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An Econometric Analysis of Determinants of Transit Ridership: 1960-1990

by

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Executive Summary

This study examines the principal determinants of the levels and changes in transit ridership for the U.S. transit operators over the 30 year period from 1960 to 1990. Transit ridership is represented by annual boardings. We would have preferred to have used linked trips for these analyses, but linked trip data are simply unavailable for most of the transit systems and 30-year period analyzed in this study.

Two types of econometric analyses are presented in this report. The first consists of 19 multiple regression equations that explain changes in annual boardings for linked samples of individual operators during 1960-70, 1970-80 and 1980-90. The second consists of 36 multiple regressions that explain variations in the levels of annual transit boardings for the individual years 1960, 1970, 1980, and 1990 respectively. The 1960 and 1970 analyses provide separate estimates for large and small systems, as well as pooled analyses.

The change and cross-section analyses both attempt to quantify the independent contributions of so-called policy and control variables to transit ridership. The distinction between these two types of explanatory variables is that policy variables, which include real fares and service levels, are subject to the discretion of system managers, while control variables are largely exogenous to the system and its managers. The control variables used in the analyses, which include the levels and changes in employment and population, gross population densities, and rates of auto ownership within each system's service area, are proxies for the large number of factors that affect transit demand. In addition, two zero-one dummy variables that indicate whether a particularly system was publicly owned or became publicly owned during the decade are included in all equations where these distinctions are meaningful. Because of measurement problems and uncertainty about how best to represent the myriad of factors that are proxied by the control variables, we present several equations for each year or decade that differ in terms of the included control variables. In contrast, the same policy variables are generally included in all specifications.

The mean values of the parameter estimates obtained for the five policy variables are shown in Table ES-1 for the three sets of change equation and four sets of pooled cross-section equations, along with the mean percentage of explained variance (R^2) for each type of equation. As the table indicates, all of the equations include either the level or changes in real fares, total revenue miles of service supplied (the product of route miles and frequency), and the rail share of total revenue miles as explanatory variables.

Table ES-1. Mean Coefficient Estimates by Type of Equation and Period or Year for Policy Variables

Equation Type and Period/Year	Real Fares	Revenue Miles	Rail Share	Public Own	Change to Public	R Square
Change						
1980-90	-0.34	0.70	0.38	NA	NA	0.75
1970-80	-0.44	0.73	0.14	0.06	-0.14	0.83
1960-70	-0.68	1.07	0.04	-0.09	-0.20	0.89
Cross-Section						
1990	-0.44	0.89	0.20	NA	NA	0.96
1980	-0.40	0.88	-0.03	-0.19	NA	0.96
1970	-0.67	1.07	0.04	-0.12	NA	0.98
1960	-0.86	1.07	0.06	-0.08	NA	0.97

The mean coefficients of both real fares and revenue miles in Table ES-1, which can be interpreted as constant elasticities, indicate the percentage change in boardings that would result from a one percent change in either explanatory variable. The mean real fares elasticities obtained for the 1980-90 and 1970-80 change and 1990 and 1980 cross-section equations, which vary between -0.34 and -0.44, are quite close to the so-called Simpson-Curtin rule. This industry rule of thumb states that each one percent increase in fares will cause roughly a -0.3 percent decline in transit ridership. The estimates are even closer to recent fare elasticity estimates by Linsalata and Pham (1991), which had a mean of -0.40 for 52 transit systems. The remaining fare elasticity estimates are significantly larger in absolute value, particularly the mean 1960 cross-section estimate, which is -0.86. For econometric reasons and because of greater doubts about data quality, we have more confidence in the parameter estimates obtained from the change regressions and in those based on more recent data.

There are fewer comparable published estimates of service elasticities, but those obtained from the two most recent change regressions, 0.70 and 0.73, are similar to, though slightly larger than, the time series estimates obtained by Kain (1996, 1989) for Atlanta and Ottawa, by Kain and Liu (1995) for San Diego, and by Liu (1993) for Portland. In contrast, the service elasticity estimates obtained for the 1960-70 change and 1960 and 1970 cross-section equations, which were all 1.07, are substantially larger.

Again, we have more confidence in the estimates obtained from the change equations and those based on more recent data.

Rail share, as the name indicates, is a share variable. While its parameter estimates have much lower statistical reliability than the real fare and service elasticities, they are generally positive, a finding that tends to support the observation that systems with greater amounts of rail service have higher levels of boardings, which partly implies higher transfer rates. The parameter estimates for the public ownership dummies also exhibit low levels of statistical reliability. Nonetheless, if taken at face value, they suggest that, holding constant the effects of all other explanatory variables, publicly owned systems have fewer boardings than privately owned ones, and that boardings decline with a shift from private to public ownership and operation.

The results for the more numerous control variables are more difficult to summarize. This is because they generally exhibit less consistency and lower levels of statistical significance than the estimates obtained for the policy variables and because most do not appear in all equations. The two exceptions are the percent of city residents owning zero cars, which appears in all of the equations, and a measure of system size (total revenue miles at the start of the decade), which is included in all of the change equations.

Comparing the results obtained in this study to those obtained in earlier ones, our estimates are unique in several aspects. Firstly, they are obtained from an unusually large and extensive data base, which includes data for 184 transit systems and up to four dates during the 30-year period 1960-90 that encompassed a massive transition from private to public provision of transit services. A major effort was made to compile consistent transit statistics and link them with service area demographic and land use data. Secondly, the ridership change equations used in this study do a better job in separating the effects of control variables from those of the policy variables than earlier estimates that relied on cross-section data. This is because service miles supplied are a policy variable highly correlated with both employment and population in the service area. Because of these correlations, the elasticity estimates obtained from the cross-section equations may not reflect the true effects of these variables. While an argument can be made for estimating structural equations to deal with this simultaneity problem, unavailability of adequate instruments prevented us from pursuing this approach. Finally, in contrast to the elasticity estimates obtained from time series data for a single system, the cross-section estimates and decade-change estimates reported in this study are long-run elasticities.

Chapter 1

Introduction

This study examines the principal determinants of the levels and changes in transit ridership for U.S. transit operators over the 30 year period 1960-90. In the analyses that follow, transit ridership is represented by annual boardings. We would have preferred to have used linked-trips for these analyses, as we believe they are a more meaningful measure of transit ridership. Linked-trip data, however, are simply unavailable for a large number of systems over the 30-year period examined in this study, and we therefore had no choice but to use boardings data to represent ridership in the analyses that follow.[1]

The use of boardings data to represent transit ridership can be very misleading in certain situations. When tripmakers board more than one transit vehicle in the course of a particular journey, as for example when they transfer from one bus line to another, or use both feeder bus and rail, the linked-trip concept combines them into a single linked-trip. As we discuss in greater detail in subsequent chapters, the use of boardings data can provide a very misleading impression of the growth and declines in transit ridership, particularly in situations where there are major system changes.

As the data on annual total boardings and boardings per urban resident shown in Figure 1-1 indicate, the 30 year period examined in this report was a fairly stable one, at least in comparison to other periods in the often turbulent history of urban public transport in the United States. Figure 1-1 also includes data on per capita levels of auto ownership. All three series - total annual boardings, boardings per urban resident, and auto ownership per capita - are displayed as indexes with 1950 as their common base.[2] We chose 1950 as the base in constructing these indexes because it allows some time for the unusually high World War levels of transit use to return to a more "normal" level and yet precedes the 30 year period examined in the report by a decade.

The two transit boardings series, which span the period 1914-1992, generally track one another fairly closely. There are some differences between them, however, and

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[1] Some transit operators estimate annual linked-trips for the purpose of management decision-making. These data, however, are not reported in FTA Section 15 statistics and APTA annual operating statistics, the two major data sources for this study.

[2] The use of the indexes permits us to include variables with very different magnitudes in the same graph.

the most important of these differences are discussed below. The most pronounced feature of both transit series is an abrupt increase in boardings between 1940 and 1945. The explanation for these sharp increases is not hard to come by; they were caused by World War II. Following Pearl Harbor, the populations and levels of employment in the nation's cities and metropolitan areas grew rapidly, and, more importantly, wartime controls on the construction of new housing, private car production, and gasoline and tire rationing created a growing and largely captive market for urban transit systems. As a result, annual boardings increased from 13.1 billion in 1940 to an all time high of 23.4 billion in 1946, while boardings per urban resident increased from 175 per year in 1940 to a war-time peak of 280 per year in 1944.

Trends in total and per capita boardings for the period 1917-1926 are more divergent. During this 10 year period, total boardings for the nation as a whole grew from 14.5 billion in 1917 to 17.2 billion in 1926; per capita boardings for the same period, however, declined from 285 per year to 272. On the assumption that these data are accurate, the declines in per capita boardings between 1917 and 1926 are presumably due to rapid increases in incomes and automobile ownership per capita during the same period.[3] Auto ownership per capita grew from 33 per thousand persons in 1917 to 164 per thousand persons in 1926.

Starting in 1930, both total and per capita boardings fell abruptly. Again the explanation is not difficult to discern. With the onslaught of the Great Depression, employment and real household incomes fell sharply. Fewer people working and less discretionary spending dealt transit a double blow. As Figure 1-1 indicates, the disastrous drops in employment and earnings during the depression also caused declines in per capita car ownership. In 1936 the United States began its painful recovery from the depression and both total and per capita boardings steadily increased until the outbreak of World War II. Even so, in 1940, at the eve of World War II, total boardings were only 77 percent of their 1929 level and per capita boardings were only 70 percent of their 1929 level.

With the end of hostilities, gas and tire rationing were discontinued and Detroit quickly converted its factories from the production of trucks and jeeps to the production

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[3] The estimates of transit boardings are undoubtedly measured with considerable error. In addition, the denominator of the boarding per capita measure is only a crude proxy of the desired measure of the population of areas served by urban transit. Nonetheless, the estimates are sufficiently accurate for the purpose.

of private cars. The conversion of the nation's factories from the production of wartime to civilian goods was followed in quick order by an unprecedented residential building boom. The much larger and much richer populations of the nation's metropolitan areas, aided by low downpayment amortized mortgages that had been developed during the Great Depression, began to buy new, single family housing in record numbers. Increasingly this new housing was provided at locations outside the central city (Kain, 1968; Meyer, Kain, and Wohl, 1965). Both population suburbanization and employment dispersal were continuations of long term trends that had been interrupted by first the depression and then by World War II. In addition, as Kain (1968) demonstrates, a fair amount of largely unnoticed employment dispersal occurred during World War II.

By 1960, the initial year of the analyses presented in this report, the especially rapid declines in total and per capita boardings from abnormal wartime levels had largely run their course. Nonetheless, as the data in Figure 1-1 indicate, transit ridership continued to decline during 1960-1970, albeit at a somewhat slower rate. By 1970, transit boardings per urban resident were only 65 percent of their 1960 level.

