop long-range plans. This is especially important for capital-intensive projects such as rail transit that operate along fixed routes. The argument is put forth that without dedicated funding, long-range planning is difficult and that subsequently, uncertainty over the availability of funding may result in shortsighted planning efforts (Heathington 1979). Short-term planning for long-term projects such as rail transit systems may result in incomplete or partially completed systems that offer relatively little in terms of transit service. Short-term planning involves short-term goals which are often not conducive to meeting long-term goals set forth for rail transit systems that often remain a part of the urban landscape for many decades.

A major disadvantage of dedicated funding is that the basic criteria that are required for a transit system to receive funding change very slowly and it is often very difficult to change the goals for which the funds are designated. If it is the intent of a region to build a rail transit system of a specific size to realize certain goals, the transit authority has an incentive to continue building and spending funds even after an agreed upon "optimum" size has been reached. Once funds have been dedicated, government agencies have an incentive to continue to spend those monies (Pucher, Markstedt, and Hirschman 1983). The end result is often increasing costs and decreasing productivity resulting, in a large part, from the guaranteed availability of funding.

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[6] For directly generated taxes, "other" taxes include all taxes except: income, sales, property and gasoline.

[7] For state and local taxes, "other" taxes include any special dedicated tax such as motor vehicle excise taxes and gross receipts tax, but excludes income, sales, and property or gasoline taxes.

b. General Revenue Funding

General revenue funding sources also have one primary advantage: they offer an opportunity to link funding to performance. Yearly budget negotiations insure at least an attempt at transit agency oversight based on an established set of criteria. It is the negotiation process that determines the level of available funding for the following fiscal year. Such negotiations can include consideration of transit system performance that can assist in insuring that transit systems are run more efficiently and that desired goals are being met. It is the possibility of changes in funding, either an increase or decrease, that gives transit authorities an incentive to improve service, while at least attempting to maintain system performance (Miller 1980).

An important disadvantage of flexible funding sources is that yearly budget negotiations can lead to extreme variation in year-to-year funding which can result in inappropriate, short-term planning, decreased quality of service, decreased ridership and an eventual deterioration in system productivity (Heathington 1979).

3. Summary

Although it is often required that funding from both dedicated and general revenue sources are allocated for specific purposes, there is one additional difference between the two that was not mentioned previously. The ease with which funds are reallocated is very different when comparing dedicated and general revenue funding sources (Manheim 1979). It can be a relatively straightforward administrative process (albeit at times a difficult political process) to reallocate general revenue funding; a vote of elected officials is usually required. It is much more difficult to obtain or change allocations for dedicated sources. Such changes almost always require a public vote, which is time consuming, expensive, and politically contentious.

Thus given the advantages and disadvantages of each, when considering the use of dedicated or general revenue funding the question is not whether funding should either be completely flexible or completely dedicated, but rather, what is the optimum combination of funding types necessary for transit systems to continue long-range planning, while incorporating shorter-term performance standards into decisions affecting system operations? Developing a theoretical optimum mix of funding types is beyond the scope of this study. What this study can do is to measure the impact that different combinations of dedicated and general revenue funding have had on the performance of rail transit systems in the US. Such information will assist transit operators and policymakers to understand the impact of funding type on rail transit performance.

E. Conclusion

The discussion in section A of this chapter concerning whether mass transportation in the US is a public good or a publicly provided private good makes it clear that transit system performance relies heavily on how society in general, and government in particular, view their role in the provision of mass transportation. The past involvement of the federal government in the provision of rail transit reveals a pattern of increasing federal involvement, especially at times when democrats held the Presidency. From the history of federal financial participation in rail transit presented in section B it is obvious that today the federal government has assumed a role that may be likened to that of a rich uncle, providing a majority of capital funding, yet requiring little in return. Meanwhile systems operating costs are left to state and local governments and the transit districts and systems themselves. For their part, state and local governments have increasingly relied on various types of dedicated taxes to supply operating funding for their rail systems, especially sales taxes.

Many would agree that government spending for mass transportation is a primary determinant of the impact of mass transportation in many ways. Many have at least an inkling of what those impacts might be, both economic and social. The crux of the matter is that past research has not fully addressed the impact of three important determinants of system productivity: subsidy type, program form, and program implementation. Past research has contributed a great deal to our knowledge regarding the impact of transit subsidies on transit system performance, but gaps remain, gaps that will be identified in Chapter II and filled in Chapter III of this research.

CHAPTER II

Measuring Transit System Performance

When changes in available capital and operating funds are considered, one must be sure to view such changes in real, inflation-adjusted, dollars. When adjusted for inflation, what happened to transit finance in the first half of the 1990s was an overall increase of 25.5% in the total amount of available capital funding and a 4.3% decrease in operating funding (National Transit Summaries and Trends 1995). While capital funding for transit projects continues to come primarily from federal sources, transit agencies at the state and local level have become heavily involved in the process of obtaining operating funding for their transit programs. One main contention of this research is that the concentration of transit agencies on obtaining continuous streams of operating funding has important, and measurable, impacts on the operating performance of rail transit systems in the US. Before that determination can be made it is important to take a look at past research in order to determine if there are gaps in existing research, and equally as important, how to fill such gaps with this research.

The first section of this chapter, section A, contains results from past research on the performance of transit systems, beginning with a short explanation of the importance of performance-related research in the transit field. Following a discussion of the need for conducting performance research is a section that reviews the impact of various types of government funding on mass transit system operating performance, including the impact of overall government subsidies, funding source, and funding type.

Section B of this chapter contains tables of performance measures included in transit performance research over a recent twenty-year period. In addition, Section B contains definitions and conceptual reasons for the inclusion of specific performance measures in previous research and in this research. The final portion of Section B includes a discussion of the performance measures selected for inclusion in this research, including indications, advantages and factors that affect the interpretation of each measure.

Presented in the final section of this chapter, section C, is a discussion of three important gaps in existing literature that have become apparent through the analysis of past research. These gaps include a determination of the impact of specific types and sources of government subsidies, the concentration of existing performance research on bus transit operations, and the determination of the impact of local political relationships on the operating performance of rail transit systems.

A. Past Research on Transit System Performance

1. Why Conduct Research on Transit System Performance?

The history of mass transit in the United States is well documented. From the earliest omnibuses (mid - 1820s) and steam railroads (early 1830s - 1850s), to the horse drawn streetcars (1850s - late 1880s) and finally the electrified street railways, cable cars and electric trolleys (1880s - 1910s), mass transit was primarily used as a way to extend urban boundaries (Warner 1962). As cities expanded, owners of large tracts of property, who also owned transit lines, were able to build suburban developments. Profits from development insured the continued expansion of transit. By the late nineteen teens and early 1920s automobile ownership had increased to a point where it began to have a negative impact on transit ridership. From then on, the auto became the largest source of transportation and private ownership of mass transit began to falter (Wachs 1984). If we skip ahead to the 1960s, we find that transit ridership had declined nearly 50% between 1950 and 1960, large-scale abandonment of routes continued, service quality decreased, and mass transit was in danger of disappearing altogether in many cities across the US. According to Fielding (1983) the social conflicts of the 1960s focused public attention on urban problems. Lack of adequate transportation was one urban problem that assisted local government officials in attracting government funds to their troubled cities. Mayors and labor union leaders alike supported transit as a focal point for public investment and the era of private ownership of mass transit virtually ended.

With public ownership and public assistance, the provision of mass transit was no longer a local issue. The public and government attached new expectations to mass transit (see Chapter I, Section A 1b for an in depth discussion of changing goals for transit). As goals for transit changed, a newly found interest in research associated with measuring and improving the productivity (output per dollar of input) of mass transportation systems began gaining momentum.

There were a number of reasons for this newfound interest in the productivity of mass transportation. First, public assistance, initially in the form of capital assistance (1964) and later in the form of operating assistance (1974), drastically changed the goals for mass transit, thus new ways of measuring and determining whether or not goals were being met were necessary. Second, federal subsidies, which had initially been offered as a way to prop-up an ailing transit industry quickly became an indispensable source of funding (Meyer, Kain, and Wohl 1965). If mass transit was ever to be weaned off of public assistance, research was necessary to determine the impact of applying or removing public assistance. Third, one of the main goals of government operating subsidies was to stabilize and increase transit ridership. This was accomplished by stabilizing, and in certain instances decreasing passenger fares, even in the face of rising operating costs (Lave 1991). As a result, transit agencies ran up large deficits (see Anderson 1983; Pucher, Markstedt, and Hirschman 1983; Bly and Oldfield 1985; Pickrell 1985; and Wachs 1989 for writings dealing with the connection between transit system deficits and government subsidies). It soon became apparent that research was necessary to understand the effects of government subsidies on transit system performance. Once the relationship was clarified, it was hoped that changes in the operation of public transit systems would increase system productivity, thereby decreasing financial shortfalls. Service levels and ridership would also increase and government subsidies would decrease as transit systems became more productive. As will be shown in the remainder of this section, although researchers have gained a detailed understanding of the impacts of subsidies on transit system productivity, there are still a great deal more details that can be incorporated into the current understanding of the subject.

2. Government Funding and Transit System Performance

The seminal research on developing transit performance measures was conducted in the mid-1970s by Fielding and Glauthier. Shortly afterward, Fielding, Glauthier, and Lave (1977) outlined how specific performance indicators could be applied to transit system management. This research addressed the questions of which performance indicators should be used for analysis and how they could be applied, but did not compare existing transit systems. Results of research that began measuring the impact of subsidies on transit system performance in a systematic and quantitative manner began appearing in academic journals in the late 1970s. Since that time researchers have used numerous performance indicators to both compare and contrast existing transit systems and to help understand the impact government subsidies have on transit system performance.

a. Overall Impact of Government Subsidies

In general, most research involving transit system performance has shown that government assistance has had both positive and negative impacts. Positive impacts include increased ridership, increased level of service (measured in vehicle miles of service), and reduced fares, while negative impacts include nearly all indicators involving costs. For example, one statistical study conducted by Bly, Webster, and Pounds (1980) which included data from transit systems in 18 nations including the US, UK, and the larger nations of Europe for the period of 1965 - 1977, indicated that a one percent increase in operating subsidy resulted in increases of 2-3% in ridership, increases of 0-3% in vehicle kilometers, decreases of 5-7% in fares, and increases of 4-6% in operating costs. In another study Pickrell (1985) found that for US transit providers between 1970 and 1982, ridership increased 1.8%, average fares decreased 20%, level of service increased 13.2%, and operating cost/vehicle mile increased nearly 62% of which nearly half was attributable to increases in driver's wages. Finally, results of Cervero's (1983) statistical study, which included data from 17 California transit properties from 1971-1981, indicated that government subsidies seemed to have the greatest impact on cost trends.

b. Impact of Funding Source: Federal, State, and Local Funding

Results of empirical research aimed at uncovering the impact that subsidies from different levels of government have on transit system costs have generally been conflicting. Pucher, Markstedt, and Hirschman (1983) in a statistical analysis of data from 77 US bus transit systems in 1979 and 135 systems in 1980, while not including local funding sources, found that federal subsidies had twice the impact on per-hour costs when compared to the impact of state subsidies. Cervero (1983, p. 551) found that in his California sample "the effects of local aid seemed generally to be about twice as great as federal aid, while state subsidies were largely inconsequential." Finally, Anderson (1983) in a study including data for the US bus transit industry from 1960-1975, found that local aid resulted in smaller increases in costs, larger decreases in average fares and smaller decreases in ridership and frequency of service than either state or federal aid. Also, federal aid resulted in the largest increases in costs.[8]

Thus although it seems clear that state funding contributes less to transit system cost increases than federal sources, the question remains of which source of funding, local or federal, contributes most to escalating costs.

c. Impact of Funding Type: Dedicated vs. General Revenue

As stated previously, dedicated funding refers to funding that is both raised and then appropriated for a specific purpose and is often supplied by specifically earmarked taxes.

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[8] Although Anderson (1983), Cervero (1983) and Pucher et al (1983) investigated the impact of subsidies from different levels of government on transit system performance, it must be noted that Anderson's study included only capital assistance, as operating assistance was not available until 1974, thus her study does not incorporate significant impacts on ridership and service levels that occurred in the mid-late 1970s.

Research which includes consideration of the type of funds available to transit systems are not common, but are in general agreement. For example, Pucher, Markstedt, and Hirschman (1983, p. 167) indicated "transit systems with more than half their state and local funding dedicated had costs that were $1.48 higher than systems with little or no dedicated funding." Meanwhile, Anderson (1983) in measuring the impact of what she called "passive sponsorship" or subsidies that are only loosely tied to performance standards also found that dedicated funding resulted in higher costs/hour. In addition, she found that transit authorities that had the power to collect taxes experienced higher costs/hour and paid higher wages than systems without taxing authority. Results of existing research indicate that wages are extremely important to transit system productivity as it has been estimated that labor costs make up as much as 74% of transit operating costs and increases in subsidies have been directly linked to increases in wages (Pickrell 1985).

Thus type of funding, dedicated or general revenue (non-dedicated), has been shown to have an important impact on the performance of transit systems in the US. Also of primary importance is whether or not a transit authority has the power to collect its own taxes as specified by the voters of a local transportation district.

3. Summary

Results of past research, although not necessarily in complete agreement, indicate that public operating assistance has had a significant impact on transit system performance both in the US and in Europe, especially for indicators that include cost considerations. With regards to the impact that subsidies from different levels of government (federal, state, or local) have on transit system performance, results are mixed. All that is really known is that impacts on performance are different depending on the level of government that provides subsidies. Also evident is that not only is the level of government from which subsidies are dispersed important, but, possibly even more important, are the requirements that are attached to government subsidies by policymakers at each level. Although past research has revealed that funding type, either dedicated or general revenue, may be an indication that specific requirements are tied to subsidies, past research has not addressed the question of the impact of funding type on transit system performance.