As we discuss in greater detail subsequently, urban public transit in the U. S. around 1945 was predominantly a private for-profit activity, although a number of larger cities were served by publicly owned and operated systems. After World War II, ridership declines, resulting from rising incomes, the emergence of an increasingly low density and dispersed pattern of workplaces and residences, and the steady growth in auto ownership, began to take their toll on the private operators of urban public transit. In a growing number of metropolitan areas, moreover, regulators refused to allow private operators to raise fares in real terms or to make the service cuts that might have enabled them to remain profitable. The result was declining profitability, bankruptcy in some cases, and, with increasing frequency, the public acquisition of private transit systems by local governments. Tramontozzi and Chilton (1983 pp. 2-3) report that in 1955 only three percent of transit systems were publicly owned. By 1980, 55 percent of all urban transport systems were publicly owned, and the publicly owned systems carried 94 percent of all transit boardings in 1980.

In a number of cases, the public acquisition of private transit firms was done in conjunction with the creation of regional transit authorities. It was common, moreover, for these newly created regional authorities to be given authority to impose various taxes, most often sales or payroll taxes, on the residents and businesses located in their service areas. As we discuss in greater detail subsequently, however, public ownership and operation was by no means the only alternative that was available to policymakers.

Federal, state, and local governments could have provided subsidies to existing private operators for the provision of unprofitable services. In fact, some subsidies, typically indirect, were provided to private operators. But in the end, encouraged by federal legislation and policy, most local governments opted for public ownership and operation of their transit systems.

As will become evident in subsequent chapters, the national trends in transit ridership shown in Figure 1-1 mask a great deal of variation among cities and metropolitan areas. In the econometric analyses presented in this report, we exploit this variation by estimating multivariate statistical models that quantify the independent contributions of what we refer to as policy and control variables on transit ridership. Among the most important of the policy variables that affect transit ridership are real fare levels, the extent of transit operators' route networks, and service frequencies. Important exogenous determinants of transit ridership (control variables) examined in the report include levels and changes in employment and population, gross population densities, and rates of auto ownership within each transit operator's service area.

Two types of econometric analyses are presented in this report. The first consists of a number of multivariate regressions that explain changes in annual transit ridership for linked samples of individual operators during each of the three decades between 1960 and 1990: 1960-70, 1970-80, and 1980-90. The second employs multivariate regressions to explain variations in the levels of annual transit ridership for the individual years 1960, 1970, 1980, and 1990 respectively. As noted previously, both kinds of analyses use boardings as their measure of transit ridership, rather than the more desirable linked-trip data, because reliable estimates of linked-trips are not available for most transit operators. Both analyses, moreover, are based on a database compiled especially for this study, which combines employment, population, and household data from the 1960, 1970, 1980, and 1990 censuses with boarding and system operations data from APTA and FTA Section 15 reports for individual transit operators in the same years. For reasons we discuss more fully later, we regard the change models as the more useful and reliable of the two types of analyses in this report.

The remainder of this report is divided into three substantive chapters and two appendices. Chapter 2 provides a detailed description of the data used in the study. Chapter 3 describes the ridership change regressions and Chapter 4 describes the single year cross-section regressions. Appendix A provides brief analyses of a number of related issues, including the relationship between boardings and linked-trips estimates in

1960 and 1970 and the relationship between census journey-to-work data and boardings data for 1980 and 1990. Appendix B lists the data compiled specifically for this study.

Chapter 2

Structure of the Analysis and Data Sources

I. Data Sources

As noted in the introduction, two kinds of econometric analyses, decade change and single year cross-sections, are presented in this report. These analyses are based on a common data base that was developed specifically for this study, although the larger part of data used for the 1980-1990 change regressions and 1980 and 1990 cross sections samples were developed for and used in a complementary FTA (Federal Transit Administration) study by Kain and Liu (1995).

The units of analysis (observations) used in the econometric analyses presented in Chapters 3 and 4 are individual transit operators. The dependent variables are the annual transit boardings in the cross-section samples, and decade-long changes in boardings in the ridership change analyses. In both types of analyses, boardings are transformed to natural logarithms, as are most of the explanatory variables. Both the ridership change and single-year cross-section equations use two kinds of variables, policy and control variables, to explain either decade changes in, or levels of, annual boardings among transit systems.

Policy variables are under the direct control of the owners and managers of the individual transit systems. In the analyses presented in this report, these include real fares, total revenue miles of service supplied (the product of route miles and frequency), the rail share of total revenue miles, and dummy variables for public versus private ownership of operations and changes from private to public ownership.

Control variables, the second type of explanatory variables, are largely beyond the control of individual transit operations. The specific control variables which are used as explanatory variables in the regression analyses presented in Chapters 3 and 4 are crude proxies for the extent of the service areas and the level of demand for transit by the population served by each system.

The data used for the regressions were obtained from three principal sources: (1) FTA's (Federal Transit Administration, formerly Urban Mass Transportation Administration) Section 15 annual reports of national mass transportation statistics; (2) APTA's (American Public Transit Association) annual reports of member systems' transit operating and financial statistics; and (3) various US Census of Population and Housing publications from the 1960, 1970, 1980, and 1990 censuses. Collecting and checking the accuracy and completeness of the data, particularly the transit data, was a major undertaking.

FTA's Section 15 annual reports are the primary source for transit operating and financial data for 1980 and 1990. In places where data items for a particular system and year were missing or appeared questionable, we supplemented the 1980 and 1990 FTA data with information from previous (1979 and 1989) or subsequent (1981 and 1991) FTA reports and from APTA reports for the same years. The FTA Section 15 annual reports provide data for virtually every transit operator, but not every operator reported a complete set of operating statistics. The APTA annual reports include data only for APTA members. Because the Section 15 data became available only after the mid-1970s, the APTA annual reports are the primary source of transit ridership, operating and financial statistics for 1960 and 1970. As in the case of FTA data, APTA reports for previous and subsequent years were used to check the reliability of these data or to estimate the values of missing data.

Metropolitan area and city population and other land-use data obtained from various US Census of Population and Housing publications are used to measure the control variables. These control variables represent the myriad factors that determine the demand for transit by the residents of geographic areas (service areas) that are served by the individual transit operators included in the analysis. The need for consistent and reliable information on employment, population, and other determinants of transit demand accounts for our decision to examine transit ridership in the census years 1960, 1970, 1980, and 1990, and the periods defined by these end points.

As the data in Table 2-1 indicate, the analyses of changes in boardings presented in Chapter 3 are based on three linked samples of 75 (1980-1990), 69 (1970-1980), and 73 (1960-1970) individual transit operators/systems. In all, 122 separate transit operators are included in one or more of the three linked samples. Of these 122 systems, 30 appear in all three samples, 28 appear in two, and the remainder appear in only one. During the 30-year period included in this study, a substantial number of transit operators merged with other firms, became bankrupt, were newly formed, or were acquired by local governments. These changes, of course, affect the availability of transit operations data.[1]

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[1] This problem is examined in greater detail in Chapter 3.

Table 2-1. Summary Characteristics of Data Samples

Sample	Number of Equations Estimated	Total Number of Observations	Public Firms at Beginning Year [*]		Firms that Changed from Private to Public	
			Number	Percent	Number	Percent
Change						
1980-90	6	75	75	100%	0	0%
1970-80	6	69	39	57%	26	38%
1960-70	6	73	16	22%	16	22%
Single-Year All						
1990	6	75	75	100%	–	–
1980	6	95	75	79%	–	–
1970	6	97	52	54%	–	–
1960	6	140	27	19%	–	–
Single Year by Size						
1970-Large	3	56	31	55%	–	–
1970-Small	3	47	24	51%	–	–
1960-Large	3	88	18	20%	–	–
1960-Small	3	52	9	17%	–	–

[*] For the single-year sample, it is the number of publicly owned firms in that year.

Second, even with our efforts to use both FTA and APTA data and, when necessary, data for adjacent years, some systems had to be excluded from the analyses because of missing data. Not surprisingly, this problem was more acute for the change than for the single-year cross-section samples.[2]

The four single-year cross-section samples include a total of 184 different transit systems, and, as Table 2-1 indicates, the number varies from a low of 75 firms in both 1980 and 1990 to a high of 140 in 1960. As noted previously, the 1980 and 1990 analyses, which are extensions of analyses completed as part of a companion FTA-funded study of transit systems in Houston and San Diego, are confined to the largest 75 systems with complete data for 1980 and 1990 (Kain and Liu, 1995). As the data in Table 2-1 indicate, the cross-section analyses for 1960 and 1970 provide regression estimates for both the pooled samples in each year and for subsamples of large and small systems.

[2] The 1980 and 1990 analyses, which were completed for our FTA funded successful transit system study, followed the convention of using the same sample of 75 large transit firms in both the 1980-90 charge analysis and each of the 1980 and 1990 cross section analyses (Kain and Liu, 1994).

Table 2-1 also documents the marked shift from private to public ownership and operation of transit systems that occurred during the 30 year period included in this study. All 75 of the transit systems that are included in the 1980 and 1990 samples were publicly owned at the start of the decade. However, only slightly more than half of the 97 systems included in the 1970 sample and less than 25 percent of the 140 transit systems in the 1960 sample were publicly owned at the start of the decade. As a result, 38 percent of the 69 transit systems included in the 1970-80 sample had changed from private to public ownership during the decade. Similarly, 22 percent of transit systems in the linked 1960-70 sample changed from private to public ownership. The higher rate of ownership changes from private to public during the 1970s reflects the national pattern of public takeover of local transit operators that was encouraged by the availability of government transit capital and operating subsidies.

II. Unlinked versus Linked-trips

Transit system ridership may be measured by either the number of boardings (also called unlinked-trips) or the number of linked-trips. A passenger who boards two or more transit vehicles to complete his or her journey is counted as making two or more unlinked-trips, but only one linked-trip. While these concepts measure somewhat different things, and while neither is superior for all purposes, the number of linked-trips is arguably a better measure of transit system ridership than boardings, particularly in situations where system changes result in increased transfer rates which artificially inflate boardings numbers. This problem is most acute when an all-bus system is replaced by a bus-rail system, or when significant additions are made to an existing rail system.

Implementation of a new rail system, or significant addition to an existing rail system, is often accompanied by a major restructuring of the region's bus network in order to feed the new rail system or line. Network changes of this kind may cause dramatic increases in transfer rates as many direct bus services that previously permitted users to make their trips without transfers are replaced by separate feeder-bus and line-haul rail services that require previous users of a direct service to make one or more transfers to complete the same trip. In such situations, large increases in system-wide transfer rates produce large increases in boardings, even when the number of system users (linked-trips) increases by very little or even declines. Unfortunately, the data required to assess this problem are seldom available. These data are available for Atlanta, however, which started to implement a major rail system in 1980 and which aggressively "force fed" the new system. To take what may be an extreme example, introduction of rail and associated changes in MARTA's bus network, caused the system-wide transfer rate (boardings minus linked-trips, divided by linked-trips) to increase from about a third in 1980, before significant rail service was introduced, to more than 90 percent in 1990 (Kain, 1995).

Because the use of boardings data may produce highly misleading results, we would far rather have used linked-trip data for these analyses. Unfortunately, as noted previously, these data are not included in FTA's Section 15 reports. APTA's "Transit Operating Reports" before 1975 included estimates of total boardings, revenue passengers, free passengers, and free transfers that could possibly be used to estimate something close to the number of linked-trips. Unfortunately, these statistics are mostly available for smaller, all-bus transit operators, where cross section and time series variations in annual boardings are not much different from the variations in annual linked-trips. A brief discussion of these issues is contained in Appendix A, where data from 1960 and 1970 APTA reports on different measures of trip-making are examined.

III. Policy Variables

Real fares were calculated for each of the transit operators included in this study by dividing annual estimates of total farebox revenues for each operator and year by total annual fixed-route boardings for the same operator and year. The resulting average fare estimate is similar to the yield measure used in studies of air transportation. Annual current dollar fare estimates were then deflated by the US urban areas' average Consumer Price Index (CPI) to provide constant (1990) dollar estimates of real fares.

Neither FTA's Section 15 nor APTA's transit operating and financial statistics reports are ideal for preparing estimates of average fares. The fare variable used in the regression analyses that follow is clearly measured with some errors. These errors arise principally from two sources: inconsistent or unclear reporting of boardings and farebox revenues for contract services, and the reporting and treatment of farebox revenues and boardings for demand-responsive services. While we made every effort to use consistent definitions for the numerator and denominator in calculating average fares for each system in each year, some errors undoubtedly remain. As it turns out, the estimated regression coefficients obtained for real fares in both the cross-section and change regressions strongly indicate these problems are not serious for 1980 and 1990 period, although the results obtained for 1960 and 1970 raise somewhat more doubts about the adequacy of the fare variables. The coefficient estimates for the fare variable, which are reported in subsequent chapters, and particularly those for the 1980-90 change and 1980 and 1990 cross-section equations, are very similar to estimates from earlier studies, are highly significant statistically, and are robust to alternative equation specifications.

Transit service levels are measured in these analyses by the annual total (bus plus rail) revenue miles of fixed-route services supplied, which are the most commonly used measures of service levels. We would have liked to include separate route mileage and average frequency (vehicle miles/ route miles) variables as well, but no consistent measure of route miles was available from the sources used for this analysis. Similarly, it would have been desirable to include an index of the ratio of peak and off-peak service for each operator, but consistent measures of these variables were unavailable as well. Total annual vehicle miles of rail service (both heavy and light rail transit) is the other service variable used in these regressions. Finally, we calculated the ratio of rail revenue miles of service to total revenue miles of service, and used it as an explanatory variable in the regression models to distinguish the effects of rail services from those of bus services.

IV. Exogenous or Control Variables

Since we lacked detailed data on the geographical areas served by the individual transit systems included in the analysis, we used metropolitan areas and cities as rough measures of these service areas. Specifically, we used census data on city and metropolitan area employment and population, on city gross population density and area, and on the number and fraction of car-less households as exogenous or control variables in the ridership regressions. These control variables are crude proxies for a much larger number of factors that determine transit demand. Individual transit operators typically serve only a part (sometimes a small part) of their metropolitan areas. In most cases, these service areas include the central city and with less frequency the inner suburbs. Suburban services, moreover, are often limited to peak period service between suburban residences and central city or CBD workplaces. During the 30 year period covered by this study, there was a pronounced tendency for transit operators to extend their services to previously unserved, low-density areas, often in conjunction with a change from private to public ownership and operation. Major expansions of transit service areas were particularly common when new publicly owned regional transit authorities were created.

For most of the transit providers, we used the central city and metropolitan area to represent these service areas. In a few cases where it was obvious that a system served only a small part of a metropolitan area, we used the population of a smaller area, typically a smaller city, as opposed to the central city. We consulted the FTA Section 15 data on service area population in making these determinations, but the reliability of these data is obviously low. If sufficient time and resources had been available, we might have been able to develop more precise definitions of the areas served by each operator and the numbers of persons living and working in each of these more precisely defined service areas. Developing such measures would have been expensive and difficult, however. Worse yet, the effort might not have been particularly productive because of a tendency of many operators to provide only limited service to many, particularly low-density parts of their service areas.

Clearly, however, the definition and extent of service areas deserves more attention in FTA's Section 15 reporting system. The reporting of more accurate and detailed data on service areas and their characteristics should be combined with the reporting of information on the amount of service provided to various parts of these service areas. Fortunately, the estimates obtained from the regressions that are presented in the subsequent chapters indicate that the crude land use proxies used in these analyses do a fairly good job of controlling for the impact of cross-section differences and changes in employment and population on transit ridership for the systems studied.

Census publications provide detailed counts of resident population for all standard metropolitan statistical areas (SMSAs), component counties, and central cities. Although the more recent definition of some metropolitan statistical areas (MSAs), particularly the rapidly growing metropolitan areas such as the San Francisco-Oakland-San Jose Area, includes more than one former SMSA, we still use SMSA as defined in each census as the metropolitan area definition in each of the cross-section samples. In the three change samples, the end-of-decade metropolitan area definition is used for each of the three samples; for example, the 1990 definition is used for the 1980-1990 linked sample.

Again, it would have been preferable to use population and employment estimates for each transit operator's service area. However, such data are generally unavailable or, if available, are very crude. We used metropolitan area population and employment as the best substitutes. Knowing the fact that some transit systems served only a part of a SMSA, we used employment and population data for a particular county or counties when it was evident that a particular operator served only a part of the area. A typical example is the Orange County Transit District, whose service area was clearly limited to Orange County, instead of the entire Los Angeles metropolitan area. Other examples include San Francisco Muni, San Mateo County Transit District, Fort Worth Transit, and Dallas DART.

The number of workers living and working in the same SMSA is used as the measure of metropolitan area employment. City employment is similarly the number of workers who live in the SMSA and work in a particular central city (or central cities). In the cases where a transit operator served a metropolitan area with more than one central city, we used the sum of population living in these central cities as the central city population. For example, in the case of Boston's MBTA, we treated the sum of Boston and Cambridge as the central city.

Chapter 3

Changes in Transit Ridership

I. Data Description

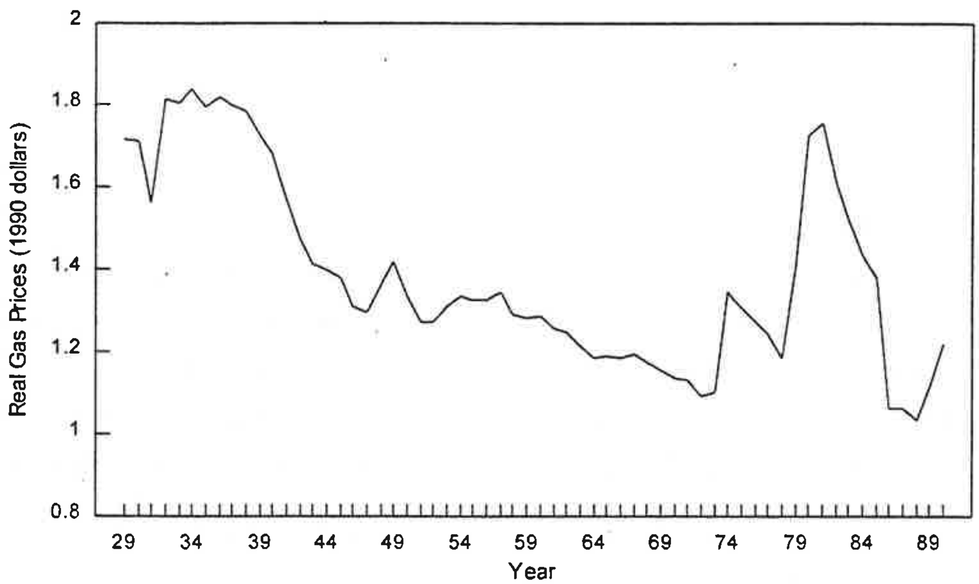
This chapter presents the results of econometric analyses of changes in transit ridership (boardings) for linked samples of individual transit operators for ten year intervals defined by the years 1960, 1970, 1980, and 1990. These samples are used to estimate change in boardings equations for: (a) 75 large transit operators during 1980-90, (b) 69 transit operators during 1970-80, and (c) 73 transit operators during 1960-70.

A major advantage of using decade changes, as contrasted with cross-section data for a single year (which are used to estimate similar equations in the next chapter), is that the use of first differences makes it less necessary to account for the effects on transit ridership of hard to quantify differences in land use and of various other area specific attributes. As Harrison and Kain (1974) demonstrate, urban development patterns change very slowly, and current urban development patterns are the result of a cumulative process occurring over several decades. By focusing on the effects of <u>changes</u> in fares and service levels on <u>changes</u> in transit boardings, we place fewer demands on the crude service area and land use measures available for use in this analysis.

The use of 1980 as an endpoint for two of these linked samples, although unavoidable, is somewhat unfortunate. High gas prices, and perhaps even more importantly, long lines at gas pumps, caused abnormally high levels of transit ridership in 1980. As the data plotted in Figure 3-1 reveal, real gas prices increased sharply (by 24 percent) between 1978 and 1980. More to the point for the analyses presented in this chapter, real gas prices in 1980 were 52 percent higher than in 1970, and 42 percent higher than in 1990.

While there is some variation in real gas prices across metropolitan areas, this cross section variation, which in principle could be represented in change models such as those described in this chapter, is small relative to the 1970-80 and 1980-90 changes in real gas prices that occurred as a result of the Middle-East oil embargo. In addition, real gas price data are not available for all of the metropolitan areas and years included in the analysis. Finally, it appears that higher real gas prices were less important than shortages

Figure 3-1. Real Gas Prices by Year in 1990 Dollars: United States, 1929-1990



and lines at gas pumps in accounting for the surge in transit ridership that occurred during 1980, and that latter effect would be extremely difficult to measure.

The effect of the oil embargo is evident in time series ridership data for every transit system we have examined. Kain (1994) and Liu (1993) have estimated time series econometric models of transit ridership in Atlanta and Portland (Oregon), and both of these analyses indicate that the 1980 increases in transit ridership exceeded the increases that would have been expected from the sharp rise in gas prices that occurred during the year. These analyses provide support for the view that, real or imagined, shortages were probably more important than higher gas prices in inducing many regular auto commuters to temporarily use transit. In the 1980-90 and 1970-80 change equations, the effects of higher gas prices and shortages in 1980 would be reflected in the constant terms of these equations.

Model Specification

The change equations presented in this chapter are all of the form shown in Equation 1:

(1) $\ln B_2 - \ln B_1$

$$= b_0 + b_1 (\ln F_2 - \ln F_1) + b_2 (\ln M_2 - \ln M_1) + b_i (R_{i2} - R_{i1}) + \Sigma_j b_j D_j + \Sigma b_k (\ln X_{k2} - \ln X_{k1}),$$

where ln indicates that the variables are natural logarithms; B denotes annual transit ridership (boardings); F is real fare levels; M represents revenue-miles of service provided, R is the rail share of the total revenue miles; D_j are dummy variables indicating whether a system was publicly owned at the beginning of the decade, and whether a system that was privately owned at the beginning of the decade became publicly owned during the decade; X_k is a vector of exogenous or control variables; the subscripts 1 and 2 denote the beginning year and ending year of the period studied and b_0, b_1, b_2, b_i, b_j and b_k are the coefficients to be estimated.