B. Two Elements of Transit System Performance - Efficiency and Effectiveness

1. Definitions and Widely Held Conceptualizations

Transit systems are not operated in vacuums. Nearly innumerable factors influence the ways in which nations, states, regions, and cities provide mass transportation. Inevitably the question is asked of which systems are doing the best job of providing transportation services. In order to attempt to make such a judgment, a set of criteria must be developed. Although nearly all would argue that comparisons among systems are necessary and can result in discoveries that can assist in improving the ways in which transportation is provided, few agree on the exact criteria to be used as a basis for comparison. Comparison of transit systems is primarily based on performance. Performance has been defined as being comprised of two elements: efficiency and effectiveness (Fielding and Glauthier 1976). Efficiency in transportation is a measure of the ratio of resource inputs to service outputs, (e.g. cost / vehicle-hour or vehicle-hour / employee), with the desired goal being to minimize input and maximize output. Effectiveness is a measure of how well goals are met by the provision of service (e.g. passengers / vehicle hour or revenue / expense). According to Fielding and Glauthier, 1976, efficiency measures reflect production, while effectiveness measures reflect consumption, thus the two types of measures should neither be confused nor combined in an analysis.

2. Typology of Performance Measures

Tables 3A, 3B, and 3C are based on categories developed by Fielding and Glauthier, 1976, and are an extension and refinement of a similar table presented by Miller in 1980. Tables 3A and 3B contain transit performance measures suggested in twenty studies conducted over twenty-years (1976 - 1996). The tables are broken down into two categories of performance measures: efficiency and effectiveness. The efficiency category is further separated into sections for cost measures, labor productivity, and vehicle utilization measures. The effectiveness category is also separated into sections for cost measures, accessibility, service utilization, quality, and other measures which do not fit into any of the existing categories. Overall, more than fifty separate performance measures are suggested by the twenty studies considered. Although each measure reveals a slightly different aspect of a system's performance, not all measures are appropriate, especially when considering only rail transit systems.

Table 3A
Transit Performance Measures Suggested By Various Studies
Efficiency

Measure	Study in which measure was used.
Efficiency	
(input per produced measure of output)	
Cost Measures	
Operating Cost / Vehicle-Mile	10, 11, 14, 17, 20
Operating Cost / Vehicle-Hour	1, 2, 5, 6, 8, 9, 11, 12, 13, 15, 16
Operating Cost (w/o Deprec.) / Vehicle-Hour	15
Cost / Seat-Kilometer	20
Labor Productivity	
Vehicle-Hour / Employee-Hour	6
Vehicle-Hours / Employee	1, 2, 3, 5, 11, 13, 15
Passengers / Employee-Hour	6
Passengers / Employee	4, 11
Passenger-Miles / Employee	10, 20
Passenger-Trips / Employee	10
Vehicle-Miles / Employee	10, 11, 13, 17, 20
Seat-Kilometer / Employee	20
Operator's Wage Rate	12, 13, 17
Vehicle Utilization	
Vehicle-Miles / Vehicle	3, 11
Vehicle-Hours / Vehicle	1, 2, 3, 6, 11
Average Vehicle-Hours / Vehicle	2
Vehicle-Miles / Vehicle-Hours	15
Peak-Vehicle / Base-Vehicle	15
Vehicle Miles Total	17
Vehicle-Miles / Route-Mile	12
Revenue Miles / Vehicle	11
Revenue Hours / Vehicle	11
Revenue / Vehicle-Hour	8, 18

Table 3B
Transit Performance Measures Suggested By Various Studies
Effectiveness

Measure	Study in which measure was used.
Effectiveness	
(consumption per consumed output unit)	
Cost Measures	
Operating Cost / Passenger (unlinked trip)	2, 4, 5, 10, 11, 12
Operating Cost / Revenue Passenger (linked trip)	2
Capital Cost / Passenger	19
Operating Cost / Passenger-Mile	6, 10,
Energy / Passenger	3
Accessibility	
Percent Population Served	1, 4
Percent Employment Served	4
Percent Transit Dependent Served	4
Service Utilization	
Passengers / Service Area Population	1, 2, 4
Passengers / Vehicle-Hour	3, 5, 6, 8, 9, 11,
Passengers/ Vehicle-Mile	11, 14
Passengers / Vehicle	2, 11
Passengers / Route-Mile	19
Passengers Total	12
Revenue Passengers / Revenue Vehicle-Hour	2
Transit Trips / All Other Trips	17
Ridership / Total Population	18
Percent Change in Ridership / Year	17, 18
Quality	
Percent Trips Missed	4
Seat-Hours / Capita	4
Transfer Opportunities / Route-Miles	4
Vehicle Cleanliness and Condition	7
Driver Performance	7
Headway	4
Other	
Deficit / Passenger-Mile	6
Revenue / Expense	3, 4, 6, 8, 9, 18
Revenue / Operating Expense	8, 14, 15
Revenue / Op. Expense + Depreciation	15
Revenue / Revenue Passengers	12, 14, 15
Subsidy / Passenger-Trip (linked)	18
Deficit / Passenger	14

Deficit (Revenue - Expense)	18

Table 3C
Studies Including Transit Performance Measures by Author and Year

1. Fielding, Glauthier (1976)
2. Fielding, Glauthier, Lave (1977)
3. Drosdat (1977)
4. California DOT (in Drosdat, 1977)
5. California Auditor General (1977)
6. Keck, Schneider - New York (1979)
7. Abrams, McLaughlin - New Jersey (1978)
8. Pennsylvania DOT (1975)
9. Miller (1980)
10. Bly, Webster, Pounds (1980)
11. Cervero (1983)
12. Anderson (1983)
13. Pucher, Markstedt, Hirschman (1983)
14. Pickrell (1985)
15. Lave (1991)
16. Pucher 1982
17. Wachs (1989)
18. Perl and Pucher (1995)
19. Lawlor (1995)
20. Wunsch (1996)

3. Individual Measures Selected for Inclusion in This Research

Any list of performance measures by which transportation systems are compared could be extensive. The goal of the current study is not to be exhaustive, but to provide a foundation from which to begin comparing the performance of all rail transit systems in the US. For this reason five measures, one representing each category from the list provided in Tables 3A and 3B save accessibility and quality, were chosen for use in evaluating system performance.[9] Performance measures representing system accessibility and quality are not common in existing literature as they are extremely difficult to interpret over time and across systems given that nearly innumerable local factors can affect the interpretation of either measure, therefore representative measures for these two categories are not included in this research.

a) Conceptual Reasoning Underlying Choice of Measures

Out of over fifty possible performance measures the group of five included in this research were chosen in order to create a tool that transit system operators and policy makers can use for comparing the performance of individual systems over time or among similar systems in regions across the US. Selecting a small group of measures is important in that the larger the number of indicators, the greater the incidence of disagreement as to the comparative value and final interpretation of results (see for example Fielding 1992 and Lee 1989 for writings on the difficulties associated with the interpretation of performance measures and comparing measures across systems). Basically this is a result of regional differences in operating goals for rail transit systems. As the number of performance measures increase, so too does the likelihood that the goals of individual systems will not be reflected by the chosen measures, therefore only a small number of performance measures are able to reflect the main goals of individual systems across the US.

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[9] Measures which include distance (e.g. cost per mile or miles per employee etc.) are not employed in that such measures are often extremely difficult to interpret as any number of locally contingent factors influence system size, route alignment, etc. and are not conducive to cross-system comparisons.

The five performance measures selected for this research were included for two main reasons. First, each measure reveals a different characteristic of rail transit system operating efficiency and effectiveness. Each measure yields insight into one of the five major facets of rail system operations. Efficiency: 1) cost per produced output unit; 2) labor productivity; 3) vehicle utilization. Effectiveness: 4) utilization of service. Efficiency and Effectiveness: 5) cost per consumed output unit. It is important that representative measures from each major facet of system operations be included in any analysis in order for policy makers and system operators to gain a more complete understanding of the entirety of transit operations.

Second, the five measures selected for this research are prominent in existing transit system performance evaluation literature. Each of the five measures has been included in no less than twenty-five percent of the twenty studies listed in Table 3C, while one variable, Operating Cost / Vehicle-Hour, was included in nearly sixty percent of the studies observed. This fact alone would not automatically insure the appropriateness of the five performance measures included in this research, but coupled with the fact that each of the five measures selected represents an important facet of transit system operations, the fact that many transit professionals accept the five measures as accurately representing important facets of transit system performance is an important indication of the accuracy of selections made in this research.

b. Performance Measures: Indications, Advantages and Factors Affecting Interpretation

This section contains a list of the five performance measures selected for inclusion in this research. Following the identification of each measure is an explanation of the facet of transit system performance represented by the measure, the insight into system operations provided by the measure, and the main factors that affect the interpretation of the measure.

Efficiency Measures

1. Operating Cost[10] / Vehicle-Hour

This measure is a cost measure that represents the ratio of total, yearly operating expenditures over total, yearly revenue vehicle hours. Total operating costs include expenditures for transportation, maintenance, marketing, fuel, and depreciation (Fielding and Glauthier 1976). This measure indicates the cost per vehicle-hour produced.

* Advantages

This measure is applicable to all sizes and modes of service and uses readily available data. The use of vehicle hours instead of vehicle miles assists in correcting for differences between transit properties including those relating to size, mode, congestion, and geography.

* Factors Affecting Interpretation

This measure is affected by the local peak / off-peak ratio, hours of daily service, and labor union contracts (Fielding, Glauthier, and Lave 1977). Specifically, the size and duration of an area's peak periods determines the number of vehicles and drivers that are necessary to provide adequate service to passengers. Fewer vehicles and drivers are necessary during off-peak hours, but many labor agreements prohibit requiring drivers to work split-shifts, thus the total number of drivers is determined by peak period capacity requirements rather than average daily ridership (Chomitz and Lave 1981). Systems with larger peak-periods may exhibit weaker efficiencies than systems in areas where peak periods are smaller.

2. Vehicle-Hours / Employee-Hour

This measure assists in determining a transit property's level of labor productivity. The measure represents the total, yearly revenue vehicle hours over the total number of employee -

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[10] In this section, the term "Total Operating Costs" is used as defined by Fielding and Glauthier, 1976, and includes expenditures for transportation, maintenance, marketing, fuel, and depreciation.

hours (operational and administrative) of a transit property. This measure indicates the number of vehicle-hours per employee-hour (output unit produced). In this case employee-hour is used rather than the number of employees. The reason for this is twofold. First, if the total number of employees is used, then part-time employees' labor is not included in the analysis. Second, data sources used in this analysis report the number of employee work hours, including part-time employee hours.

* Advantages

This measure uses readily available data, includes all personnel directly employed by the transit agency, and is applicable to all sizes and modes of transit operations.

* Factors Affecting Interpretation

Newly created or expanding systems will potentially have a greater number of employee hours than established, stable systems due to the need for contract employees for planning, construction, and public relations which will skew the employment numbers.

3. Vehicle-Hours / Vehicle Max

A vehicle utilization measure that represents the total, yearly vehicle hours over the maximum number of vehicles operated by a transit property at any one time during the year. This measure indicates the number of vehicle hours per vehicle (output unit produced). In this case the maximum number of vehicles operated during evening peak is used rather than the total number of vehicles owned by the transit authority. The reason for this is that it allows a more accurate interpretation of the utilization of vehicles in day-to-day operation and is unaffected by vehicle inventories which are more closely connected to capital expenses rather than operating expenses.

* Advantages

This measure uses physical rather than monetary units, thus it is relatively independent of wage rate differences among cities. Additionally, vehicle hours are used; thus it is relatively independent of local differences in speed, trip length and congestion.

* Factors Affecting Interpretation

This measure is primarily affected by peak / off-peak ratio. The concern is that the shorter and larger a transit property's peak period, the fewer hours vehicles would be in service, thus transit systems that experience a smaller peak / off-peak ratio would perform better according to this measure.

Effectiveness Measures

4. Passengers / Vehicle-Hour

A service utilization measure that represents the total, yearly, unlinked passenger trips over the total, yearly vehicle hours. This measure indicates system usage (consumption) per vehicle-hour produced.

* Advantages

As with the previous measure, this measure uses physical rather than monetary units, thus it is relatively independent of wage rate differences among cities. Additionally, vehicle hours are used; thus it is relatively independent of local differences in speed, trip length and congestion.

* Factors Affecting Interpretation

This measure is affected by the peak / off-peak ratio, hours of service, vehicle capacity, and average trip length of the system.

Overall Measure

5. Operating Cost / Passenger[11]

A cost measure that represents the ratio of total, yearly operating expenditures over the yearly total number of unlinked passenger trips. This measure indicates the cost per unit of output consumed.

* Advantages

This measure has been defined as an "overall performance measure for a transit system, combining efficiency (total operating costs) with the system's effectiveness (passengers)" (Fielding, Glauthier, and Lave 1977, p. 4; Cervero 1983).

* Factors Affecting Interpretation

This measure does not include operating revenues, thus a system that charges low fares would gain passengers which would reflect positively according to this measure, while having a poor Revenue / Expenditure ratio.

4. Summary

Five performance measures were selected for use in the performance analysis of rail transit systems in the US. Not only do each of the five measures reveal important information relating to each of the five major facets of transit performance, each measure is also well accepted in existing performance literature, appearing in no less than twenty-five percent of the studies listed in Table 3C.

The information presented in this section establishes a basis from which to begin an interpretation of results of performance measure analyses presented in Chapter IV. This section provides in-depth information concerning the definitions and conceptual underpinnings of the application of performance measures in existing literature in addition to a view of the advantages and difficulties involved in interpreting selected performance measures.

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[11] In this section the term "Passengers" refers to total unlinked trips. Although totals for linked passenger trips are preferable, those data are not readily available from US Federal Transit Administration sources.

C. Conclusion

This chapter reveals that three important gaps exist in the current literature involving rail transit system performance in the US. The first is in determining the impact that source and type of government funding has on transit system performance. Analysis of the financial information presented in Chapter I combined with the results of past research on transit system performance presented in Chapter II suggest that the goals for capital projects are primarily influenced by the federal government as it is that level of government which supplies the largest portion of capital assistance. For operating assistance, the picture is far murkier. The fact that local governments and individual transit authorities provide the largest share of operating funding suggests that their goals may be more readily pursued. Keeping with this line of reasoning, it therefore would not be incorrect to expect that local level funding has the greatest impact on system performance. Disagreement with this conclusion would be difficult but for the fact that a large share of operating funding is provided by dedicated sources which have relatively few performance requirements attached to them. Existing research has not fully examined this question, thus it is a goal of this research to strive to determine the impact that dedicated and general revenue funding have on the performance of individual transit systems.