The functional form used for the cross section models provides for interactions among the several explanatory variables and has the further advantage, where both the dependent and independent variables are measured in logarithms, of providing the convenient interpretation of the individual regression coefficients as constant elasticities.[1]

Several different equations are reported for each of the linked samples/time periods. These equations all have the same functional form and all include both policy and control variables. The several equations for each time period differ according to the particular policy and control variables included in each equation. The policy and control variables used in the change equations are all derived from the data summarized in Table 3-1. While the individual explanatory variables used in the change equations, with few exceptions, are decade differences in natural logarithms, the table gives the unweighted means of these variables in original (untransformed) units for each sample and year.

Three policy variables are included in the change in ridership equations for the 1980-90 decade. They are changes in the natural logarithm of average real fares, the natural logarithm of annual revenue miles, and in the ratio of rail to total revenue miles. The 1970-80 and 1960-70 change in ridership equations include the above mentioned policy variables plus two more. The additional variables identify important changes in the structure of the transit industry that occurred during the 20 year period 1960 to 1980, a period that was marked by a pronounced shift from private to public ownership and operation. The shifts from private to public ownership are represented in the 1970-80 and 1960-70 change equations by two dummy variables: a zero-one variable that indicates whether a particularly system was publicly or privately owned at the start of the decade, and a second zero-one variable that indicates whether each of the systems that were

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[1] Elasticities indicate the percentage change in the dependent variable that would result from a one percent change in a particular independent (explanatory) variable.

Table 3-1. Mean Values of the Variables Used for the Analyses: 1960-70, 1970-80, and 1980-90 Samples

	1960-70 Obs.=73		1970-80 Obs.=69		1980-90 Obs.=75	
Variable	1960	1970	1970	1980	1980	1990
Dependent Variable						
Annual Boardings ('000)	72,802	56,517	64,398	82,015	90,794	89,461
Policy Variables						
Average Real Fares in 1990$	$0.68	$0.79	$0.82	$0.41	$0.42	$0.51
Annual Revenue Miles ('000)	16,088	15,885	18,062	17,940	19,893	22,738
Rail Revenue Miles ('000)	6,130	6,281	6,707	4,728	5,008	7,106
Rail/Total Revenue Miles (%)	8.6	3.3	5.4	4.4	5.5	7.8
Number of Publicly Owned Firms	17	36	39	65	75	75
Exogenous/Control Variables						
Revenue Miles at Beginning Year ('000)	16,088	-	18,062	-	19,893	-
Metro Area Employment ('000)	433	474	529	635	656	856
Metro Area Population ('000)	1,235	1,385	1,537	1,631	1,788	2,001
City Employment ('000)	239	233	235	262	281	335
City Population ('000)	553	571	575	566	595	621
City Land Area (square miles)	61	94	113	127	121	130
City Density (persons per sq. mile)	6,789	5,937	5,888	5,208	6,181	6,071
City % Households with No Car	28.2	25.5	23.9	20.5	22.2	21.0

privately owned at the start of the decade was converted to public ownership and operation during the decade.

In addition to the five policy variables identified above, the change equations employ a variety of control variables to account for changes during the decade in those factors that affect transit ridership but are exogenous to transit management. These control variables include one transit operations variable, total annual revenue miles of service at the start of the decade, which is included as a measure of each system's initial size. The remaining control variables, which are metropolitan area and city employment and population, city density and land area, and the fraction of city households that do not own private cars, are meant to represent or "proxy" the effects on transit ridership of changes in a much larger number of exogenous factors that have impacted transit ridership, usually negatively, over the thirty year period included in the study.

In contrast to the policy variables, individual transit operators had almost no ability to control, or even influence, the powerful economic and technological forces that have so strongly affected their operating environments during the 30 year period covered by this study. Federal, state, and local policymakers had somewhat more influence over these changes, but it is easy to overestimate their ability to affect patterns of urban growth and development and other variables that strongly affect the demand for transit as well. The changes in metropolitan and city population and employment, in city population density and area, and in car ownership that are included as controls in the change equations reflect persistent consumer preferences, as well as long standing and powerful economic and technological forces that are causing similar changes in urban form and densities in urban areas throughout the world (Ingram and Carroll, 1981: Meyer, Kain, and Wohl, 1965; Meyer and Gomez-Ibanez, 1981; Liu, 1993; Kain and Liu, 1994; Mills, 1970; Mills and Tan, 1980).

Because the three linked samples used to estimate the change equations have somewhat different memberships and include different numbers of transit operators, two values of each dependent variable and of each of the explanatory variables are included for 1970 and 1980 in Table 3-1. As examination of the mean values of both the dependent and independent variables for 1970 and 1980 reveals, the differences in sample membership may make a significant difference in summary statistics. Mean annual boardings for 1970 in the 1970-80 sample, for example, are nearly 8 million greater than the same statistic for the same year in the 1960-70 sample. About the same absolute difference exists for the two 1980 estimates of mean boardings. It is important to keep in mind the differences in sample membership and the large differences in mean values for some variables in the same year when assessing the differences in individual coefficient estimates obtained for the individual estimating equations for the different linked samples.

The Data

Table 3-2 lists the 122 transit systems that appear in one or more of the three linked samples. For each system, when they are available, information is provided on annual boardings and on the year the system became publicly owned. The table also includes three columns with 0,1 dummy variables that indicate whether a particular system is included in each of the three samples that are used to estimate each of the three sets of change equations. These dummy variables are also used to group the 122 systems into six panels depending on the number and particular years each system appears in the analyses. The top panel, for example, includes 33 systems that appear in all three linked samples, the second panel includes 17 systems that appear in both the 1970-80 and

Table 3-2: List of Transit Firms Included in the Ridership Analyses

Transit System	Date of Public Owner-ship	Included in Change Equations (Yes=1, No=0) 60-70	70-80	80-90	Annual Total Passenger Boardings ('000) 1960	1970	1980	1990
New York CTA	32	1	1	1	1,781,795	1,666,570	2,021,213	2,191,757
Philadelphia-SEPTA	70	1	1	1	568,070	274,462	377,065	317,503
Chicago-CTA	47	1	1	1	534,757	386,157	720,834	586,916
New Jersey Transit Corp.		1	1	1	268,955	193,486	113,003	122,140
Boston-MBTA	47	1	1	1	256,392	253,970	252,951	303,992
Detroit-SEMTA	71	1	1	1	183,022	158,610	126,887	93,852
Milwaukee County TS		1	1	1	173,956	99,135	85,560	64,794
Baltimore-MTA	70	1	1	1	124,784	77,894	118,772	113,039
Pittsburgh-PAT	64	1	1	1	93,645	103,724	108,179	86,719
Buffalo-Niagra Frontier	74	1	1	1	87,723	64,430	34,274	30,352
Minneapolis MTC	70	1	1	1	87,339	63,755	105,203	69,588
Atlanta-MARTA	72	1	1	1	69,554	61,050	120,163	147,845
AC Transit/BART, SF-Oak	60	1	1	1	57,744	56,061	114,708	62,162
Cincinnati-SORTA	73	1	1	1	55,431	33,746	33,666	30,496
Kansas City Area TA	69	1	1	1	50,724	22,065	25,236	18,455
Dallas DART	60	1	1	1	47,313	40,408	38,066	51,010
Seattle Metro	11	1	1	1	41,476	31,751	74,233	78,804
Rochester-Genesee RTA	68	1	1	1	40,463	27,794	25,511	15,202
Louisville-TA River City	74	1	1	1	34,217	18,350	22,073	21,892
Memphis Area TA	61	1	1	1	33,792	28,371	24,393	13,858
San Diego MTS/MTDB	67	1	1	1	31,784	16,296	36,009	53,677
San Antonio-VIA Metro Tr	59	1	1	1	30,890	25,377	36,931	42,138
Providence RI PTA	66	1	1	1	30,116	19,439	27,558	16,030
Indianapolis PTC	75	1	1	1	29,461	21,559	16,362	12,312
Dayton Miami Valley RTA	72	1	1	1	28,996	16,671	9,042	16,046
Portland-Tri-County MTD	69	1	1	1	27,917	18,171	46,811	54,235
Syracuse-CNY Centro	72	1	1	1	22,649	14,762	14,803	13,242
Omaha, TA of Omaha	72	1	1	1	20,910	9,583	13,289	6,745
Nashville-MTA		1	1	1	19,908	13,414	17,980	8,827
Jacksonville TA		1	1	1	16,083	12,533	16,958	9,642
Fort Worth, The T-Fort Worth	72	1	1	1	14,120	7,372	6,090	5,404
Charlotte TS		1	1	1	13,317	11,295	11,230	11,855
Harrisburg-CAT		1	1	1	9,610	5,548	7,190	4,238
Sum		33	33	33	4,886,913	3,853,809	4,802,242	4,674,768
Mean					148,088	116,782	145,522	141,660
Los Angeles-SCRTD	58	0	1	1		198,883	396,618	401,055
New Orleans - RTA	83	0	1	1	164,075	124,105	106,668	77,913
Miami-Dade Cnty TA	62	0	1	1		55,875	67,448	80,740
Houston-MTA	74	0	1	1		38,888	47,774	88,367
Richmond, Gr Richmond TC	73	0	1	1		32,916	24,466	21,680
Denver-RTD	74	0	1	1		16,490	46,942	53,262
Santa Monica Muni Bus	28	0	1	1		12,484	16,425	18,998
Long Beach Public Trans	63	0	1	1		12,232	18,275	20,711
Camden, Port Authority TC	69	0	1	1		8,656	10,890	11,405
Tacoma-Pierce Cnty Trans	61	0	1	1		7,756	7,532	10,570
Sacramento RTD	73	0	1	1	11,549	7,512	16,959	19,707
Toledo RTA	71	0	1	1		5,545	8,222	6,353
Madison Metro	70	0	1	1		4,627	13,424	9,096

Table 3-2: List of Transit Firms Included in the Ridership Analyses

Transit System	Date of Public Owner-ship	Included in Change Equations (Yes=1, No=0) 60-70	70-80	80-90	Annual Total Passenger Boardings ('000) 1960	1970	1980	1990
Phoenix TS		0	1	1	(145	4,020	14,297	30,046
Salt Lake City-Utah TA	70	0	1	1		3,954	19,083	23,903
Albuquerque-Sun-Tran	66	0	1	1	6,873	2,911	6,816	6,373
Fresno TS	61	0	1	1		2,746	10,459	9,074
Sum		0	17	17	NA	539,600	832,299	889,251
Mean					NA	31,741	48,959	52,309
Akron-Metropolitan RTA	69	1	1	0	13,151	2,963	1,902	5,394
Savannah TA	60	1	1	0	10,224	9,031	4,517	5,951
Little Rock-Metroplan	72	1	1	0	9,544	5,430	2,428	2,563
Allentown-LANTA	72	1	1	0	8,502	4,016	5,162	4,505
Charleston Transit Co	71	1	1	0	8,001	3,704	3,861	2,025
Gr Lynchburg TC	74	1	1	0	4,697	3,827	2,409	1,617
Springfield MTD	68	1	1	0	3,075	2,213	3,422	2,653
Oshkosh City Transit Lines		1	1	0	1,345	1,178	903	925
Sum		8	8	0	58,539	32,362	24,604	25,632
Mean					7,317	4,045	3,076	3,204
New York-Triboro Coach Co.		1	0	0	28,691	27,864		
Bridgeport-Conn Railway		1	0	0	24,687	13,339		7,298
Cincinnati, Newport & Cov		1	0	0	15,434	7,069		
Evanston Bus Co.		1	0	0	11,640	8,745		
Charleston, SC Electric & Gas		1	0	0	9,475	5,336		4,044
Gary Railway Inc		1	0	0	8,024	7,521	4,773	2,641
Grand Rapids Transit Au	64	1	0	0	7,190	2,938	4,617	3,778
Fondy Area Bus Corp	73	1	0	0	6,736	366		
Colmbia, SC Electric & Gas		1	0	0	6,264	5,313		3,323
Shaker Height, City DOT	44	1	0	0	6,180	4,831		
DesPlaines, United Motor Coach		1	0	0	5,639	3,290		
Wilkes-Barre Transit Corp		1	0	0	5,167	3,074	5,556	2,780
Durham, Duke Co.		1	0	0	5,042	4,322		2,408
Greenville City Coach Lines		1	0	0	4,582	3,785		
City Utilities of Spr.		1	0	0	4,198	2,264	1,403	1,794
St Joseph Light & Power Co		1	0	0	4,149	1,767		
Holyoke Street Railway		1	0	0	4,073	3,335		
Fitchburg & Leo. Street Railway		1	0	0	3,951	3,423		
Interstate Power Co	73	1	0	0	3,389	2,172	1,647	707
Asheville TA	66	1	0	0	3,318	2,227	1,848	1,467
Raleigh-NC Transit Div		1	0	0	3,301	3,008	3,441	1,695
Clarksburg, City Lines of WV		1	0	0	1,939	827		
Spartanburg, Duke Power Co		1	0	0	1,678	1,583		
Fairmont, City Lines		1	0	0	1,633	510		
New Castle Area Transit	59	1	0	0	1,525	620		
Zanesville, Y-City Transit Co.		1	0	0	1,164	1,052		
Anderson, Duke Power Co		1	0	0	917	659		
Sum		27	0	0	179,986	121,240	NA	NA
Mean					6,666	4,490	NA	NA
Chattanooga Area RTA	72	0	1	0		3,628	4,332	2,708

Table 3-2: List of Transit Firms Included in the Ridership Analyses

Transit System	Date of Public Owner-ship	Included in Change Equations (Yes=1, No=0) 60-70	70-80	80-90	Annual Total Passenger Boardings ('000) 1960	1970	1980	1990
Stockton MTD	65	0	1	0		2,604	2,848	3,733
Broome Cnty Dept of PT	68	0	1	0		2,136	3,321	3,046
Galveston Island Trans		0	1	0		1,900	1,914	980
Flint-MTA	64	0	1	0	5,586	1,865	1,303	3,367
Amarillo Transit System		0	1	0		1,352	700	850
Green Bay TS	73	0	1	0		1,283	1,208	1,358
Colorado Springs Transit	72	0	1	0		1,036	2,758	3,397
Lafayette-COLT	66	0	1	0		943	1,009	1,331
City of Elgin, DOT	68	0	1	0		723	1,631	1,672
City of Santa Rosa	58	0	1	0		241	911	1,521
Sum		0	11	0	NA	17,711	21,932	23,963
Mean					NA	1,610	1,994	2,178
San Francisco-MUNI	12	0	0	1	201,504	(1,004	309,132	233,468
Washington, D.C.-WMATA	73	0	0	1	188,226	(170	299,042	357,508
San Francisco BART & AC TD		0	0	1			158,144	140,809
Cleveland RTA	72	0	0	1			116,973	73,930
St Louis-Bi-State	63	0	0	1	127,179	(**)	84,215	44,578
Honolulu DOT Service	73	0	0	1	38,803	(108	74,055	73,513
Santa Clara County TD	73	0	0	1		(54	31,254	45,723
Orange County TD	71	0	0	1		(**)	28,983	44,846
Hartford-Conn Transit		0	0	1		(399	21,952	19,158
Columbus-Central Ohio TA		0	0	1	38,376	(240	19,941	18,415
New Haven-Conn Transit		0	0	1	46,968		18,254	9,305
San Mateo County District		0	0	1		(**)	18,213	18,399
Albany-Capital Dist TA	72	0	0	1	20,807		16,089	12,443
Ft Lauderdale-Browrd Cnty	72	0	0	1		(**)	12,041	17,474
Santa Barbara MTD	67	0	0	1		(12	10,630	5,655
San Fran-Golden Gate TD	28	0	0	1		(**)	10,581	10,243
Tucson, City of Tucson MTS	69	0	0	1	(52	(**)	8,814	13,441
N. San Diego Transit Dev		0	0	1		(25	8,157	11,228
Spokane Transit Authority	68	0	0	1		(66	7,290	7,293
Worcester RTA		0	0	1	14,692	(152	6,285	4,968
Eugene-Lane County MTD	70	0	0	1			6,283	5,917
Santa Cruz MTD	68	0	0	1		(**)	6,111	6,739
New Bedford SERTA	70	0	0	1	6,135	(111	5,620	4,969
Hillsborough Area RTA	71	0	0	1		(62	4,434	10,622
Orlando TCT	72	0	0	1		(80	3,833	8,061
Pinellas Suncoast TA	73	0	0	1		(59	3,382	9,030
Sum		0	0	26	NA	NA	1,289,706	1,207,734
Mean					NA	NA	49,604	46,451
Systems with Boardings Data					81	96	102	106
Sum of Annual Total Boardings					5,996,211	4,564,722	6,994,068	6,853,284
Average Annual Boardings					74,027	47,549	68,569	64,654

Notes: (1) The numbers in parentheses are the numbers of revenue vehicles for the corresponding transit firms;

(2) The double astericks in parentheses identify systems that appear to have existed in that year

1980-90 samples, and the third panel includes 8 systems that appear in both the 1960-70 and 1970-80 samples. The last three panels include those systems that appear in only one of the linked samples.

The table also contains the sums and means of annual boardings, when available, by year for each of the six panels, as well as the sum of total boardings by year for all of the 122 systems used in any of the three analyses. The estimates of mean boardings per system for each of the samples make it clear that the systems included in the first panel, which are those that appear in all three samples, are much larger (have more boardings) than those included in any of the other three panels. The mean figure in 1990 for the 33 systems that appear in all three samples was 141.7 annual million boardings, as contrasted with an average of 52.3 million annual boardings for the 17 systems that are included in both the 1970-80 and 1980-90 linked samples.

The totals for all 122 systems, shown at the bottom of the table, indicate both the number of systems for which we were able to obtain boardings data for each of the four years, and the sum of annual boardings for those systems for which these data were available. The number of systems with boardings data by year are 81 in 1960, 96 in 1970, 102 in 1980, and 106 in 1990. The corresponding estimates of total boardings by year for the 122 systems included in Table 3-2 are 5,996 million in 1960, 4,564 million in 1970, 6,994 million in 1980, and 6,853 million in 1990.

Two systems in 1960 and 14 in 1970 have numbers in parentheses under annual total passenger boardings in Table 3-2. These are reported estimates of the number of buses operated in revenue service during that year for some of the systems without boardings data. These fleet data, which were obtained from a variety of industry sources, are provided, whenever possible, for systems that did not report boardings data to APTA in 1960 or 1970. In most cases these systems did not belong to APTA during these years or in the prior or subsequent years. In a few cases, they belonged to APTA, but did not report boardings to APTA in these years.[2] Many small transit operators, however, did not belong to APTA in any of the years covered by the survey.

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[2] When an APTA member did not report all or some of the required operations data in a particular year, we used estimates based on the previous or subsequent year, or both, when they were available. Thus, in a few instances, we replaced missing data for 1970 with estimates based on 1969 and 1971 data. FTA Section 15 data were the principal source of operations data for 1980 and 1990. When these data were missing or incomplete, we consulted the APTA reports for the same year and/or used previous and subsequent year FTA reports to estimate missing operations data.

Before FTA's Section 15 reports became available, APTA used data on the number of buses in revenue service, similar to those shown in parentheses in Table 3-2, and estimates of boardings per bus for similar systems, to expand the annual boardings data obtained from their members to national totals. Since other operations data that were required to estimate ridership models were not available for these systems, we saw no particular benefit from preparing crude boardings estimates for them. We include the fleet size data in Table 3-2, however, to give a rough idea of the amount of service provided by these systems. In addition to the above mentioned fleet size estimates, one of the systems in 1960 and seven in 1970 have asterisks in the boardings column. These asterisks identify systems for which we could find neither boardings or fleet size data, but for which we found some information that indicated the system operated in a particular year.

Keeping in mind the above mentioned differences in sample composition, the unweighted mean percentage change in annual boardings for the 73 common firms that comprise the 1960-70 sample, as shown in Table 3-3, is -33.3 percent. Ridership declines during 1960-70 reflect the combined effects of long term trends in household incomes, car ownership, and urban form and structure that worked strongly to the disadvantage of transit providers, as well as policies (fare increases and service cuts) that accentuated the effects of these adverse trends. In combination with a regulatory environment that prevented private transit operators from making the fare and service adjustments that might have permitted them to remain profitable, adverse household and land use trends led to declining profitability, bankruptcy, and ultimately to the public acquisition of a growing number of private transit firms.

Only 17 of the 73 large transit systems included in the linked 1960-70 sample were publicly owned at the start of the decade; by the end of the decade, however, this number had more than doubled to 36. Conversions from private to public operation of the transit systems serving large United States cities continued in the decade that followed. In 1970, 39 of the 69 large transit operators included in the linked 1970-80 sample were publicly owned, but by the end of the decade 65 of them were publicly owned, an increase of 67 percent. Finally, all of the 75 larger systems included in the 1980-90 linked sample were publicly owned and operated at both the start and end of the decade.

The dramatic shifts from private to public ownership of transit systems that occurred in the 30 year period included in this study are traceable to the inability of private transit operators to maintain profitability in an increasingly difficult operating

Table 3-3. Frequency Distribution of Percentage Changes in Annual Boardings for 1960-70, 1970-80, and 1980-90

Range of Percentage Change	Number of Transit Firms 1960-70	1970-80	1980-90	Frequency Distribution 1960-70	1970-80	1980-90
Increases in Boardings						
> 100%	0	15	4	0.0%	21.7%	5.3%
75% - 100%	0	3	2	0.0%	4.3%	2.7%
50% - 75%	0	4	2	0.0%	5.8%	2.7%
25% - 50%	0	12	7	0.0%	17.4%	9.3%
0% - 25%	1	12	19	1.4%	17.4%	25.3%
Subtotal	1	46	34	1.4%	66.7%	45.3%
Decreases in Boardings						
0% - -25%	27	14	25	37.0%	20.3%	33.3%
-25% - -50%	29	8	15	39.7%	11.6%	20.0%
-50% - -75%	14	1	1	19.2%	1.4%	1.3%
-75% - -100%	2	0	0	2.7%	0.0%	0.0%
< -100%	0	0	0	0.0%	0.0%	0.0%
Subtotal	72	23	41	98.6%	33.3%	54.7%
Total	73	69	75	100.0%	100.0%	100.0%
Weighted Mean	–	–	–	-22.4%	27.4%	-1.5%
Unweighted Mean	–	–	–	-33.3%	48.9%	4.4%

environment, at least under terms that were acceptable to regulators and policy makers. It should be emphasized, however, that the shift from private to public ownership and operation also resulted from an explicit decision by federal, state, and local government policy makers to replace private transit operators with publicly owned systems, rather than to pursue regulatory and subsidy policies that would have allowed existing private operators to continue as the principal providers of transit services in many metropolitan areas, albeit with a different fare and service mix or with the aid of explicit public subsidies for the provision of socially desirable services that could not be provided at a profit.