Another gap in existing literature is that nearly all of the studies focus on bus transit. It is acknowledged that until recently adequate data for rail transit have not been available, but over the past several years rail transit data have been available and still few researchers have raised the question of the factors that affect the performance of rail transit systems. There are several reasons for focusing specifically on rail transit. First, rail transit systems have become high profile investments in larger urban areas across the US; nearly taking the position of municipal status symbols, a position that bus transit is not in. Second, rail transit operates along fixed routes often traversing numerous jurisdictions. This suggests that the amount of interjurisdictional cooperation necessary to establish rail systems is often greater than the amount necessary for bus transit systems. These first two factors suggest that not only are bus and rail transit systems often in competition for limited government funding, but that regions may be achieving different goals when they choose to construct and operate a rail system than they do by operating a bus system.

A final gap in existing literature is that transit system performance has often been viewed as being chiefly determined by analyzing system usage and financial data. If these were the only significant determinants then all systems could achieve optimum performance if only the right mix of funding per an established level of output could be determined. The problem is that there is little agreement as to the level of output or even what the exact output should be. Current literature on the subject does not adequately address the impact that political relationships have on transit system output by incorporating political information into analyses. This has resulted in an incomplete understanding of the factors that influence transit system performance in general and, more specifically, our understanding of rail transit system performance.

In Chapter III the gaps in existing literature identified in this chapter will be discussed in greater detail. Chapter III contains an explanation and outline of the methods used to conduct quantitative, statistical research in the area of rail transit performance.

CHAPTER III
Methods for Quantitative Analyses

Given the gaps in the existing literature that were highlighted in Chapter II, what is indicated is a new framework for the analysis of the nature of rail transit system performance. In this framework performance is viewed as being comprised of the following four dimensions: administrative, financial, demographic, and political. Each dimension serves to provide information about the effect of important performance components. The administrative dimension provides information about administrative decisions. The financial component provides information concerning the sources and types of funding provided to rail transit operators. The demographic dimension is concerned with providing information about demand for rail transit. Finally, the political dimension is concerned with providing information about the relationships between local jurisdictions and their impact on rail transit system performance. These four dimensions are interconnected and combine to form a more complete view of rail transit system performance than heretofore provided.

Data from each of the four dimensions were gathered to provide insight into the following areas:

1. The impact of administrative decisions that determine vehicle operations and scheduling and decisions associated with employee compensation packages and scheduling of work hours.

2. The impact of both source (i.e. federal, state, and local) and type (i.e. dedicated vs. flexible) of funding on rail transit system performance.

3. The impact of local demand for transit on rail transit system performance.

4. The nature and impact of interjurisdictional cooperation and conflict on rail transit system performance.

In order to fully understand the impacts of different variables on the performance of rail transit systems in the US, regression analysis was conducted to gain a macro level understanding of the impact of selected independent variables on those dependent variables described in Chapter II Section B3b.

A. Regression Analysis

The quantitative research method previously referred to is explained in detail in this section. Models for regression analysis are specified. Also included in this section is a discussion of the results of existing research involving the independent variables discussed previously in this paper; why they are applied in the current research, and the understanding expected to be gained from each.

1. Model Specification

Data for the five performance measures discussed previously in Chapter II were gathered from the Federal Transit Administration's Data Tables publication over a nine-year period, 1987 - 1995. The five measures served as the dependent variables in regressions and include: Operating Cost / Vehicle-Hour (COSTVEH); Vehicle-Hours / Employee-Hour (VEHEMP); Vehicle-Hours / Vehicle Max (VEHMAX); Passengers / Vehicle-Hour (PASSVEH); and Operating Cost / Passenger (COSTPASS). Definitions and descriptive statistics for each of the dependent variables are contained in Table 4.

Table 4
Descriptive Statistics for Dependent Variables Used in Regression Models

Variable Name	Definition	Mean	Standard Deviation
Efficiency Indicators			
COSTPASS	Operating cost per unlinked passenger trip	3.50	2.56
COSTVEH	Operating cost per vehicle revenue hour	196.58	85.47
VEHEMP	Vehicle revenue hours per employee work hours	0.26	0.10
VEHMAX	Vehicle revenue hours per maximum number of vehicles operated	4648.87	2035.58
Effectiveness Indicators			
PASSVEH	Unlinked passenger trips per vehicle revenue hour	73.82	30.76

Eight independent variables were hypothesized to influence the five performance measures referred to above. These included: the percentage of operating expenditures paid to employees as wages, salaries and fringe benefits (PAYROLL), the ratio of the number of vehicles operated in PM peak period to vehicles operated in average base period (PBRATIO), the percentage of operating funding provided by dedicated sources (TDED), the percentage of operating funding provided by state sources (TSTATE), the percentage of operating funding provided by local sources (TLOCAL), the population density of metropolitan areas in which transit districts are located (DENSITY), unemployment rates for metropolitan areas in which transit districts are located (UNEMP), and the ratio of central city population to the population of the metropolitan area in which transit systems are operated (PDOM) (See Table 5).

Table 5

Independent Variables For Mode Comparison

Independent Variable	Definition
PAYROLL	Transit employees' salaries, wages and fringe benefits as a percentage of operating costs
PBRATIO	Ratio of the number of vehicles operated in PM peak period to vehicles operated in average base period
TDED	Percent of operating subsidies from dedicated sources
TSTATE	Percent of operating funding provided by state sources
TLOCAL	Percent of operating funding provided by local sources
DENSITY	Population density of transit district
UNEMP	Unemployment rate in transit district
PDOM	Ratio of the population of the central city to the population of the metropolitan area in which systems were operated.

Each of the five regression models are specified as follows:

Performance Measure = *f* (PAYROLL, PBRATIO, TDED, TSTATE, TLOCAL,
DENSITY, UNEMP, PDOM)

Multiple Regression Analysis was used to estimate each model.

$$\text{Performance Measure} = \text{Constant} + B_1\text{PAYROLL} + B_2\text{PBRATIO} + B_3\text{TDED} + B_4\text{TSTATE} + B_5\text{TLOCAL} + B_6\text{DENSITY} + B_7\text{UNEMP} + B_8\text{PDOM} + E$$

2. Results of Existing Research

Independent variables were chosen because each influences performance in a substantial and specific manner. First, the administrative dimension of a transit district serves as an indication of administrative decisionmaking. Administrative decisionmaking is a key component of transit system performance for it is at the level of administration that system performance must ultimately be addressed, the point where goals and action meet. Potentially the two most important areas of decisionmaking that administrators face are associated with employee salaries and benefits (PAYROLL) and provision of service (PBRATIO) (Jennings, Smith, and Traynham 1978 and Wachs 1989), therefore both variables have been included in the models to determine their impact on the performance measures chosen for analysis. Existing research indicates that increases in the amount of salaries, wages, and benefits companies or agencies pay to its employees have a detrimental impact on the performance of the entity (Pucher, Markstedt, and Hirschman 1983 and Pickrell 1985). In addition, exiting research indicates that increases in the peak to base ratio of vehicles in operation also has a deleterious impact on system performance (Pucher, Markstedt, and Hirschman 1983). Declines in performance associated with increases in peak to base ratio have been attributed to the presence of employees who are paid, but idle during non-peak periods when service levels are low. Thus these two "administrative" variables have been included in this study to test the hypothesis that any increase in either variable has a negative impact on system performance.

Second, the financial dimension of a transit district serves as an indication of sources and types of funding provided to rail transit districts. Research indicates that the greater the percentage of operating costs supplied by subsidies, the larger the increase in overall costs (Altschuler, Womack, and Pucher 1981; Anderson 1983; Bly, Webster, and Pounds 1980; Cervero 1983; Pucher, Markstedt, and Hirschman 1983). The percentage of operating subsidies provided by state and local sources are included in the model to test the hypothesis that local subsidies have a greater impact on transit system performance than state subsidies. The main reason for testing this hypothesis is that financial involvement is often accompanied by regulation aimed at attaining goals that are less connected with the efficient provision of transit service than with the attainment of indirect social goals established by federal and state governments (Cervero 1983; Fielding 1983; Wachs 1989). A second reason for testing this hypothesis is that there exists little agreement in the literature as to which level of government subsidy has the greatest impact on transit system performance. A third financial variable, the percentage of funding from dedicated sources, is also included in the models. Researchers have often argued that dedicated funding reduces the incentive for cost control and improvement in productivity by local transit providers (Pucher, Markstedt, and Hirschman 1983). This question is especially important as a larger number of regions turn to tax increases that often serve as dedicated sources of mass transit funding.

Third, the demographic dimension of a transit district serves as an indication of potential transit usage. The first demographic variable (DENSITY) is included in the models because research has shown a strong relationship between population density and ridership, indicating that increases in population density result in increased transit patronage (Newman and Kenworthy 1989; Pusharev and Zupan 1977; Bernick and Hall 1990; and Frank and Pivo 1995). The second demographic variable, unemployment rate (UNEMP), is included in the models because research has shown a strong relationship between work-related travel and transit patronage (Cervero 1989; Pushkarev and Zupan 1977). Thus the unemployment rate of an area should provide insight into the local demand for mass transit.

Fourth, the political dimension of a transit district serves as an indication of the level of interjurisdictional cooperation or conflict that exists within a transit district. The final variable included in the regression models is the regional political dominance of the central city or (PDOM). This variable represents the ratio between the population of a central city and the population of the metropolitan area in which transit systems are operated. This variable serves as an indication of the relative political power of a central city with regard to decisions involving rail transit service provided to a metropolitan area. Specifically, intergovernmental interaction is necessary to not only plan for, construct, and operate rail transit systems, but also to increase their impact on the existing transportation system. Research indicates that in order to maximize a rail transit system's impact, local jurisdictions must strive to not only integrate rail service with existing transportation services, but also to increase development densities near transit stations, thereby increasing the demand for rail transit (Bernick and Cervero 1997). The integration of transit-oriented development (TOD) designs into local land use planning has recently gained much recognition in planning literature and is often referred to as being a necessary component of increasing the impact of rail transit systems in the US (Calthorpe 1993). The integration of local land use and regional transportation planning requires extensive cooperation among the jurisdictions through which rail transit systems operate. The degree to which cooperation or conflict exists between local jurisdictions with respect to regional transportation planning plays an important role in increasing the impact of rail transit systems. The inclusion of a variable designed to indicate the political dominance of the central city compared to the remainder of the metropolitan area therefore provides important insight into the role of political relationships in the operating performance of rail transit systems.

3. Expected Results

Expected results of regression analyses are included in Table 6. A discussion of and explanation for expected results are presented in the sections that follow.

Table 6 Expected Results of Regression Analyses

Expected relationships between performance measures and independent variables.

Independent	*Performance Measures*				
Variables	COSTVEH	COSTPASS	VEHEMP	VEHMAX	PASSVEH
PAYROLL	positive	positive	negative	negative	positive
PBRATIO	positive	positive	negative	negative	positive
TDED	positive	positive	negative	negative	negative
TSTATE	positive	positive	negative	negative	negative
TLOCAL	negative	negative	positive	positive	positive
DENSITY	negative	negative	positive	positive	positive
UNEMP	positive	positive	negative	positive	negative
PDOM	negative	positive	positive	positive	negative

a. Cost per Vehicle Hour of Service

$$\begin{aligned}\text{COSTVEH} = \text{Constant} &+ B_1\text{PAYROLL} + B_2\text{PBRATIO} + B_3\text{TDED} + B_4\text{TSTATE} \\ &+ B_5\text{TLOCAL} + B_6\text{DENSITY} + B_7\text{UNEMP} + B_8\text{PDOM} + E\end{aligned}$$

PAYROLL

In this case the hypothesis tested is that there is a positive relationship between the percentage of a transit property's budget paid out to employees as salaries, wages and fringe benefits and the transit system's costs per vehicle hour of service. A main reason for this expected result is that increases in employee compensation have a direct and positive impact on operating costs, while vehicle hours of service may either remain stable or increase more slowly than associated costs. Thus it is expected that an increase in transit system's PAYROLL results in a rate of increase in operating costs that outpaces increases in vehicle hours of service.

PBRATIO

The hypothesis tested here is that a positive relationship exists between the ratio of the number of vehicles operated during peak periods and those operated during an average base period and a transit system's costs per vehicle hour of service. The reason for this expected result is that any increase in the ratio between vehicles operated during peak and base periods necessarily results in increases in the maximum number of vehicles operated and the number of full-time equivalent employees necessary to operate such vehicles. An increase in the peak to base ratio results in only a marginal increase in the number of vehicle hours of service supplied, while all other factors associated with system operations increase, thus operating costs increase at a faster rate than vehicle hours.

TDED and TSTATE

This research tests the hypothesis that a positive relationship exists between the percentage of operating funding provided by either dedicated or state sources and a transit system's costs per vehicle hour. The main reason for this expected result is that funding from both dedicated and state sources is often targeted in areas of operations that are not associated with improving system efficiency. On the contrary, increases in the amount of funding from sources that are outside of a region are often directed toward employee's compensation or other activities not directly related to the efficient or effective provision of public transit service. Such actions necessarily result in increases in system operating costs that outpace increases in vehicle hours of service.

TLOCAL

This research tests the hypothesis that a negative relationship exists between the percentage of operating funding provided by local sources and a transit system's costs per vehicle hour. The main reason for this expected result is that local policies are more readily identifiable by the public and thus more likely to be connected with the efficient provision of service. Thus it is hypothesized that increases in the percentage of local funding result in increases in vehicle hours that outpace related increases in operating costs.

DENSITY

In this instance the hypothesis is that a negative relationship exists between density increases along a rail system's routes and the transit system's costs per vehicle hour of service. A main reason for this expected result is that as density increases peak periods expand, both in size and duration. The lengthening of the duration of peak periods results in a rate of increase in the number of vehicle hours that outpaces associated increases in operating costs. This result is mainly due to the necessity of employing full-time employees who are necessary to meet peak-period demand for service, but who are not providing service and are paid during off-peak periods. Thus as the duration of peak periods expands existing employees are available to meet demand, resulting in the ability of transit systems to increase vehicle hours with relatively little increase in operating costs.

UNEMP

The hypothesis here is that a positive relationship exists between the local unemployment rate and a transit system's costs per vehicle hour of service. A main reason for this expected result is that as unemployment increases, the number of trips taken decreases. As mentioned in the previous section, the largest percentages of trips made on public transportation are work-related. It is therefore expected that when unemployment increases, systems reduce the number of vehicles operating during peak periods, which results in a decrease in overall vehicle hours of operation. System costs, which to a large extent are dependent upon employee' salaries, also decrease, but at a slower rate than vehicle hours of service. The time gap that exists between increased unemployment, decreased vehicle hours of service, and the laying off of system employees results in the negative impact that increased unemployment has on system cost per vehicle hour of service. This is especially true for larger transit operators who must negotiate with powerful employee unions.