As Lave (1991) has shown, the decision to acquire bankrupt or declining private transit systems and to replace them with publicly owned and operated transit systems adversely affected the productivity and cost-effectiveness of transit systems serving the nation's cities and metropolitan areas. In an analysis of productivity and cost changes for 62 large transit systems, Lave (1991, p. 115) concluded that "if transit productivity had merely remained constant from 1964 ... through 1985," the last year included in his study, total operating expenses would have been 40 percent lower in 1985. To place these changes in perspective, he noted, that maintaining transit productivity at its 1964 level would have provided enough cost savings to "erase most of the operating deficits of US transit systems in 1985 - with no increase in fares." As noted above, as an alternative to public takeovers of privately owned and operated transit systems, governments could have permitted continued private operation and have provided subsidies for socially desirable fare levels and/or services that could not be provided at a profit.

The U.S. experience with government ownership and operation of urban transit systems is by no means unique. Declines in the profitability of privately owned transit systems and a shift from private to public ownership and operation of formerly private transit systems is a world-wide phenomenon with results that are similar to those in this country (Armstrong-Wright and Thirez, 1987). In both the United States and in other countries, governments confronted with steady increases in subsidies to publicly owned urban transit systems have subsequently begun to privatize all or part of publicly owned urban transit systems. Great Britain, for example, has privatized the provision of all road urban transport services except for London Transport. This and several other experiences with privatization are discussed in Gomez-Ibanez and Meyer (1993).

In the U.S. the decision to embrace public ownership and operation of urban transport services and to create regional transit authorities in many large metropolitan areas, typically with dedicated sources of tax revenues, led to rapid increases in both capital and operating subsidies. The causes of this rapid growth in subsidies have been examined by Pickrell (1984), Pucher (1982) and others for the entire U.S. and more detailed assessments have been provided by Gomez-Ibanez (1994), Kain (1994), and Liu (1993) for individual metropolitan areas.

The rapid growth in transit capital and operating subsidies during 1970-80 permitted transit operators in many metropolitan areas to reduce real fares and to rapidly expand service, particularly to many previously unserved suburban communities. These fare cuts and service expansions reversed the national decline in transit ridership for the nation as a whole, although not in all metropolitan areas. In contrast to the previously noted 33.3 percent decline in unweighted mean annual boardings during 1960-70, unweighted mean annual boardings grew by 48.9 percent during 1970-80 (Table 3-3). However, continuing adverse trends (for transit) in the location of jobs and population and further increases in auto ownership, ultimately took their toll on publicly owned and operated transit systems, just as they previously had on the privately owned systems that these public systems had replaced. In many metropolitan areas, particularly those with dedicated revenue sources, the ridership increases produced by subsidy-fueled expansionary policies eventually came to a halt when the growth of these subsidies slowed and in some cases stopped or even declines. When this occurred, ridership stagnated, or even began to decline, as the growth of subsidy dollars and the expansionary policies they permitted slowed.[3] Being mindful of the differences between the 1970-80 and 1980-90 linked samples, the difference between the 49 percent growth in (unweighted) boardings during 1970-80 and the modest (4.4 percent) increase during 1980-90 is largely due to the trends discussed above. The weighted changes in boardings for the same samples and periods were 27.4 percent during 1970-80 and -1.5 percent during 1980-90.

Distributions of Gains and Losses in Transit Ridership

As the data on the distribution of ridership gains and losses by period in Table 3-3 reveal, both the weighted and unweighted mean percentage changes in boardings, shown in the bottom two lines, mask a great deal of variation in boardings growth and decline among the systems included in the three linked samples. Even so, all but one of the 73 systems included in the 1960-70 linked sample had fewer riders in 1970 than in 1960. The experience in the second period was more evenly distributed between gains and losses; exactly a third (23 of 69) of the systems lost and exactly two thirds (46 of 69) gained riders, at least as measured by boardings. In considering the boardings data for the 1970-80 period, it is important again to keep in mind the impact of the oil embargo on transit ridership in 1980.

The frequency distribution of ridership gains and loses for the 1980-90 period clearly demonstrates the wisdom of paying attention to the distributions. As these data indicate, the unweighted mean percentage changes in boardings was slightly positive and the weighted mean was slightly negative. Examination of the distributions, however, reveal that more than half of the systems included in the 1980-90 linked sample had fewer riders in 1990 than in 1980, while more than 10 percent of these systems increased their ridership (boardings) by more than 50 percent.

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[3] The Portland, Oregon experience as documented by Liu (1993) provides a good example of this dynamic.

Policy Variables

As discussed previously, the ridership change regressions include both policy and control variables as explanatory variables. The weighted and unweighted means of three of the five policy variables used in the ridership-change equations are shown in Table 3-4, the other two variables are dummy variables and they are not meaningfully represented as percentage changes. The table also gives weighted and unweighted changes in boardings for each of the periods.

Table 3-4. Weighted and Unweighted Percentage Changes in the Dependent and Policy Variables Used in the Ridership Change Equations for 1960-70, 1970-80, and 1980-90

	Weighted Percentage Change			Unweighted Percentage Change		
Variable	1960-70	1970-80	1980-90	1960-70	1970-80	1980-90
Dependent Variable						
Annual Boardings ('000)	-22.4%	27.4%	-1.5%	-33.3%	48.9%	4.4%
Policy Variables						
Average Real Fares in 1990$	17.3%	-50.0%	21.4%	18.5%	-47.7%	30.6%
Annual Revenue Miles ('000)	-1.3%	-0.7%	14.3%	-13.5%	35.9%	23.9%
Rail Revenue Miles ('000)	2.5%	-29.5%	41.9%	-12.2%	-3.9%	8.0%
Rail/Total Revenue Miles	-61.6%	-18.5%	41.8%	-4.9%	-1.1%	2.3%
Number of Publicly Owned Firms	111.8%	66.7%	0.0%	111.8%	66.7%	0.0%
Publicly-Owned Firms at Start of Decade	NA	NA	NA	NA	NA	NA

It is well understood by transit operators that increases in real fares, everything else being equal, cause ridership declines, and similarly that decreases in real fares cause increases in transit ridership. Indeed, the so-called Simpson-Curtin rule, a widely-accepted industry rule of thumb, suggests that each one percent increase in real fares will produce roughly a one-third of one percent decline in transit ridership. The econometric analyses presented in this chapter and in Chapter 4 provide additional evidence to the adverse effect of fare increases on ridership, although the evidence on the precise size of this effect is mixed.

Accepting the conventional wisdom as represented by the Simpson-Curtin rule for the moment, the increase in real average fares from 68 cents in 1960 to 79 cents in 1970, which corresponds to an unweighted real fare increase of 18.5 percent, would have accounted for about a fifth (6.1 percentage points) of the 33 percent (unweighted) decline in transit ridership during the decade. The 47.7 percent unweighted decrease in mean real fares for the 68 systems included in the 1970-80 sample would similarly have been expected by itself to cause a 15.7 percent increase in transit ridership. Finally, the 30.6 percent increase (unweighted) in real fares for the 75 large systems included in the 1980-90 sample would have been expected to cause a 10.1 percent decline in transit ridership.

The substantial 47.7 percent decline in real fares between 1970 and 1980 was thus an important contributor to the 48.9 increase in boardings that occurred during the decade. These fare reductions, which it should be kept in mind followed unweighted fare increases of 18.5 percent during 1960-70, were made possible by huge increases in operating subsidies for these transit systems. In considering the effect of fare increases and service expansions on transit ridership during 1970-80, the previous observations about the impact of the oil shock on boardings during 1980 should also be kept firmly in mind.

As important as lower fares were in helping to reverse ridership declines, major system expansions, including the construction of new rail systems, additions to existing rail systems, and large increases in bus service miles were perhaps even more important. The increases in bus service miles resulted from services to new routes and probably increases in frequencies on existing routes as well. As the data in Table 3-4 indicate, after a period when the 73 large transit operators included in the 1960-70 linked sample cut total revenue service miles by 13.5 percent, the 69 large systems included in the 1970-80 linked sample increased revenue service miles by 35.9 percent. As comparison of the weighted and unweighted means for revenue miles indicates, however, that a number of larger systems reduced revenue miles of service during the 1970-80 period. Indeed, eight systems cut revenue miles of service by between 25 and 50 percent, and one cut service miles by more than 50 percent.

While the 75 large firms included in the linked 1980-90 linked sample increased real fares during the decade (a 21.4 percent weighed increase and a 30.6 percent unweighted increase), they continued to add additional service miles. The larger unweighted mean increase in service miles, 23.9 percent, than weighted increase, 14.3 percent, again indicates that smaller systems expanded more rapidly (or cut service by less) than larger ones. It should be noted, moreover, that 26 of the 75 large systems included in the 1980-90 sample cut total revenue miles of service during the decade.

It can reasonably be argued that the 23.9 percent increase in total revenue miles of service during 1980-90 understates the extent of system expansion during this decade. As the data on rail revenue miles indicate, rail vehicle miles, after declining by 29.5 percent (weighted) and 3.9 percent (unweighted) during 1970-80, increased by 41.9 percent (weighted) and 8.0 percent (unweighted) during 1980-90. Since a single light or heavy rail vehicle can carry a larger number of passengers than a single bus, a given increase in rail service miles represents a larger capacity increase than the same increase in bus service miles.

The ridership models that are presented in subsequent sections also include the rail share of total revenue miles as a policy variable. As the summary statistics for this variable included in Table 3-4 indicate, the unweighted value of this ratio declined by 4.9 percent between 1960 and 1970 for the 73 systems included in the 1960-70 sample, and fell by an additional 1.1 percent between 1970 and 1980, before increasing by 2.3 percent between 1980 and 1990. The weighted changes in the rail share of total revenue miles were 3.8 percent during 1960-70, -29.0 percent during 1970-80, and 24.1 percent during 1980-90.