PDOM

The hypothesis here is that a negative relationship exists between the population of a central city relative to the population of an entire metropolitan area in which a rail transit system operates and the transit system's per vehicle hour operating costs. Specifically, the more dominant a central city is, the more likely it is that intermetropolitan cooperation exists, resulting in greater integration of all forms of public transit within the metropolitan area. As smaller, outlying cities encourage the expansion of rail lines and service within their jurisdictions, the rise in the total number of vehicle hours of service outpaces the rise in associated operating costs.

b. Cost per Passenger

$$\text{COSTPASS} = \text{Constant} + B_1\text{PAYROLL} + B_2\text{PBRATIO} + B_3\text{TDED} + B_4\text{TSTATE} \\ + B_5\text{TLOCAL} + B_6\text{DENSITY} + B_7\text{UNEMP} + B_8\text{PDOM} + E$$

PAYROLL

The hypothesis here is that a positive relationship exists between the percentage of a transit system's operating costs paid to employees as salaries, wages and fringe benefits and the system's costs per passenger trip. One major reason for this expected result is that increases in the percentage of operating costs paid to employees as wages, salaries and fringe benefits usually indicate and increase in transit system operating costs, while having relatively little impact on the total number of passenger trips.

PBRATIO

In this case the hypothesis is that a positive relationship exists between the ratio of the number of vehicles operated during peak periods and the number operated during base periods and a transit system's costs per passenger trip. Although a larger peak to base ratio indicates an overall increase in passenger trips, it also indicates an increase in system costs associated with increases in employee hours. As the number of employee hours increases so too do associated operating costs and due to the absence of split shifts, increased costs outpace ridership gains.

TDED and TSTATE

The hypothesis is that a positive relationship exists between the percentage of operating funding from dedicated or state sources and a transit system's costs per passenger trip. The reason for this expected result is that funding from outside sources is often used for service-related expenses which may have little impact on the total number of passenger trips relative to expenditures, thus there is a potential for costs to increase at a greater pace than passenger trips. In addition, such outside funding is frequently directed toward employee compensation that also tends to increase the ratio between operating costs and passenger trips.

TLOCAL

In this case the hypothesis is that a negative relationship exists between the percentage of operating funding provided by local sources and a transit system's costs per passenger. The local electorate more closely scrutinizes local sources of funding; therefore local officials are more likely to use such funding in a more efficient manner. Many see that getting more for the same cost is a sign of good management. As the percentage of total operating funding that comes from local sources increases, transit operators are more likely to pursue policies that strive to decrease the ratio between operating costs and passenger trips.

DENSITY

The hypothesis in this case is that a negative relationship exists between the population density in an area served by rail transit and a transit system's costs per passenger trip. Higher population densities cause congestion on local roadways that often results in increased transit usage. Although an increase in transit usage will likely result in increased operating cost, increases in passenger trips outpace cost increases.

UNEMP

In this instance the hypothesis is that a positive relationship exists between the local unemployment rate in a region in which a transit system operates and the system's costs per passenger. As the unemployment rate increases the number of passenger trips decreases, as most are work-related. The time necessary to adjust system costs, mainly by reducing service and system employment, results in costs remaining relatively stable while the number of passenger trips declines.

PDOM

The hypothesis is that a positive relationship exists between the ratio of central city population relative to the population of an entire metropolitan area in which a rail transit system operates and the system's per passenger operating costs. This expected result is due mainly to the expansion of service into less densely populated areas outside of the urban core. Although expanding service in jurisdictions outside of the urban core is potentially politically beneficial and can heighten a system's regional impact through increased overall ridership, such expansions frequently result in a rate of increase in operating costs that outpaces the rate of increase in passenger trips.

c. Vehicle Hour per Employee Hour

$$\begin{aligned} VEHEMP = {} & Constant + B_1PAYROLL + B_2PBRATIO + B_3TDED + B_4TSTATE \\ & + B_5TLOCAL + B_6DENSITY + B_7UNEMP + B_8PDOM + E \end{aligned}$$

PAYROLL

The hypothesis here is that a negative relationship exists between the percentage of operating costs paid to employees as wages, salaries and fringe benefits and the ratio between vehicle hours and employee hours. One reason for this expected result is that an increase in PAYROLL serves as an indication that either employees' salaries are increasing for the same amount of work, measured in hours, or that PAYROLL is increasing because existing employees are working more hours. While both can occur individually or simultaneously, only in the second instance is vehicle hour per employee hour affected.

PBRATIO

The hypothesis tested in this case is that there is a negative relationship between the ratio between vehicles operated during peak periods to vehicles operated in an average base period and a transit system's vehicle hours per employee hours. A main reason for this expected result is that an increase in the number of vehicles operating during peak periods results in an increase in the number of drivers necessary to operate the vehicles. The greater the peak to base ratio, the greater the increase in drivers, measured in terms of employee hours, necessary to meet peak period ridership demands. Meanwhile, off-peak ridership and corresponding service measured in terms of vehicle hours, remains relatively constant, resulting in fewer vehicle hours per employee hours.

TDED and TSTATE

In this instance the hypothesis is that a negative relationship exists between the percentage of operating subsidies provided by either dedicated or state sources and the ratio between vehicle hours and employee hours. One reason for this expected result is that while both sources of funding are frequently applied to increase the overall amount of service a transit property provides, such service increases tend to target peak periods. Increases in peak period service result in increases in both vehicle and employee hours, but during off-peak periods employee hours continue, while service, measured in vehicle hours, lessens. Therefore, an increase in either dedicated or state sources of funding has a negative impact on this performance measure.

TLOCAL

For this variable, the hypothesis is that a positive relationship exists between the percentage of operating funding provided by local sources and the ratio between vehicle hours and employee hours. One reason for this expected result is that funding from local sources results in a more efficient use of employees and a more efficient provision of service. An increase in the percentage of funding provided by local sources therefore results in a more evenly distributed rate of increase in both peak and off-peak service, further resulting in a correspondingly smaller increase in employees and employee hours.

DENSITY

In this case the hypothesis is that a positive relationship exists between the population density of an area in which a rail transit system is operated and the ratio between vehicle hours and employee hours. The primary reason for this expected result is that an increase in population density results in an increase in the total amount of service necessary to meet demand. Higher densities not only assist in expanding demand for peak-period service, both in terms of size and duration, but also demand for off-peak service. The result is an increase in both peak and non-peak service provided, measured in vehicle hours, which outpaces increases in the number of employee hours associated with enhanced service.

UNEMP

The hypothesis for this variable is that a negative relationship exists between the unemployment rate of an area in which a rail transit system is operated and the ratio between vehicle hours and employee hours. A main reason for this expected result is that as the unemployment rate increases, ridership, which is linked to work-related trips, decreases. As ridership decreases, service also decreases. The key here is the timing of the decrease in employee hours that correspond to decreased service. Decreases in service often occur at a faster pace than decreases in employee hours, thus an increase in the local unemployment rate results in fewer vehicle hours per employee hours.

PDOM

For this variable the hypothesis is that a positive relationship exists between the central city's population relative to the population of a metropolitan area in which a rail transit system is operated and the ratio of vehicle hours to employee hours. The explanation for this expected result is that increased center city dominance results in greater intermetropolitan cooperation, which, in turn, results in greater integration of all types of transit service. Rail service, measured in vehicle hours of operation, subsequently increases, especially with respect to off-peak service. Off-peak service requirements are readily met by existing employees who are necessary to meet peak period service requirements, with the result being vehicle hours of service increasing at a faster rate than employee hours.

d. Vehicle Hour per Vehicle Operated in Maximum Service

$$\begin{aligned} VEHMAX = {} & Constant + B_1PAYROLL + B_2PBRATIO + B_3TDED + B_4TSTATE \\ & + B_5TLOCAL + B_6DENSITY + B_7UNEMP + B_8PDOM + E \end{aligned}$$

PAYROLL

The hypothesis in this case is that a negative relationship exists between the percentage of operating costs paid to employees as wages, salaries and fringe benefits and a transit system's vehicle hours per vehicle operated in maximum service. A main reason for this expected result is that an increase in PAYROLL indicates an increase in payment to employees. Such an increase in a transit property's payroll may be attributed to increased employee compensation or increased service, measured in vehicle hours. Since a large percentage of service increases result from properties meeting peak hour travel demand, it is probable that such service increases result in an increase in the number of vehicles in operation. Again, when considering peak/off-peak service, increases in employee hours result from increases in the number of vehicles operated during peak hours rather than increases in the total number of vehicle hours of operation. Therefore increases in PAYROLL indicate a rate of increase in the maximum number of vehicles operated that outpaces increases in the total number of vehicle hours of operation.

PBRATIO

It is hypothesized that a negative relationship exists with respect to the ratio between the number of vehicles operated during peak hours and the number of vehicles operated during an average base period and the number of vehicle hours per vehicle operated during maximum service. An increase in the local peak period would result in a rate of increase in the total number of vehicles in service that is higher than the rate of increase of total vehicle hours of operation. As the peak to base ratio increases, the number of vehicles in operation that are necessary to meet peak demand increases at a faster rate than the total number of vehicle hours because of decreased vehicle operations during off-peak periods.

TDED and TSTATE

The hypothesis is that a negative relationship exists between the percentage of operating funding provided by either dedicated or state sources and the number of vehicle hours per vehicle operated during maximum service. The main reason is as has been stated in previous sections: funding from sources that are outside the local decision-making process tend to be applied without special regard to efficiency concerns. In this instance dedicated or state funding is likely directed toward expanding peak period service that results in a rate of increase in the maximum number of vehicles operated that outpaces the associated rate of increase in total vehicle hours of operation.

TLOCAL

In this case the hypothesis is that a positive relationship exists between the percentage of a property's operating budget provided by local sources and the number of vehicle hours per vehicle operated in maximum service. Again, when funding is provided by local sources, transit properties are operated more efficiently. This results in an increase in service provided for both peak and off-peak periods; with fewer vehicles being added during peak periods and more vehicle hours of operation added during non-peak periods.

DENSITY

A positive relationship is hypothesized to exist between the population density in a transit system's service area and the ratio between total vehicle hours of operation and the maximum number of vehicles operated during peak periods. Again, the greater the population density in an area, the greater the number of trips made in an area. As the population density increases, peak-periods expand both in size and duration. The key here is that longer peak periods result in a higher ratio of vehicle hours per vehicle operated during maximum service. In other words, the maximum number of vehicles operated by a transit property are operated for longer periods, thus the ratio between total vehicle hours of operation and the maximum number of vehicles operated during peak periods increases.

UNEMP

The hypothesis is that a positive relationship exists between an area's unemployment rate and the ratio between total vehicle hours of operation and the maximum number of vehicles operated during peak periods. A main reason for this expected result is that ridership during peak periods, which is primarily work related, decreases as the unemployment rate increases. The decrease in demand results in a faster rate of decrease in the number of vehicles operated during peak periods than the rate of decrease in total vehicle hours of operation that includes both peak and off-peak vehicle hours.

PDOM

In this case, the hypothesis is that a positive relationship exists between the ratio of central city population to the population of metropolitan areas in which a rail transit system operates and the total vehicle hours of operation per maximum number of vehicles operated during peak periods. The explanation for this expected result is once again due to the expansion in off-peak service. The number of vehicles necessary to provide service during peak periods is generally determined by demand generated by metropolitan cores. The greater a central city's political dominance in a metropolitan area, the greater the level of cooperation between individual jurisdictions, resulting in a greater integration of rail transit service with other forms of mass transit. The greater the intermetropolitan cooperation, the more likely it is that rail service, especially off-peak service, will be increased in areas outside of the urban core, resulting in a rate of increase in the total number of vehicle hours of operation that is faster than the increase in the maximum number of vehicles operated during peak periods.

e. Passengers per Vehicle Hour

$$\begin{aligned} PASSVEH = {} & Constant + B_1 PAYROLL + B_2 PBRATIO + B_3 TDED + B_4 TSTATE \\ & + B_5 TLOCAL + B_6 DENSITY + B_7 UNEMP + B_8 PDOM + E \end{aligned}$$

PAYROLL

It is hypothesized that a positive relationship exists between the percentage of a transit property's operating costs paid to employees as salaries, wages and fringe benefits and the number of passengers per vehicle hour of service. A main reason for this expected result is that an increase in PAYROLL is likely in response to an increase in peak period service. Peak period service expansion results in an increase in the number of vehicles operated, and an increase in the total passengers carried, but has a relatively minor impact on total vehicle hours of service. Therefore, increases in PAYROLL reflect the impact of increases in the demand for transit, measured in terms of passengers, which is greater than increases in the supply of transit, measured in terms of vehicle hours.

PBRATIO

In this instance the hypothesis is that a positive relationship exists with respect to the ratio between the number of vehicles operated during peak periods and the number of vehicles operated during a base period and the number of passengers per vehicle hour of service. A main reason for this expected result is that the increase in demand, measured in terms of passenger trips, that causes peak period expansion increases the number of vehicle hours of service during peak periods while demand remains relatively unchanged during non-peak periods. Thus an expansion of the peak to base ratio indicates a larger increase in passenger trips than vehicle hours of service.

TDED and TSTATE

The hypothesis here is that a negative relationship exists between the percentage of operating subsidies provided by dedicated or state sources and the number of passengers per vehicle hour of service. Again, funding from outside of the local decisionmaking process is generally applied with little consideration of its impact on the efficient operation of systems. An increase in service, whether peak or base period, that is not in response to an increase in passenger demand results in an increase in total vehicle hours of service, while the total number of passenger trips remains relatively constant.

TLOCAL

In this case the hypothesis is that a positive relationship exists between the percentage of a property's operating budget provided by local sources and the number of passengers per vehicle hour of service. Again, the greater the portion of operating funding provided from within the local decisionmaking process, the more likely it is that rail transit operators will be concerned with the efficient and effective application of the funds. Rather than simply increasing the level of service with little regard to the efficiency connected with such a decision, local transit operators are more likely to increase service only if such an increase is necessary because of existing demand for transit.

DENSITY

In this case the hypothesis is that a positive relationship exists between the population density in a transit system's service area and the number of passengers per vehicle hour of service. Population densities, and corresponding congestion, are important determinants of the demand for mass transit. If the population density of an area increases, the number of passengers demanding service increases, with the greatest increase in demand occurring during peak periods. As density increases, demand during both peak and non-peak periods increases, but non-peak period demand increases at a much slower rate than peak-period demand. The result is that the total number of passenger trips increases at a faster rate than total vehicle hours of service.

UNEMP

The hypothesis here is that a negative relationship exists between the unemployment rate in an area where rail transit systems are operated and the number of passengers per vehicle hour of service. The rationale behind this expected result is very similar to that employed when thinking about density, only in reverse. The greater the unemployment rate in an area, the fewer work-related trips made. Fewer work-related trips result in a decrease in demand for mass transit, thus fewer passenger trips. Again, it is necessary to consider the relative rates of decline between supply of and demand for transit. Changes in the supply of transit service are generally made in response to the demand for transit, thus decisions associated with changing the supply of transit often lag behind demand. Another consideration is that transit users generally do not respond to an over supply of transit as they do to an under supply of transit, the latter usually evoking a much more immediate and vocal response. Thus an increase in the local unemployment rate results in a decrease in the number of passengers that both precedes and outpaces the corresponding decrease in the number of vehicle hours of service provided.

PDOM

The hypothesis is that a negative relationship exists between the ratio of central city population to the total population of metropolitan areas in which a rail transit system is operated and the number of passengers per vehicle hour of service. Again, increased intermetropolitan cooperation resulting from the greater dominance of a central city results in increased rail transit service, especially off-peak service. Service increases in areas outside of the central city, where population densities are far lower than those in the urban core, result in a rate of increase of vehicle hours of service that is larger than the corresponding rate of increase in passenger trips.

4. Intermodal and Intramodal Comparison

The main objective of the regressions is to explain the variability in the values of each performance measure among the many heavy and light rail transit systems in the US. Due to the many differences that exist among different types of rail transit, it was necessary to separate systems by type: commuter, heavy, and light. Upon further comparison of system ownership, management, routing and general organization, physical, financial, and bureaucratic, it also became apparent that commuter rail transit should not be included in comparisons. Not only does the operation of commuter rail transit systems frequently involve numerous jurisdictions, private, state, regional, county, and local, the administration, financing, and especially the goals associated with the operation of commuter rail systems is far too complex to be included in the current research which primarily concentrates on the administration of individual rail transit operations within closely related metropolitan areas or specific regions. Therefore, results of regression models from data obtained for only two types of rail transit: heavy and light are presented in Chapter IV.

B. Conclusion

The importance of Chapter III is not only in the specification of regression models, but also the outline of a framework through which the relationship between important factors and rail transit system performance may be observed and understood. In this framework rail system performance is separated into four dimensions: administrative, financial, demographic, and political. Independent variables were chosen as representative of each dimension and included in the models to reveal unique insight into the nature of rail transit performance. Each dimension has been outlined and discussed in detail; including a discussion of how to interpret results of regression models. Finally, expected results of each regression model were presented according to results of past research and the understanding of performance developed through this research. In this way, results presented in Chapter IV of this paper will not only serve to strengthen the established understanding of the factors that affect transit performance, but also to expand understanding to include the nuances associated with interpreting the performance of rail transit systems.

Chapter IV contains the results of regression models specified in this chapter. The impact of variables representing the four dimensions of rail transit performance is determined and interpreted followed by a discussion of the nature of rail transit performance given results of regressions. The final section of Chapter IV contains a discussion of what has been learned through this research and the direction research should follow in order to gain an even greater understanding of rail transit system performance than currently available.

CHAPTER IV

Regression Results

Presented in the following chapter are results of regression analyses conducted using data from all heavy and light rail transit properties in the US, 1987 - 1995. In the first section, A, results of regressions run for both types of rail transit systems, heavy and light, are presented. The results of each regression are discussed, with special attention paid to the relationship between the independent variables and the performance measures identified and discussed in previous chapters. Also included in section A, following the discussion of the results of each model, is a short discussion concerning whether or not the hypotheses stated in Chapter III were proved or disproved. Presented in the second section, B, is a discussion of the macro-level understanding gained from the interpretation of regression results concerning the nature of rail transit performance in the US.

A. Regression Results By Type of Rail System: Heavy and Light

Presented in this section are results of ten regression models, two for each of the five indicators used to measure the performance of heavy and light rail transit systems in the US. The impact of statistically significant independent variables in each model is explained followed by a short discussion of whether or not the results were expected. The final portion of each section contains an explanation of what an unexpected result indicates about the impact of the specific independent variable on the performance measure included in the model presented at the beginning of the section.

1. Cost per Vehicle Hour of Service (COSTVEH)

$$\begin{aligned} COSTVEH = {} & Constant + B_1PAYROLL + B_2PBRATIO + B_3TDED + B_4TSTATE \\ & + B_5TLOCAL + B_6DENSITY + B_7UNEMP + B_8PDOM + E \end{aligned}$$

Figure 4.1

COSTVEH

	Heavy Rail	Light Rail
Number of obs.	81	60
R-squared	0.337	0.503
Adj R-squared	0.264	0.425

	Coef.	Std. Err.	t	P>|t|		Coef.	Std. Err.	t	P>|t|
PAYROLL	**-299.519**	**67.774**	**-4.419**	**0.000**		**-163.334**	**62.493**	**-2.614**	**0.012**
PBRATIO	**8.731**	**4.226**	**2.066**	**0.042**		11.344	12.024	0.943	0.350
TDED	**70.399**	**28.427**	**2.477**	**0.016**		**65.636**	**30.699**	**2.138**	**0.037**
TSTATE	**117.336**	**40.495**	**2.898**	**0.005**		**108.261**	**57.880**	**1.870**	**0.067**
TLOCAL	-22.083	31.907	-0.692	0.491		32.986	38.893	0.848	0.400
DENSITY	0.016	0.010	1.629	0.108		**0.067**	**0.019**	**3.538**	**0.001**
UNEMP	**8.834**	**3.496**	**2.527**	**0.014**		**-11.087**	**5.568**	**-1.991**	**0.052**
PDOM	-134.713	92.817	-1.451	0.151		-132.953	88.083	-1.509	0.137

Heavy Rail

The results of the model for heavy rail indicate that the coefficients of five variables were statistically significant at the 0.05 level. The variables represented the percentage of operating costs paid out to employees as salaries, wages and fringe benefits, the ratio of vehicles operated during peak periods to those operated during an average base period, the percentage of operating funding provided by dedicated sources, the percentage of operating funding provided by state sources, and the unemployment rate in the metropolitan areas in which heavy rail transit systems were operated.

Only the sign of the coefficient of PAYROLL was negative indicating that a decrease in the percentage of operating costs paid out to employees as salaries, wages and fringe benefits resulted in an increase in the hourly cost of operating a heavy rail vehicle.

The signs of the remaining four significant coefficients were positive indicating that increases in the ratio of vehicles operated during peak periods to those operated during an average base period (PBRATIO), the amount of funding from dedicated (TDED) or state (TSTATE) sources, or an increase in the local unemployment rate (UNEMP) resulted in an increase in the hourly operating cost of heavy rail transit vehicles in the US.

Figure 4.1A

Relationship between performance measure and independent variables.

Performance Measure: COSTVEH

Variable	Relationship	Expected	Unexpected
payroll	**negative**		**X**
pbratio	**positive**	**X**	
tded	**positive**	**X**	
tstate	**positive**	**X**	
unemp	**positive**	**X**	

Of those statistically significant variables, only the sign of PAYROLL was negative and unexpected, indicating that an increase in the percentage of operating costs paid out to employees as salaries, wages and fringe benefits resulted in a rate of increase in the total vehicle hours of service that was higher than the rate of increase in operating costs. The signs of the coefficients of the remaining statistically significant variables were as expected.

Light Rail

The results of the model for light rail indicate that the coefficients of three variables were statistically significant at the 0.05 level. The variables represented the percentage of operating costs paid out to employees as salaries, wages and fringe benefits, the percentage of operating funding provided by dedicated sources, and the population density of the metropolitan areas in which light rail systems were operated. Two variables were statistically significant at the 0.1

level; the percentage of operating funding provided state sources, and the unemployment rate of the metropolitan areas in which light rail systems were operated.

The positive signs of the coefficients of TDED, TSTATE and DENSITY indicate that an increase in their values resulted in an increase in the average hourly cost of operating a light rail vehicle in the US. The negative signs of the coefficients of PAYROLL and UNEMP indicate that an increase in the value of either resulted in a decrease in the average hourly cost of operating a light rail vehicle in the US.

Figure 4.1B

Relationship between performance measure and independent variables.

Performance Measure: COSTVEH

Variable	Relationship	Expected	Unexpected
payroll	**negative**		**X**
tded	**positive**	**X**	
tstate	**positive**	**X**	
density	**positive**		**X**
unemp	**negative**		**X**

In this case, the relationship between operating cost per vehicle hour (COSTVEH) and the percentage of operating funding provided by dedicated (TDED) and state (TSTATE) sources was as expected: positive. The signs of the coefficients of PAYROLL, DENSITY and UNEMP were unexpected. The negative relationship between COSTVEH and PAYROLL may indicate that an increase in the percentage of a transit property's operating costs paid to employees as wages, salaries and fringe benefits resulted in a rate of increase in the total vehicle hours of service that was higher than the rate of increase in operating costs. The positive relationship between operating cost per vehicle hour of service and DENSITY indicates that the per-hour costs of operating a light rail vehicle are greater in higher density regions. This may be a result of higher local wage rates in more dense areas. The negative relationship between

COSTVEH and UNEMP may indicate that an increase in the unemployment rate in metropolitan areas resulted in a decrease in the maximum number of vehicles operated. This result may be as a result of the nature of peak and base service requirements, where a decrease in the maximum number of vehicles operated results in decreases in employee-related operating costs that outpace decreases in vehicle hours of service provided.

2. Operating Cost / Passenger (COSTPASS)

$$\begin{aligned}\text{COSTPASS} = \text{constant} &+ B_1\text{PAYROLL} + B_2\text{PBRATIO} + B_3\text{TDED} + B_4\text{TSTATE} + \\ &B_5\text{TLOCAL} + B_6\text{DENSITY} + B_7\text{UNEMP} + B_8\text{PDOM} + \text{Error}\end{aligned}$$

Figure 4.2

COSTPASS

	Heavy Rail	Light Rail
Number of obs.	81	60
R-squared	0.425	0.141
Adj R-squared	0.361	0.006

	Coef.	Std. Err.	t	P>|t|		Coef.	Std. Err.	t	P>|t|
PAYROLL	**-3.137**	**0.930**	**-3.374**	**0.001**		-2.317	4.428	-0.523	0.603
PBRATIO	**0.102**	**0.058**	**1.752**	**0.084**		-0.592	0.852	-0.695	0.491
TDED	**1.094**	**0.390**	**2.805**	**0.006**		3.101	2.175	1.425	0.160
TSTATE	0.304	0.556	0.546	0.587		3.861	4.101	0.941	0.351
TLOCAL	-0.326	0.438	-0.746	0.458		1.049	2.756	0.381	0.705
DENSITY	0.000	0.000	-0.201	0.842		0.000	0.001	0.294	0.770
UNEMP	**0.205**	**0.048**	**4.278**	**0.000**		-0.577	0.395	-1.463	0.150
PDOM	0.032	1.274	0.025	0.980		4.891	6.242	0.784	0.437

Heavy Rail

The results of the model for heavy rail indicate that the coefficients of three variables were statistically significant at the 0.05 level. The variables represented the percentage of operating costs paid out to employees as salaries, wages and fringe benefits (PAYROLL), the percentage of operating funding provided by dedicated sources (TDED), and the unemployment rate of the metropolitan areas in which light rail systems were operated (UNEMP). The coefficient of the variable representing the ratio of vehicles operated during peak periods to those operated during an average base period (PBRATIO) was significant at the 0.1 level.

The positive signs of the coefficients of PBRATIO, TDED and UNEMP indicate that an increase in their values resulted in an increase in the yearly average operating cost per heavy rail passenger in the US. The negative sign of the coefficient of PAYROLL indicates that a decrease in its value resulted in an increase in the average operating cost per heavy rail passenger in the US.

Figure 4.2A

Relationship between performance measure and independent variables.

Performance Measure: COSTPASS

Variable	Relationship	Expected	Unexpected
payroll	**negative**		**X**
pbratio	**positive**	**X**	
tded	**positive**	**X**	
unemp	**positive**	**X**	

The signs of the coefficients of three statistically significant variables were positive and expected: the ratio of vehicles operated during peak periods to those operated during an average base period (PBRATIO), the percentage of operating funding provided by dedicated sources (TDED), and the unemployment rate of the metropolitan areas in which a rail systems were operated (UNEMP).

The sign of the coefficient of the variable representing the percentage of a transit property's operating costs paid to employees as salaries, wages and fringe benefits (PAYROLL) was unexpected. The unexpected sign of PAYROLL indicates that increases in the percentage of operating costs paid to employees resulted in a rate of increase in passengers that outpaced increases in operating costs. One possible explanation for this result is that an increase in PAYROLL indicates an increase in service-related employee hours. Increases in service may then result in a rate of increase in the number of passengers that outpaces associated increases in operating costs.

Light Rail

The results of the model for light rail indicate that none of the coefficients of any of the independent variables were statistically significant. This result indicates that the average operating cost per light rail transit passenger is not significantly related to changes in any of the independent variables chosen for inclusion in the model.