The rail revenue miles data shown in Table 3-4 include streetcars, trolleys, light-rail, and heavy rail rapid transit. The first decade (1960-70) was dominated by the continued abandonment of streetcars and trolleys, which had been the primary urban transit mode in the 1920s. The 1970-80 decade combined the continued abandonment of streetcar and trolley lines in many cities with the introduction of new grade-separated, heavy rail systems in a limited number of U.S. cities, most notably San Francisco-Oakland, Washington, D.C., and Cleveland. During the third decade (1980-90), the list of U.S. cities opening new, grade-separated heavy rail or modern light rail systems grew to include Atlanta, Baltimore, San Diego, Miami, Santa Clara (San Jose, CA), Portland (OR), Sacramento, and Buffalo. During the decade, moreover, Chicago, Washington, D.C., New York, and Boston made significant additions to existing systems.[4]

The fact that the rail share and change in rail share variable does not distinguish between streetcars and trolleys, grade-separated heavy-rail, and modern light rail systems is less of a problem for the analyses reported in this chapter than it might at first seem because of the timing of these developments. As noted above, during 1960-70 and 1970-80 most of the changes in rail shares reflected changes in streetcar and trolley services; during 1980-90, by contrast, virtually all of the changes in rail share were due to the

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[4] Atlanta's new rail system began limited operations on one line in 1979, but it was not until the following decade that there was significant rail service in Atlanta (Kain, 1995).

completion of new, or expansion of existing, grade-separated heavy rail or modern light rail systems.

Control Variables Included in Change Equations

Eight control variables are used in one or more of the several change equations reported in this chapter. All but one of these variables are change variables (generally the difference in natural logarithms); the exception is revenue miles at the beginning of the period, which is used to control for system size. In addition to initial revenue miles, the other control variables are changes in metro-area and city population, changes in metro-area and city employment, changes in city population density and area, and changes in the percentage of central city households who do not own a private car. In most instances the city is defined as the central city, but where it is clear that a system serves an area other than the central city, typically a smaller city, the population of this smaller area is used as a proxy for service area population. As we noted previously, more accurate measures of the service areas of the systems included in the analysis is an obvious area for improvement. Obtaining such measures would have been difficult and expensive, however, if not impossible, and thus metropolitan areas, central cities, and in a few instances smaller cities, are used as crude approximations of these areas.

Weighted and unweighted mean percentage changes in annual boardings and of all of the eight control variables except initial service miles are shown in Table 3-5. Metropolitan area definitions change from one census to the next. For this study we generally employ the Census Bureau's definition of each metropolitan area at the end of the decade for each of the three ridership change analyses. The 1980-90 change equations thus use the 1990 definition of the metropolitan area for both 1980 and 1990. Similarly, the 1970-80 analyses use the 1980 metropolitan area definition, and the 1960-70 analyses employ the 1970 definition of the metropolitan area. City population and employment data similarly are based on legal boundaries, and we make no effort to account for annexations.[5] Since the service areas of most of these systems are generally extended to include newly annexed area, the use of legal boundaries, in the absence of more precise definitions of service areas, is probably more justified than the alternative of

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[5] See Kain (1968) for a discussion of this problem and an example of an alternative approach that obtains estimates of central city employment and population.

Table 3-5. Weighted and Unweighted Percentage Changes in the Dependent and Control Variables Used in the Ridership Change Equations: 1960-70, 1970-80, and 1980-90 Samples

Variable	Weighted Percentage Change			Unweighted Percentage Change		
	1960-70	1970-80	1980-90	1960-70	1970-80	1980-90
Dependent Variable						
Annual Boardings ('000)	-22.4%	27.4%	-1.5%	-33.3%	48.9%	4.4%
Exogenous/Control Variables						
Revenue Miles at Beginning Year ('000)	–	–	–	–	–	–
Metro Area Employment ('000)	9.5%	20.0%	30.5%	24.1%	31.1%	23.9%
Metro Area Population ('000)	12.1%	6.1%	11.9%	13.9%	12.6%	10.9%
City Employment ('000)	-2.5%	11.5%	19.2%	7.3%	22.3%	20.6%
City Population ('000)	3.3%	-1.6%	4.4%	8.6%	4.0%	4.2%
City Land Area (square miles)	54.1%	12.4%	7.4%	87.0%	20.5%	8.4%
City Density (persons per sq. mile)	-12.5%	-11.5%	-1.8%	-12.8%	-10.8%	-3.4%
City % Households with No Car	-9.6%	-14.2%	-5.4%	-0.5%	-16.5%	-6.2%

using constant areas.[6] Changes in city area, moreover, are included among the control variables that appear in the change equations.

The data on mean changes in metropolitan area employment and population in Table 3-5 indicate that the average transit system reporting ridership and other data in all three periods operated in a metropolitan area with substantial population and employment growth. Reflecting the steady growth in labor force, female labor force participation and declining family size during this 30 year period, moreover, these data indicate that metropolitan area employment grew more rapidly than metropolitan area population during all three time periods. Thus, metropolitan area employment growth during the three decades ranged from an unweighted average of 23.9 percent during 1980-90 to an unweighted average of 31.1 percent during 1970-80. At the same time, metropolitan area population grew at only about half as much: the range for the same two periods was 10.9 percent to 12.6 percent (both unweighted).

[6] If sufficient resources were available, one promising approach to defining the population of each system's "effective" service area in each year, would be to use census tract or block group data to identify areas with more than some threshold level of transit use. The population of these areas might then be summed to provide an estimate of service area population. An alternative, and far more expensive, approach would be to obtain route maps for each system and to define each system's service area as the population living within a certain distance of each route. An even more ambitious approach would combine these data with information on service frequencies. Analyses that use data of this kind to explain the level of transit ridership in a single metropolitan area (Portland, OR) are included in Liu (1993).

City employment and population within legal boundaries (including annexations) also grew during all three periods, although the city growth rates, particularly those for population, were substantially lower than the same rates for metropolitan areas. During 1980-90, for example, mean unweighted city population growth, which was 4.2 percent for the decade, was less than half the metropolitan area rate of 10.9 percent. These data, particularly those for cities mask a great deal of variation. Thirty-eight of the 69 systems included in the 1970-80 sample, for example, served cities that lost population during the decade. The average loss for these 38 systems was 10.4 percent over the decade. Nine systems, moreover, served cities that lost more than 15 percent of their population over the decade. During the same period, however, the average city population growth rate for the 30 systems serving growing cities was 23.1 percent.

City population densities declined in all three decades, with the largest decline in population density, -12.8 percent (unweighted), occurring during 1960-70. These persistent declines in population density are the result of modest population growth and extensive annexations by many cities, particularly in the South and Southwest. Annexations were significant in all three decades, but especially in the first. During 1960-70, the unweighted mean percentage change in city area was a remarkable 87 percent. The growth of city area was somewhat slower if weighted means were used, but was still 54 percent. Annexations slowed during the next two decades, but the average city included in the sample still increased its area by 20.5 percent over the 1970-80 decade. By 1980-90, annexations were only 6.1 percent of 1980 city land areas.

As was true of the boardings, fare, and revenue service data, the mean values of the several control variables in Table 3-5 mask a great deal of variation among metropolitan areas. For the statistical analyses that follow, this variation is highly desirable, as it increases the likelihood of obtaining reliable estimates of the effects of changes in the several explanatory variables on changes in transit ridership. We now turn to the first of three analyses of changes in transit ridership, those for the linked sample of 75 large transit systems for the most recent period (1980-90).

Estimates for the 1980-90 Linked Sample

The 75 large transit systems included in the linked 1980-90 sample operated in 66 different metropolitan areas. In all but four of these areas the sample includes only a single large system, generally the largest transit operator serving the area. The four metropolitan areas with more than one transit operator, with the number of transit operators shown in parentheses, are: New York (2), Los Angeles (3), San Francisco-Oakland (4), and San Diego (2). In addition, all but four of the 75 transit providers included in the sample had the same ID number in both the 1980 and 1990 Section 15 reports and are thereby "identical" organizations, although their legal status and service areas may have changed during the period.

The four observations in the linked 1980-90 sample that combine data for two or more enterprises with different Section 15 ID numbers include two combined systems in the San Francisco-Oakland Bay Area and San Diego, where new "independent" rail systems were introduced during the decade. These new rail systems, BART and the San Diego Trolley, had major impacts on AC Transit and San Diego Transit, the bus systems that previously served these markets (Kain and Liu, 1995). We concluded that better and more meaningful results would be obtained if the operations data for these rail and bus operators were combined into single observation for the regression analyses.

In addition to combining operations data for BART and AC Transit and for the San Diego Trolley and San Diego Transit, we also aggregated operations data for individual operators serving the Detroit, Dallas and Phoenix metropolitan areas. New regional transit authorities were created in these areas during 1980-90, and we determined that the resulting changes and their impacts on ridership would be best represented by combining the operations data for the operators serving each of these metropolitan areas in each year. In the case of Dallas, for example, the linked sample treats as a single entity the city-owned Dallas Transit System in 1980 and the combined operations of Dallas Area Rapid Transit (DART) and Trailways Commuter Transportation in 1990. DART existed in 1980, but did not acquire the Dallas Transit System from the City of Dallas until sometime during the 1980-90 period.

Even with the merging of data for San Diego Transit and San Diego Trolley, the 1980-90 linked sample still includes two San Diego metropolitan area operators, the combined San Diego Transit-San Diego Trolley entity and North San Diego Transit, as well as four Bay Area operators: the combined BART-AC Transit entity, San Francisco Municipal Transit System (MUNI), San Mateo County Transit, and the San Francisco-Golden Gate Transit District.

Between 1980 and 1990, the growing availability of local and state subsidy dollars for transit led to the creation of a large number of subsidized demand response services in the 66 metropolitan areas included in this study.[7] In some cases, these new services were operated by one of the 75 large transit operators included in the sample. More often, they were supplied by other specialized demand-responsive operators, frequently under contract to one of the 75 large operators included in the regression analyses.[8] While these services are important to their users, they account for a very small share of total boardings in each of the areas included in this analysis. According to APTA (1991, p. 25) statistics, demand-responsive services were operated by 77 percent of all transit systems, but these services account for less than one percent of all boardings nationally. We have essentially ignored them in the analyses that follow.

Table 3-6 provides the mean values for all of the variables that are used in the 1980-90 change equations. As these data indicate, the mean number of boardings for the 75 large transit operators in 1990 is slightly less than the mean number of boardings for

Table 3-6. Mean Values of Variables for the Sample of 75 Large Transit Operators in 1980 and 1990, and Absolute and Percentage Changes for 1980-1990

Variable	1980	1990	Absolute Change	Percentage Change Weighted	Percentage Change Unweighted
Dependent Variable					
Annual Boardings ('000)	90,794	89,461	(1,333)	-1.5%	4.4%
Policy Variables					
Average Real Fares in 1990 $	$0.42	$0.51	$0.09	21.4%	30.6%
Annual Revenue Miles ('000)	19,893	22,738	2,845	14.3%	23.9%
Rail/Total Revenue Miles (%)	5.5	7.8	2.3	41.8%	NA
Exogenous Variables					
Metro Area Employment ('000)	656	856	200	30.5%	23.9%
Metro Area Population ('000)	1,788	2,001	213	11.9%	10.9%
City Employment ('000)	281	335	54	19.2%	20.6%
City Population ('000)	595	621	26	4.4%	4.2%
City Land Area (sq. miles)	121	130	10	8.0%	8.4%
City Density (persons per sq. mile)	6,181	6,071	(110)	-1.8%	-3.4%
Percent City Households w/o Car (%)	22.2	21.0	-1.2	-5.4%	-6.2%

[7] Federal subsidies actually declined over this period.