3. Vehicle Hour per Employee Hour (VEHEMP)

$$\begin{aligned}\text{VEHEMP} = \text{Constant} &+ B_1\text{PAYROLL} + B_2\text{PBRATIO} + B_3\text{TDED} + B_4\text{TSTATE} \\ &+ B_5\text{TLOCAL} + B_6\text{DENSITY} + B_7\text{UNEMP} + B_8\text{PDOM} + E\end{aligned}$$

Figure 4.3

VEHEMP

	Heavy Rail	Light Rail
Number of obs.	80	60
R-squared	0.31	0.408
Adj R-squared	0.232	0.315

	Coef.	Std. Err.	t	P>|t|		Coef.	Std. Err.	t	P>|t|
PAYROLL	**0.277**	**0.087**	**3.195**	**0.002**		**-0.197**	**0.097**	**-2.033**	**0.047**
PBRATIO	**-0.012**	**0.005**	**-2.275**	**0.026**		-0.011	0.019	-0.582	0.563
TDED	**-0.078**	**0.037**	**-2.124**	**0.037**		-0.073	0.048	-1.529	0.132
TSTATE	**-0.222**	**0.051**	**-4.369**	**0.000**		-0.091	0.090	-1.008	0.318
TLOCAL	-0.032	0.040	-0.785	0.435		-0.021	0.060	-0.351	0.727
DENSITY	0.000	0.000	0.129	0.898		**0.000**	**0.000**	**-1.972**	**0.054**
UNEMP	0.000	0.004	-0.078	0.938		0.009	0.009	1.097	0.278
PDOM	-0.026	0.117	-0.219	0.827		**0.304**	**0.137**	**2.220**	**0.031**

Heavy Rail

The results of the model for heavy rail indicate that the coefficients of four variables were statistically significant at the 0.05 level. The variables represented the percentage of operating costs paid out to employees as salaries, wages and fringe benefits (PAYROLL), the ratio of vehicles operated during peak periods to those operated during an average base period

(PBRATIO), and the percentage of operating funding provided by dedicated (TDED) and state (TSTATE) sources.

The positive sign of the coefficient of PAYROLL indicates that an increase in the percentage of operating costs paid out to employees as wages, salaries and fringe benefits resulted in an increase in the number of vehicle hours of operation per employee hour. The negative signs of the coefficients of PBRATIO, TDED and TSTATE indicate that an increase in their values resulted in a decrease in the number of heavy rail vehicle hours per employee hour.

Figure 4.3A

Relationship between performance measure and independent variables.

Performance Measure: VEHEMP

Variable	Relationship	Expected	Unexpected
payroll	**positive**		**X**
pbratio	**negative**	**X**	
tded	**negative**	**X**	
tstate	**negative**	**X**	

The signs of the coefficients of three variables, PBRATIO, TDED, and TSTATE, were negative and expected, while the sign of the coefficient of PAYROLL was positive and unexpected. This result indicates that an increase in PAYROLL resulted in a rate of increase in the number of vehicle hours of operation that outpaced any increase in employee hours. Such a result is likely attributable to increases in off-peak, rather than peak, period service. A main reason for this conclusion is that increases in peak period service result in increases in the number of vehicle operators, associated employee hours and vehicle hours of operation, such increases generally result in increases in employee hours that outpace increases in vehicle hours. Full-time employees are hired, while vehicles are operated only when necessary during peak periods. That is the opposite of what has occurred here. In this case what has happened is that as the percentage of heavy rail transit properties' budgets paid out to its employees has increased, the number of vehicle hours has increased faster than the number of employee hours, thus indicating that increases in PAYROLL were related to increases in off-peak service.

Light Rail

The results of the model for light rail indicate that the coefficients of two variables were statistically significant at the 0.05 level. The variables represented the percentage of a transit property's operating costs paid to employees as salaries, wages and fringe benefits (PAYROLL) and the ratio of central city population to the population of the metropolitan area (PDOM). The coefficient of the variable representing the population density of the metropolitan areas in which systems are operated (DENSITY) was statistically significant at the 0.1 level.

The negative signs of the coefficients of PAYROLL and DENSITY indicate that an increase in either the percentage of operating costs paid out to employees as salaries, wages and fringe benefits or the population density of the metropolitan areas in which systems were operated resulted in a decrease in the number of light rail vehicle hours per employee hour.

The positive sign of the coefficient of PDOM indicates that an increase in the ratio of central city population to the population of the metropolitan area resulted in an increase in the ratio of light rail vehicle hours to employee hours.

Figure 4.3B

Relationship between performance measure and independent variables.

Performance Measure: VEHEMP

Variable	Relationship	Expected	Unexpected
payroll	**negative**	**X**	
density	**negative**		**X**
pdom	**positive**	**X**	

The signs of the coefficients of two variables, PAYROLL and PDOM were as expected, while the sign of the coefficient of DENSITY was unexpected. One possible explanation for the unanticipated negative sign of the coefficient of DENSITY is that an increase in the density of a metropolitan area results in an increase in the size of the peak period that outpaces any increases in the duration of the peak period. If this is the case, the result would be a rate of increase in the number of employee hours that outpaces the associated rate of increase in vehicle hours of service and thus a negative relationship between density and the ratio of vehicle hours to employee hours.

4. Vehicle Hour per Vehicle Operated in Maximum Service (VEHMAX)

$$\begin{aligned} VEHMAX = {} & Constant + B_1 PAYROLL + B_2 PBRATIO + B_3 TDED + B_4 TSTATE \\ & + B_5 TLOCAL + B_6 DENSITY + B_7 UNEMP + B_8 PDOM + E \end{aligned}$$

Figure 4.4

VEHMAX

	Heavy Rail	Light Rail
Number of obs.	81	60
R-squared	0.649	0.242
Adj R-squared	0.61	0.123

	Coef.	Std. Err.	t	P>|t|		Coef.	Std. Err.	t	P>|t|
PAYROLL	**2874.662**	**714.107**	**4.026**	**0.000**		-207.385	1032.551	-0.201	0.842
PBRATIO	**-389.498**	**44.529**	**-8.747**	**0.000**		-220.552	198.667	-1.110	0.272
TDED	**-844.071**	**299.521**	**-2.818**	**0.006**		-640.615	507.234	-1.263	0.212
TSTATE	**-1354.482**	**426.684**	**-3.174**	**0.002**		-1077.529	956.328	-1.127	0.265
TLOCAL	214.223	336.193	0.637	0.526		-1066.830	642.618	-1.660	0.103
DENSITY	**-0.362**	**0.102**	**-3.565**	**0.001**		-0.205	0.314	-0.651	0.518
UNEMP	-56.767	36.836	-1.541	0.128		-12.887	92.004	-0.140	0.889
PDOM	**2384.492**	**977.978**	**2.438**	**0.017**		**2527.176**	**1455.362**	**1.736**	**0.089**

Heavy Rail

The results of the model for heavy rail indicate that the coefficients of six variables were statistically significant at the 0.05 level. The six variables represented the percentage of a transit property's operating costs paid to employees as salaries, wages and fringe benefits (PAYROLL), the ratio of vehicles operated during peak periods to those operated during an average base period (PBRATIO), the percentage of operating funding provided by dedicated sources (TDED), the percentage of operating funding provided by state sources (TSTATE), the population density of the metropolitan areas in which heavy rail systems were operated (DENSITY), and the ratio of central city population to the population of the metropolitan area (PDOM).

The positive signs of the coefficients of PAYROLL and PDOM indicate that an increase in their values resulted in an increase in the number of vehicle hours of operation per vehicle operated in maximum service.

The negative signs of the coefficients of four variables indicates that an increase in the peak to base ratio (PBRATIO), percentage of operating funding from dedicated (TDED) or state (TSTATE) sources, or population density of the metropolitan areas in which systems were operated (DENSITY) resulted in a decrease in the ratio between the number of hours of heavy rail vehicle operation and the total number of vehicles operated in maximum service.

Figure 4.4A

Relationship between performance measure and independent variables.

Performance Measure: VEHMAX

Variable	Relationship	Expected	Unexpected
payroll	**positive**		**X**
pbratio	**negative**	**X**	
tded	**negative**	**X**	
tstate	**negative**	**X**	
density	**negative**		**X**
pdom	**positive**	**X**	

While the signs of the coefficients of four variables; PBRATIO, TDED, TSTATE (negative), and PDOM (positive), were as expected, the signs of the coefficients of PAYROLL and DENSITY were not.

The positive relationship between PAYROLL and VEHMAX indicates that an increase in the percentage of operating costs paid to employees as salaries, wages and benefits resulted in an increase in the number of hours of operation per maximum number of heavy rail transit vehicles operated. Again, the most likely explanation for this unexpected result is that increases in PAYROLL were more closely associated with increases in off-peak hour service rather than peak-hour service.

The unexpected negative relationship between DENSITY and VEHMAX indicates that an increase in the population density of a metropolitan area in which heavy rail transit systems were operated resulted in fewer hours of operation per maximum number of heavy rail transit vehicles operated. Stated another way, the greater the density of a metropolitan area, the larger the disparity between peak and off-peak hour travel. The greater the disparity between peak and off-peak travel the greater the disparity between peak and off-peak transit service, thus the greater a city's density the greater the number of vehicles necessary to meet peak-hour demand. Meanwhile the level of service necessary to meet off-peak hour demand either remains relatively constant or increases at a much slower pace than peak-hour service.

Light Rail

The results of the model for light rail indicate that only the coefficient of one variable, that representing the ratio of central city population to the population of the metropolitan area (PDOM), was significant at the 0.1 level.

The positive sign of the coefficient of PDOM indicates that an increase in the ratio of central city population to the population of the metropolitan area resulted in an increase in the ratio between the number of vehicle hours of operation and the maximum number of light rail vehicles operated.

Figure 4.4B

Relationship between performance measure and independent variables.

Performance Measure: VEHMAX

Variable	Relationship	Expected	Unexpected
pdom	**positive**	**X**	

The sign of the coefficient of PDOM was positive and expected.

5. Passengers per Vehicle Hour (PASSVEH)

$$\text{PASSVEH} = \text{Constant} + B_1\text{PAYROLL} + B_2\text{PBRATIO} + B_3\text{TDED} + B_4\text{TSTATE} + B_5\text{TLOCAL} + B_6\text{DENSITY} + B_7\text{UNEMP} + B_8\text{PDOM} + E$$

Figure 4.5

PASSVEH

	Heavy Rail	Light Rail
Number of obs.	81	60
R-squared	0.337	0.386
Adj R-squared	0.263	0.289

	Coef.	Std. Err.	t	P>|t|		Coef.	Std. Err.	t	P>|t|
PAYROLL	-16.733	30.197	-0.554	0.581		3.940	36.337	0.108	0.914
PBRATIO	-1.894	1.883	-1.006	0.318		-10.485	6.991	-1.500	0.140
TDED	-14.630	12.666	-1.155	0.252		-18.955	17.850	-1.062	0.293
TSTATE	**47.326**	**18.043**	**2.623**	**0.011**		**-65.489**	**33.654**	**-1.946**	**0.057**
TLOCAL	-0.189	14.217	-0.013	0.989		-6.686	22.614	-0.296	0.769
DENSITY	**0.008**	**0.004**	**1.828**	**0.072**		**0.048**	**0.011**	**4.308**	**0.000**
UNEMP	**-4.598**	**1.558**	**-2.952**	**0.004**		1.113	3.238	0.344	0.733
PDOM	**-75.089**	**41.356**	**-1.816**	**0.074**		**-162.953**	**51.216**	**-3.182**	**0.002**

Heavy Rail

The results of the model for heavy rail indicate that the coefficients of two variables were statistically significant at the 0.05 level. The two variables represented the percentage of operating funding provided by state sources (TSTATE) and the unemployment rate of the metropolitan areas in which systems were operated (UNEMP). Additionally, two variables representing the population density of a metropolitan area in which heavy rail transit systems were operated (DENSITY) and the ratio of central city population to the population of the metropolitan area (PDOM) were significant at the 0.1 level.

The positive signs of the coefficients of TSTATE and DENSITY indicate that an increase in either resulted in an increase in the number of passenger trips made per hour of heavy rail vehicle operation. The negative signs of the coefficients of UNEMP and PDOM indicate that an increase in either resulted in a decrease in the number of passenger trips per hour of heavy rail vehicle operation.

Figure 4.5A

Relationship between performance measure and independent variables.

Performance Measure: PASSVEH

Variable	Relationship	Expected	Unexpected
tstate	**positive**		**X**
density	**positive**	**X**	
unemp	**negative**	**X**	
pdom	**negative**	**X**	

The signs of the coefficients of three statistically significant variables, DENSITY, UNEMP and PDOM, were as expected, while the sign of the coefficient for TSTATE was unexpected.

One possible explanation for the unexpected, positive sign of the coefficient for TSTATE is that funding provided by state sources was used to expand peak-period service rather than overall service. The expansion of peak-period service would tend to increase the number of passengers, while vehicle hours, a combination of peak and non-peak service, would remain relatively constant or increase at a much slower pace than peak-hour service alone.

Light Rail

The results of the model for light rail indicate that the coefficients of two variables, representing the population density of the metropolitan areas in which systems were operated (DENSITY) and the ratio of central city population to the population of the metropolitan area (PDOM), were statistically significant at the 0.05 level. The coefficient of the variable representing the percentage of operating funding provided by state sources (TSTATE) was statistically significant at the 0.1 level.

The negative signs of the coefficients of TSTATE and PDOM indicate that increases in the percentage of operating funding provided by state sources and the ratio between central city population and the population of the metropolitan area in which light rail systems were operated resulted in a decrease in the number of passenger trips made per light rail vehicle hour of operation. The positive sign of the coefficient of DENSITY indicates that an increase in the population density of metropolitan areas in which light rail systems were operated resulted in an increase in the number of passenger trips made per light rail vehicle hour.

Figure 4.5B

Relationship between performance measure and independent variables.

Performance Measure: PASSVEH

Variable	Relationship	Expected	Unexpected
tstate	**negative**	**X**	
density	**positive**	**X**	
pdom	**negative**	**X**	

The signs of the coefficients of all three variables: TSTATE, DENSITY, and PDOM were as expected.

B. Discussion of Regression Results

1. General Overview

As stated in Chapter II, section B1 of this paper, comparison of transit systems is primarily based on performance. Performance has been defined as being comprised of two elements: efficiency and effectiveness, where efficiency is a measure of the ratio of resource inputs to service outputs and effectiveness is a measure of how well goals are met by the provision of service (Fielding and Glauthier 1976). In other words, efficiency measures reflect production, while effectiveness measures reflect consumption. Also presented in previous chapters was the concept that performance is comprised of four dimensions, administrative, financial, demographic and political. In this research both efficiency and effectiveness measures served as dependent variables in regression models that were developed to determine the impact of a number of administrative, financial, demographic and political variables on the performance of both heavy and light rail transit systems in the US over a nine-year period (1987-1995).

Results of regression models indicate that a distinct difference in determinants of performance exists when comparing the operation of heavy and light rail transit systems. The impacts of independent variables representing the four dimensions of rail transit performance on performance measures are discussed in the following sections, where impact is a determination of whether an increase in the value of the independent variable would result in an increase in the value of the performance measure. For cost measures a positive impact required a decrease in the cost per output unit produced. For the ratios between vehicle hours and employee hours (VEHEMP) and vehicle hours and vehicles in maximum service (VEHMAX) a positive impact required an increase in the ratio of vehicle hours to employee hours or vehicles in maximum service. For the ratio of passenger trips to vehicle hours (PASSVEH) a positive impact required an increase in ratio of passenger trips to vehicle hours. The determination of the impact of independent variables on performance measures is not meant to imply that a positive impact is good or bad, only that efficiency or effectiveness, based on the relationship between independent variables and performance measures, would increase or decrease if the value of the independent variable increased.

a. Efficiency - COSTVEH, VEHEMP, VEHMAX

Three performance measures served as dependent variables in the models to indicate the efficiency, or input per output unit produced, of heavy and light rail transit systems in the US. The first of these variables, operating cost per vehicle hour (COSTVEH), indicates the cost per vehicle-hour produced. The second, vehicle hour per employee hour (VEHEMP), indicates the number of vehicle-hours per employee-hour or the labor productivity of a rail transit system. The third, vehicle hour per vehicle operated during maximum service (VEHMAX), indicates the number of vehicle hours per vehicle or the vehicle utilization of a rail transit system.

* Heavy Rail

Results of regressions indicate that one administrative variable, the percentage of operating funding paid out to employees as salaries, wages and fringe benefits (PAYROLL), had a positive impact on all three efficiency measures. Although the manner in which payroll-related funding was applied is unknown, results indicate that an increase in PAYROLL resulted in lower cost per vehicle, a higher ratio of vehicle hours to employee hours, and a higher ratio of vehicle hours to vehicles operated during maximum service of heavy rail transit systems in the US. These results were unexpected and require further investigation to more fully understand specifically how funding was applied.

The second administrative variable, the ratio of vehicles operated during peak periods to those operated during an average base period (PBRATIO), was found to have a negative impact on all three efficiency measures. This result was expected and indicates that heavy rail transit operators need to be aware that overemphasis on peak vs. non-period operations can lead to operating inefficiencies.

Of the three financial variables included in the models, the percentage of operating funding provided by dedicated (TDED) and state (TSTATE) sources was found to have had a negative impact on all efficiency measures. This result was expected and suggests that funding from dedicated and state sources has been applied by operators in a manner that has not been conducive to the efficient operation of heavy rail transit systems in the US.

Two variables were included in the models to determine the impact of demographic changes in areas in which heavy rail transit systems were operated. The two demographic variables represented the densities (DENSITY) and unemployment rates (UNEMP) of areas in which systems were operated. Each variable was found to have had a negative impact on one efficiency measure. Density was found to have had a negative impact on vehicle hours per vehicle operated during maximum service. This result was unexpected, but may be explained if increases in the densities of areas resulted in increases in peak hour demand for transit that outpaced increases in non-peak hour demand for transit. In such cases the number of vehicles operated in maximum service would increase at a faster pace than vehicle hours.

The unemployment rates of areas in which heavy rail transit systems were operated were found to have had a negative impact on cost per vehicle hour of service. This result was expected and may indicate that increased unemployment lead to decreases in ridership and service that outpaced decreases in associated operating costs. As payroll constitutes the largest portion of operating costs, results may indicate that operators should strive to insure that decreased demand for transit be accompanied by decreased supply of service. In other words, it is necessary for operators to insure that systems maintain labor at levels that are accurately reflected by demand for service.

Finally, one independent variable was included in the models to measure the impact that the local political climate has had on system efficiency. The variable included represented the ratio of central city population to the population of the metropolitan areas in which transit systems were operated (PDOM). Results indicate that the political dominance of the central city had a positive impact on one efficiency measure; vehicle hours per vehicle operated during maximum service. Results also indicate that the more dominant the largest city in a metropolitan area is, the more likely it is that there will be a greater number of vehicle hours of operation per maximum number of vehicles operated. The suggestion is that the greater the dominance of the central city, the more efficient a transit system's use of vehicles, which may be an indication that a greater level of intermetropolitan cooperation exists in such metropolitan areas.

* Light Rail

Results of regressions indicate that only one administrative variable, the percentage of operating funding paid out to employees as salaries, wages and fringe benefits (PAYROLL), had a statistically significant impact on two of three efficiency measures. The impact of PAYROLL on the two efficiency measures was conflicting, with PAYROLL having an unanticipated, positive impact on operating cost per vehicle hour and an anticipated, negative impact on vehicle hour per employee hour. This suggests that increases in the percentages of operating funding paid to employees by light rail transit operators have lead to lower costs per vehicle hour of service provided, while at the same time a reduction in labor productivity.

One possible explanation for the conflicting results is that light rail systems in the US are fairly new. Existing data reflects the fact that although start-up costs for rail systems are extremely high, systems are able to greatly reduce costs within the first several years of operation. This would help explain why an increase in the percentage of operating funding paid out to employees results in a decrease in cost per vehicle hour of service. In such an instance the percentage of the budget paid out to employees could increase, but because the total operating budget substantially decreases, cost per vehicle hour of service also decreases. In addition, an increase in the percentage of an operating budget paid out to employees would result in an increase in employee hours that outpaces increases in vehicle hours, which is what the results of the model indicate.

Of the three financial variables included in the models, the percentage of operating funding provided by dedicated (TDED) and state (TSTATE) sources were found to be statistically significant indicators of only one efficiency measure: cost per vehicle hour of service (COSTVEH). Regression results indicate that increases in the percentage of funding from both dedicated and state sources had a negative impact on cost per vehicle hour of service supplied by light rail transit systems in the US. This result suggests that funding from both dedicated and state sources have lead to higher costs per vehicle hour of light-rail transit systems in the US.

The two variables included in the models to determine the impact that demographic changes in areas in which light-rail transit systems were operated were found to have had both a negative and a positive impact on system efficiency. The first, the density of the metropolitan areas in which light rail systems were operated (DENSITY), was found to have had a negative impact on both cost per vehicle hour of service (COSTVEH) and vehicle hour of service per employee hour of service (VEHEMP). Results were unexpected and suggest that operators of light-rail transit systems need to pay special attention to the efficient operation of their systems when area densities increase. One possible explanation for these findings is that increases in demand for peak-period service have lead to increases in system payroll and thus operating costs, while the overall level of service provided, both peak and off-peak, has increased at a much slower rate.

The second demographic variable, the unemployment rate in areas in which systems were operated (UNEMP), was found to have had a positive impact on cost per vehicle hour of service (COSTVEH). This result was also unexpected and indicates that an increase in the unemployment rate in areas where light-rail transit systems were operated resulted in a decrease in cost per vehicle hour of service. Two possible explanations for this result are that either an increase in the unemployment rate lead to a reduction in the peak-period demand for service and system operators responded by cutting operating costs or, more likely, costs associated with system start-ups skewed results. Again, start-up costs for rail transit systems tend to be extremely high when compared to operating costs of existing systems. If system start-up costs skewed results, then unemployment could increase or decrease and systems would have lower costs per vehicle hour.

Finally, regression results indicate that the political dominance of the central city (PDOM) had a positive impact on two efficiency measures: vehicle hour per employee hour (VEHEMP) and vehicle hours per vehicle operated during maximum service (VEHMAX). The indication here is that the greater the dominance of the central city, the more likely it is that there will be a greater number of vehicle hours of operation per employee hour and per maximum number of vehicles operated. The suggestion is the same as with heavy rail systems, that the greater the dominance of the central city, the more efficient a light-rail transit system's use of vehicles, which may be an indication that a greater level of intermetropolitan cooperation exists in such metropolitan areas.

b. Effectiveness - PASSVEH

One performance measure served as the dependent variable in models used to indicate the effectiveness, or output consumed per unit of input, of heavy and light rail transit systems in the US. The variable, passenger trips per vehicle hour of service (PASSVEH), indicates system usage (consumption) per vehicle-hour produced.

* Heavy Rail

Results indicate that four independent variables affected the operating effectiveness of heavy rail transit in the US. Of the four variables, only the impact of the percentage of operating funding provided by state sources (TSTATE) was unexpected. The percentage of operating funding provided by state sources, included in the models to represent the financial dimension of rail transit performance, had a positive impact on the number of passenger trips per vehicle hour of service. This result suggests that funding from state sources was used to increase peak-hour service, which would lead to an increase in the number of passenger trips that outpaced any increase in vehicle hours. The potential problem here is that administrative policies that increase the supply of peak-hour service to increase system ridership and effectiveness, may also lead to decreased efficiencies. If increasing passenger trips is a goal, then it is necessary for transit operators to carefully balance service increases between peak and non-peak hours or suffer decreases in operating efficiency.

The two variables representing the demographic dimension of transit performance, the population density (DENSITY) and the unemployment rate (UNEMP) in areas in which rail transit systems were operated, had expected, but conflicting impacts on effectiveness. Increased density had a positive impact on the number of passenger trips per vehicle hour, indicating an increase in peak-period service. Increased unemployment had a negative impact on the number of passenger trips per vehicle hour. Again, as with the results for an increase in funding from state sources, changes in either demographic variable lead to changes in peak-period service, which could also have lead to decreases in system efficiency. The difference here is that demographic changes result in changes in demand, whereas changes relating to the administrative or financial dimension of rail transit performance result in changes in supply.

The final variable included in the models represented the political dimension of rail transit performance. The ratio of the population of the central city to the population of the metropolitan area in which rail systems were operated (PDOM) had a negative impact on the number of passenger trips per vehicle hour. The most likely explanation for this result is that the more dominant a central city, the more likely it is that systems have expanded into areas outside of the urban core. Expansion into less-densely populated areas results in increases in vehicle hours that outpace increases in ridership. This result suggests that operators of heavy rail transit systems must carefully choose the areas into which they expand service or declining system effectiveness may occur.

* Light Rail

Three factors were shown to have had an impact on the operating effectiveness of light rail transit in the US from 1987 - 1995. Two of the variables, the percentage of operating funding provided by state sources (TSTATE) and the ratio of the population of the central city to the population of the metropolitan area in which systems were operated (PDOM), were found to have had a negative impact on system effectiveness, while the population density of areas in which light rail systems were operated (DENSITY) was shown to have had a positive impact on system effectiveness.

The result of the regression model including TSTATE, a variable used to represent the financial dimension of rail transit performance, may indicate that state funding for light-rail transit has been used to expand service in areas where demand is lower than areas in which service was inaugurated. Such expansion would lead to an increase in the number of vehicle hours of service that outpaced any increases in passenger trips and therefore a negative impact on system efficiency.

The result of the model including DENSITY, a variable used to represent the demographic dimension of rail transit performance, indicates that an increase in the density of metropolitan areas in which light rail systems were operated had a positive impact on system effectiveness. This result is supported by results of previous research and suggests that system operators should strive to expand service in the highest density portions of the metropolitan area.

Finally, the result of the model including PDOM, a variable included in the models to represent the political dimension of rail transit performance, indicates that an increase in central city' dominance had a negative impact on passengers per vehicle hour. This result may suggest that the greater the dominance of a central city, the more likely it is that light rail service will be expanded in less dense areas outside of the urban core, resulting in a decrease in system effectiveness.

c. Overall Measure - COSTPASS

This performance measure served as the dependent variable in models used to indicate the overall performance of rail transit systems in the US from 1987 - 1995. This measure combines efficiency (total operating costs) and effectiveness (total passenger trips) and therefore is often used an as "overall" indicator of transit system performance.

* Heavy Rail

Both administrative variables, the percentage of operating costs paid out to employees as salaries, wages and fringe benefits (PAYROLL) and the ratio of vehicles operated in maximum service to those operated in an average base period (PBRATIO) were found to have had a significant impact on operating cost per passenger. Results indicate that an increase in PAYROLL had a positive impact on operating cost per passenger. Although this result was unexpected, it is in agreement with results of efficiency models where PAYROLL was also shown to have had a positive impact. This result suggests that choices system administrators have made with regard to the percentage of operating costs devoted to employee compensation are positively related to the efficient operation of heavy rail transit systems in the US.

The second administrative variable included in the models, PBRATIO, was shown to have had a negative impact on cost per passenger. This result indicates that an increase in the ratio of vehicles operated during peak periods to those operated during an average base period lead to an increase in cost per passenger. This result may indicate that costs related to the provision of service during peak periods are carried over to non-peak periods. The main reference in this case is to costs for labor. Employees are often hired to meet demand for peak-period service, but are also paid during off-peak periods when demand is low. The result is an increase in operating costs that outpace any increases in passenger trips. This result suggests that it is necessary for system operators to pursue policies that reduce the gap between peak and non-peak period service in order to decrease per passenger operating costs.

One financial variable, the percentage of operating costs provided by dedicated sources (TDED), was shown to have had a negative impact on cost per passenger. This result indicates that an increase in dedicated funding resulted in higher per passenger operating costs. This result suggests that adjustments in the way in which dedicated funding is distributed may be necessary in order to decrease the per passenger operating costs of heavy rail transit systems in the US.

Finally, one demographic variable, the unemployment rate of areas in which rail transit systems are operated (UNEMP), was shown to have had a negative impact on operating cost per passenger. This result is in agreement with results of prior research in this area and suggests that an increase in the unemployment rate leads to decreases in the number of passenger trips that outpace any decreases in operating costs. What is suggested here is that it is necessary for system operators to more quickly adjust operating costs during times of increased unemployment, in this way it may be possible to stabilize per passenger operating costs.

* Light Rail

None of the variables included in the models were shown to have had a statistically significant impact on the per-passenger operating costs of light-rail transit systems in the US from 1987-1995. This result is extremely interesting in that if variables applied in existing research are unable to assist in explaining the variation in the cost per light-rail passenger trip, then the current understanding of the process is woefully insufficient. The results of these models indicate that a new conceptualization of the determinants of the cost per light-rail passenger trip is required to allow researchers to begin to develop a greater understanding of the relationship between cost per passenger and light-rail transit system operation.

2. Thoughts on Results of Regressions

Regression results indicate that a significant difference exists between the operation of heavy and light rail transit systems in the US. Data for both types of rail transit systems were integrated into regression models using the same independent variables, with different results. Results indicate that administrators of heavy rail systems may be more likely to strive to achieve goals more closely associated with standard performance measures, while administrators of light rail systems may target different goals that are not directly associated with the existing performance measures included in this study and other established research.

Conflicting results, like those found in the models that included PAYROLL and its relationship to light-rail transit system efficiency, exemplify the complex relationship that exists between performance measures and factors that affect them. Numerous variables may serve to measure the efficiency or effectiveness of system operations. A positive relationship between one factor and an efficiency measure may be accompanied by a negative relationship between the same factor and another efficiency measure. Researchers and system operators must not only view the relationship between individual factors and individual performance measures, but also in relation to other efficiency and effectiveness measures. Only in this way can researchers and operators gain a clearer understanding of the impact of changes in factors representing the four dimensions of rail transit system performance on the efficiency and effectiveness of rail transit systems.

CHAPTER V

The Present and Future of Rail Transit Performance Research

The previous four chapters of this paper have served to provide insight into both the past and present of rail transit performance research. In chapter I the arguments for and against public involvement were presented, as was a history of federal financial involvement in rail transit in the US. In chapter II the history of transit performance-based research was investigated, the results of which were used to inform the development of the theoretical model presented in chapter III. In chapter IV the results and interpretations of regression analyses were presented. After all of the basis building and analysis of regression results the primary question that drives this research remains, how can the results of this research be used by those involved in the provision of rail transit service at the local, state, and national level? Stated another way, what can administrators, politicians, and the public expect when changes are made to the operations of rail transit systems?

In this final chapter the primary findings of this research are summarized and presented in a more useful and applicable manner than in chapter IV. Also included in this chapter is a consideration of the policy implications of the results of this research. In the final section of this chapter the future of rail transit performance research specifically and performance-based research in general is discussed.

A. Major Findings

* Heavy Rail

Research results indicate that many tradeoffs must be considered when performance decisions associated with the operation of heavy rail transit systems in the US are made (see Table 7). For example, if the percentage of employee compensation in an operating budget increase, cost efficiency improves. Vehicle utilization also improves. The tradeoff is that labor productivity declines. If administrators decide to increase the number of peak period vehicles in operation cost efficiency increases and vehicle utilization declines.

Heavy rail transit officials who lobby for increased funding from dedicated or state sources should realize that increases in dedicated funding cause costs to escalate, vehicle utilization to decline, and labor productivity to improve. State funding has the same impact as dedicated funding on costs, labor productivity, and vehicle utilization, while at the same time improving operating effectiveness or service utilization. Local funding was not shown to have either a detrimental or beneficial impact on system performance for reasons pointed out in chapter IV.

Transit operators have little or no control over changes in local demographic or political factors that affect rail transit performance. What operators should be aware of is that changes in these factors affect system performance and that they may want to adjust system operations in the event of changes in local demographics or political relationships. For example, increased density results in improved labor productivity and vehicle utilization, but declining service utilization. For unemployment, increases result in declining operating efficiency and effectiveness, thus a decline in overall performance.

Table 7 Summary of Regression Results[12]

HEAVY RAIL TRANSIT SYSTEMS

	COSTVEH	COSTPASS	VEHEMP	VEHMAX	PASSVEH
PAYROLL					
Coef.	**-299.519**	**-3.137**	**-163.334**	**2874.662**	-16.733
Std. Err.	**67.774**	**0.930**	**62.493**	**714.107**	30.197
PBRATIO					
Coef.	**8.731 4.226**	**0.102 0.058**	11.344	**-389.498**	-1.894
Std. Err.			12.024	**44.529**	1.883
TDED					
Coef.	**70.399**	**1.094 0.390**	**65.636**	**-844.071**	-14.630
Std. Err.	**28.427**		**30.699**	**299.521**	12.666
TSTATE					
Coef.	**117.336**	0.304 0.556	**108.261**	**-1354.482**	**47.326**
Std. Err.	**40.495**		**57.880**	**426.684**	**18.043**
TLOCAL					
Coef.	-22.083	-0.326	32.986	214.223	-0.189
Std. Err.	31.907	0.438	38.893	336.193	14.217
DENSITY					
Coef.	0.016	0.000 0.000	**0.067 0.019**	**-0.362 0.102**	**0.008**
Std. Err.	0.010				**0.004**
UNEMP					
Coef.	**8.834 3.496**	**0.205 0.048**	**-11.087**	-56.767	**-4.598**
Std. Err.			**5.568**	36.836	**1.558**
PDOM					
Coef.	-134.713	0.032 1.274	-132.953	**2384.492**	**-75.089**
Std. Err.	92.817		88.083	**977.978**	**41.356**

* Light Rail

For light rail transit systems in the US the interpretation of results is a bit more difficult. The main reason for this is that there are only a small number of light rail systems in the US and each are operated under such diverse circumstances that cross-sectional analyses can provide misleading results. With that in mind, results indicate that increases in the total amount of employee compensation result in improved cost efficiency and declining labor productivity. Increases in dedicated or state funding result in declining cost efficiencies, while increases in state funding also result in declining operating efficiency or service utilization.

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[12] Statistically significant results (@ .1 or .05 level) are in bold.

The impact of demographic factors on light rail transit system performance is mixed. Increased density results in declining cost efficiency, but improved labor efficiency and improved service effectiveness. Meanwhile, increased unemployment results in improved cost efficiency.

Table 8 Summary of Regression Results

LIGHT RAIL TRANSIT SYSTEMS

	COSTVEH	COSTPASS	VEHEMP	VEHMAX	PASSVEH
PAYROLL					
Coef.	**-163.334**	-2.317	**-0.197**	-207.385	3.940
Std. Err.	**62.493**	4.428	**0.097**	1032.551	36.337
PBRATIO					
Coef.	11.344	-0.592	-0.011	-220.552	-10.485
Std. Err.	12.024	0.852	0.019	198.667	6.991
TDED					
Coef.	**65.636**	3.101 2.175	-0.073	-640.615	-18.955
Std. Err.	**30.699**		0.048	507.234	17.850
TSTATE					
Coef.	**108.261**	3.861 4.101	-0.091	-1077.529	**-65.489**
Std. Err.	**57.880**		0.090	956.328	**33.654**
TLOCAL					
Coef.	32.986	1.049 2.756	-0.021	-1066.830	-6.686
Std. Err.	38.893		0.060	642.618	22.614
DENSITY					
Coef.	**0.067 0.019**	0.000 0.001	**0.000**	-0.205	**0.048 0.011**
Std. Err.			**0.000**	0.314	
UNEMP					
Coef.	**-11.087**	-0.577	0.009	-12.887	1.113 3.238
Std. Err.	**5.568**	0.395	0.009	92.004	
PDOM					
Coef.	-132.953	4.891 6.242	**0.304**	**2527.176**	**-162.953**
Std. Err.	88.083		**0.137**	**1455.362**	**51.216**

B. Policy Implications

One important policy implication that is apparent from the results of this research is that there is an extreme difference between the operation and thus administration of heavy and light rail transit systems in the US. Established performance measures were reasonably accurate in explaining the variation in the operating performance of heavy rail transit systems, but not light rail transit systems. Several points have been clarified with respect to the results of this research and their policy implications for rail transit system operations. First, policies that provide for state or guaranteed funding have resulted in cost increases that have outpaced increases in either vehicle hours of service produced or passenger trips and a decline in the efficient use of vehicles. At the same time, financial policies have also resulted in improved labor productivity and vehicle utilization.

For light rail systems policies that provide for state or guaranteed funding have also resulted in cost increases that have outpaced increases in vehicle hours of service produced. Policies have also resulted in a decline in the number of passenger trips per vehicle hour of service, or system effectiveness.

In summation, the best advice is that public officials must be aware that there are constant tradeoffs between system efficiencies and effectiveness. A policy that serves to improve the operating efficiency of rail transit systems, whether heavy or light, is likely to damage operating effectiveness. The most important activity that policy makers and system administrators can do is to make sure that they have established clear operating goals. To be sure it is a balancing act among many interested parties, but without clear goals, rail transit systems will run the risk of inefficiently pursuing operating goals that are also ineffective.

C. Future Research

* Performance of Rail Transit Systems

A main goal of the current research was to determine the impact of funding from local sources on the performance of rail transit systems in the US. Unfortunately, the percentage of operating funding provided by local sources was not found to be a statistically significant indicator of transit system performance in any of the regression models. One possible explanation for this result is that local funding over the nine-year period had little impact on the operation of rail transit systems in the US. Another more likely explanation is that because financial data were only available for the operating budgets of entire systems and not individual transit modes, the impact of local funding for rail transit was somehow hidden within large budgets that often included many different modes of transit service. In order to determine the impact of local funding, future research must strive to separate funding for each mode. This will be an extremely difficult task, but is necessary if the full impact of funding from dedicated, state and local sources is to be more accurately determined.

Regressions conducted in this research have aided in the understanding of the relationship that variables from the four dimensions of rail transit performance have with transit performance measures. Regression results have not lead to greater understanding in several important areas. The first is whether or not established performance measures are important to transit system operators. If they are not important to system operators, then the question becomes how transit operators measure the performance of their systems. Another area of concern is whether established performance measures reflect the goals that local operators, politicians, interest groups, and citizens have for their rail transit systems. Again, if established performance indicators do not reflect local goals for rail transit, then what factors do?

One way to begin to answer these questions is to conduct case studies on the impact of state-mandated performance policies on the performance of rail transit systems located in different regions across the US. Of primary concern in such research is the response of local interest groups to reported performance results associated with government transportation policies. Qualitative research in this area could potentially lead to a far more complete understanding of transit system performance by beginning to reveal the extent to which established performance measures reflect local goals for rail transit systems. A combination of both quantitative and qualitative research would lead to a more in-depth and useful understanding of the determinants of rail transit system performance than provided in existing research.

* Performance Evaluation in Additional Fields

Over the past thirty years methodologies for measuring the performance of mass transit systems have undergone a great deal of modification and refinement. A great deal of time and effort has been expended on developing both frameworks and individual performance indicators that reflect specific aspects of transit system performance. Although nearly all of the research was conducted with the sole purpose of advancing the existing understanding of the performance of mass transportation systems, this area of research also represents an opportunity for application in numerous other areas.

In recent years government oversight of government-operated or government-sponsored programs has substantially increased. Nearly every entity that receives government funding is required to perform at least some type of performance evaluation to determine if funds are applied to promote desired goals. The long line of performance research that has been instrumental in developing and refining frameworks for application in the transportation field is also applicable in many other fields of interest. The application of transportation-related performance evaluation frameworks in fields outside of transportation would not only result in the rapid advancement of performance evaluation in those fields of inquiry, but also lead to the advancement of the current understanding of the performance of mass transportation systems.

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Surface Transportation Assistance Act of 1978

Surface Transportation Assistance Act of 1982

Federal Mass Transportation Act of 1987

Omnibus Budget Reconciliation Act of 1990

Omnibus Budget Reconciliation Act of 1993

Intermodal Surface Transportation Efficiency Act of 1991

Federal Clean Air Act of 1990

Appendix A -US RAIL TRANSIT AUTHORITIES

City	State	Transit System	System Type
Los Angeles	CA	Southern California Regional Rail Authority	CRTS
San Francisco	CA	CalTrain	CRTS
San Diego	CA	North San Diego County Transit District	CRTS
San Francisco	CA	San Francisco Muni	CRTS
Los Angeles	CA	Los Angeles County Metropolitan Transportation Authority	HRTS
San Francisco	CA	San Francisco Bay Area Rapid Transit District	HRTS
Los Angeles	CA	Los Angeles County Metropolitan Transportation Authority	LRTS
Sacramento	CA	Sacramento Regional Transit District	LRTS
San Diego	CA	San Diego Metropolitan Transit Development Board	LRTS
San Francisco	CA	San Francisco Municipal Railway	LRTS
San Jose	CA	Santa Clara County Transit District	LRTS
Denver	CO	Denver Regional Transportation District	LRTS
New Haven	CT	Connecticut Department of Transportation	CRTS
Washington	DC	Washington Metropolitan Area Transit Authority	HRTS
Miami	FL	Tri-Rail Commuter Rail Authority	CRTS
Miami	FL	Metro-Dade Transit Agency	HRTS
Atlanta	GA	Metropolitan Atlanta Rapid Transit Authority	HRTS
Chicago	IL	Regional Transportation Authority	CRTS
Chicago	IL	Regional Transportation Authority	HRTS
Chicago	IN	Northern Indiana Commuter Transportation District	CRTS
New Orleans	LA	Regional Transit Authority of Orleans & Jefferson	LRTS
Boston	MA	Massachusetts Bay Transportation Authority	CRTS
Boston	MA	Massachusetts Bay Transportation Authority	HRTS
Boston	MA	Massachusetts Bay Transportation Authority	LRTS
Baltimore	MD	Mass Transit Administration, Maryland DOT	CRTS
Baltimore	MD	Mass Transit Administration, Maryland DOT	HRTS
Baltimore	MD	Mass Transit Administration, Maryland DOT	LRTS
Saint Louis	MO	Bi-State Development Agency	LRTS
New York	NJ	New Jersey Transit Corporation	CRTS
Philadelphia	NJ	Port Authority Transit Corporation of PA and NJ	HRTS
New York	NJ	New Jersey Transit Corporation	LRTS
New York	NY	MTA Long Island Railroad (LIRR)	CRTS
Syracuse	NY	METRO North	CRTS
New York	NY	New York City Transit Authority (NYCTA)	HRTS
New York	NY	MTA Staten Island	HRTS
New York	NY	Port Authority of New York and New Jersey	HRTS
Buffalo	NY	Niagara Frontier Transit Metro System	LRTS
Cleveland	OH	Greater Cleveland Regional Transit Authority	HRTS
Cleveland	OH	Greater Cleveland Regional Transit Authority	LRTS
Portland	OR	Tri-County Metropolitan Transportation District of Oregon	LRTS
Philadelphia	PA	Pennsylvania Department of Transportation	CRTS
Philadelphia	PA	Southeastern Pennsylvania Transportation Authority	CRTS
Philadelphia	PA	Southeastern Pennsylvania Transportation Authority	HRTS
Philadelphia	PA	Southeastern Pennsylvania Transportation Authority	LRTS
Pittsburgh	PA	Port Authority of Allegheny County	LRTS
Memphis	TN	Memphis Area Transit Authority	LRTS
Galveston	TX	Island Transit	LRTS
Washington	VA	Virginia Railway Express	CRTS