[8] APTA's 1991 Transit Fact Book reports that there were 5,073 transit systems operating in the U.S. in 1990. According to APTA (1991, p. 10), "about 2,200 of these systems operate motorbus service, 3,200 operate demand-responsive, and 100 operate other modes. About 1,500 operate more than one mode."

the same 75 operators in 1980. The mean of the absolute differences, -1,333, is 1.5 percent less than the 1980 mean level of boardings for the 75 large providers. As the unweighted percentage in Table 3-6 suggests, however, larger operators on average experienced larger losses or smaller increases than the smaller operators. As a result, the unweighted percentage change in annual boardings was 4.4 percent for the 1980-90 period.

As the data in Table 3-6 also indicate, real fares increased by an average of $0.09 for the 75 large transit providers included in this study between 1980 and 1990; this translates to a weighted increase of 21.8 percent and an unweighted increase of 30.6 percent. These averages, however, hide substantial variation in real fares. Fifteen of the 75 operators reduced their fares in real terms between 1980 and 1990; the largest reductions were by Dayton Miami Valley RTD, which reduced its average real fare by 32.7 percent, and by Houston METRO, which reduced its average real fare by 21.6 percent. One of the 75 operators, Worcester (MA) RTD, charged the same average real fare in both 1980 and 1990, while 59 operators increased their fares in real terms. The largest percentage increases were by Santa Cruz (CA) MTD, which increased its average real fare by 127 percent (from 22 cents to 50 cents per boarding) and by Santa Barbara (CA) MTD, which increased its average real fare by 117 percent (from 21 cents to 46 cents per boarding).

If we exclude Seattle's monorail, which is more of a tourist attraction than a transit facility, 19 of the 75 large providers included in our analysis operated some rail service in 1990. Using the rail share of total revenue miles of service as an index of the importance of rail operations, the extent of rail operations in 1990 varied from 100 percent for the New Jersey Port Authority Camden service to 2.8 percent for Santa Clara Transit's light rail system. While not reported in Table 3-6, total rail operations for the 75 large transit providers included in this analysis increased substantially between 1980 and 1990, from 376 million rail miles of service in 1980 to 532 rail miles of service in 1990. Expressed as a fraction of total revenue miles, the rail share for those systems operating rail service increased from 25 percent to 31 percent of their combined revenue miles during the same period.

As discussed previously, in those cases where it was obvious that an operator served only a small part of its metropolitan area, we substituted a crude estimate its service area population for the central city population variable. In the 1980-90 analyses, we made substitutions of this kind for the Santa Monica (CA) Municipal Bus System, the Long Beach (CA) Public Transit System, and the San Francisco Municipal Transit

System (MUNI). These operators served fairly well defined areas and we used population estimates for these areas as service area proxies in the analyses that follow. We were less clear about how to define the service areas for the New Jersey Port Authority services to Camden and for the New Jersey Transit Corporation. For these operators, we relied heavily on service area population data included in the Section 15 and APTA reports, although inspection of these data caused us to doubt their accuracy or relevance.

Equations Explaining 1980-90 Changes in Ridership

Table 3-7 presents six alternative specifications of the 1980-90 change models that include various combinations of policy and control variables as explanatory variables. The explanatory power of all six equations is quite high, particularly given the fact that they are first difference equations. None of the six equations explains less than 74 percent of the variance in changes in the natural logarithm of annual boardings among the 75 large systems included in the analysis.

All six equations include changes in real fares, in total revenue miles, and in the rail share of revenue miles, as well as total revenue miles of service in 1980. As we indicated previously, we view the first three variables as policy variables that are under the direct control of transit managers during the decade, although the actions of these operators are constrained by the combination of farebox revenues and subsidies from federal, state, and local governments. The fourth variable, total revenue miles at the start of the decade, which we treat as a control variable, is a measure of system size or scale at the start of the period.

The results obtained for the first two policy variables included in Table 3-7, changes in real fares and changes in total revenue miles of service, are highly consistent and robust to specification differences. The six fare elasticity estimates are all three to four times their standard errors and cluster tightly around the industry rule of thumb of -0.33. Indeed, the value of this important coefficient was remarkably either -0.33 or -0.34 in all six equations. Similarly, the six service elasticity estimates, which were even more significant statistically, varied between 0.67 and 0.74. The mean of the six estimates is 0.70.

In contrast to the change in real fares and change in total service miles variables, the rail share coefficients are not statistically different from zero in all six 1980-90 ridership change equations. Indeed, none of the six rail share coefficients is as large as its

Table 3-7. OLS Estimates of Regression Models for 1980-90 Changes in Transit Ridership for 75 Large Transit Operators (Dependent variable: change in log of boardings)

Variable	Coefficient Estimate and (Standard Error)					
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6
Constant	-0.90 (0.26)	-0.91 (0.26)	-0.86 (0.27)	-0.85 (0.24)	-0.83 (0.24)	-0.82 (0.24)
Change in log of annual revenue miles	0.71 (0.08)	0.71 (0.08)	0.74 (0.08)	0.67 (0.08)	0.68 (0.08)	0.69 (0.08)
Change in log of real average fares in 1990 $s	-0.34 (0.09)	-0.34 (0.09)	-0.33 (0.09)	-0.34 (0.09)	-0.33 (0.09)	-0.34 (0.09)
Change in the rail share of annual revenue miles	0.47 (0.48)	0.47 (0.48)	0.31 (0.48)	0.44 (0.46)	0.36 (0.46)	0.31 (0.46)
Log of revenue miles for the year of 1980	0.08 (0.03)	0.08 (0.03)	0.08 (0.03)	0.07 (0.02)	0.07 (0.02)	0.07 (0.02)
Change in log of metropolitan area employment	0.17 (0.21)	0.17 (0.21)	0.21 (0.22)			
Change in log of metropolitan area population				0.58 (0.33)	0.74 (0.33)	0.69 (0.33)
Change in log of city employment				0.29 (0.22)	0.34 (0.22)	0.31 (0.22)
Change in log of city population	0.62 (0.24)	1.03 (0.29)	0.69 (0.24)			
Change in log of city land area	0.41 (0.21)			0.32 (0.22)		
Change in log of city population density		-0.41 (0.21)			-0.14 (0.18)	
Change in city percent households with no car	1.57 (1.11)	1.57 (1.11)	1.92 (1.12)	1.71 (1.13)	1.84 (1.14)	2.00 (1.12)
R-Squared	0.75	0.75	0.74	0.75	0.75	0.74

standard errors. This is somewhat surprising, since, as we discussed earlier, there are a number of reasons to expect boardings to increase with the rail share of total service miles, and the increase over the decade in that variable was substantial. Several systems increased their rail share of total service miles, and the mean share increased from 5.5 percent to 7.8 percent over the decade.

Taken together, Equations 1-6 in Table 3-7 examine the effects of eight control variables on transit ridership and, perhaps more importantly, on the coefficient estimates for the three policy variables. As we noted above, changes in specification have almost no effect on the coefficient estimates obtained for the three policy variables. The regression coefficients obtained for the first of these control variables, total revenue miles in 1990, are highly significant statistically in all six equations, ranging from 2.5 to 3.5 times their standard error. The estimates, which are either 0.07 or 0.08, indicate that holding constant the effects of the other variables, annual boardings grew more rapidly for systems that were large at the start of the system than for smaller systems.

The six equations in Table 3-7 use different combinations of the seven land use and household variables. One reason for this strategy is that these and other possible control variables are highly correlated. As a result, use of two or more of these highly correlated explanatory variables often resulted in unreliable estimates of the individual regression coefficients. Table 3-8, which presents simple correlations between the dependent variable and each of seven land use and household variables and among each of the seven explanatory variables, documents the high correlations among these seven

Table 3-8. Simple Correlations among Control Variables: 1980-90 Sample

Variable (*)	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.50	1.00						
Metro Area Jobs	0.39	0.77	1.00					
City Pop	0.35	0.80	0.59	1.00				
City Jobs	0.41	0.73	0.69	0.75	1.00			
City Land Area	0.35	0.40	0.27	0.30	0.33	1.00		
City Pop Density	0.01	0.35	0.28	0.61	0.37	-0.57	1.00	
City % 0-Car HHs	0.11	-0.15	-0.13	-0.24	-0.28	0.11	-0.29	1.00

(*) All but "City % 0-Car HHs" are changes in the logarithms of variables for 1980 and 1990.
"City % 0-Car HHs" is the change in the percentage of zero-car households in central city.

land use and household variables that are included in the 1980-90 change equations. For example, the simple correlation between changes in metropolitan area employment and changes in metropolitan area population is 0.77, a fact that virtually guarantees that including both in the same equation would produce unreliable estimates of the individual regression coefficients of these variables. Similarly, the simple correlation between city employment and city population is 0.75.

In choosing the combinations of control variables for inclusion in Table 3-7 and in the other ridership change models presented in this chapter, we tried to avoid combinations of explanatory variables that were very highly correlated. Careful inspection of Table 3-7 reveals how this approach influenced model specification: Equations 1-3 are identical to the corresponding Equations 4-6, except that the first three use the change in metropolitan area employment as a control variable, while the second three replace it with the change in metropolitan area population. Changes in metropolitan area population work better in these equations than changes in metropolitan area employment, in the sense of having larger and more statistically significant coefficients; a result that on reflection seems reasonable. The systems included in the analysis seldom provided much transit service to suburban workplaces, but in many cases they did serve suburban populations. The coefficient estimates obtained for the change in metropolitan population variable also strongly illustrate the impact of metropolitan growth on system ridership. The estimates suggest that during 1980-90, everything else being equal, boardings increased by between 0.58 and 0.69 percent for each one percent increase in metropolitan area population. Of course, not everything else was equal for the 75 systems included in the 1980-90 change analyses, the remaining control variables included in the six equations are meant to account for these differences.

We have previously emphasized the impact that changes in auto ownership have had on the demand for transit during this century. The number or fraction of households who do not own a private car are of particular interest in this regard, since the members of these households are what transit operators and analysts frequently refer to as "captives," a reference to the fact that they have little choice but to use public transit for trips to destinations that are too far to reach by walking. Because we expected changes in the number of car-owning households to be an important determinant of changes in transit ridership, we included the change in the share of central city households that were car-less in all six 1980-90 ridership change equations. As the data in Table 3-6 indicate, the unweighted mean of this fraction fell from 22.2 percent in 1980 to 21.0 percent in 1990. This change may not seem very large, but taking the coefficients for percent of city households who did not own a car at face value, the 1.2 percentage point decline in this share during 1980-90 would have reduced the increase in total boarding on the average systems by between 1.9 and 2.4 percent. Expressed in another way, if the share of car-less households had not changed over the decade, boardings for the 75 large systems would have increased by between 6.3 and 6.8 percent, rather than the actual increase of 4.4 percent.

The parameter estimates in Table 3-7 indicate that changes in city population have a larger effect on transit ridership than changes in city employment. The elasticities for changes in city population vary between 0.62 and 1.03, while the employment change elasticities are much smaller, between 0.29 and 0.34. In interpreting these differences, however, it is important to keep in mind that corresponding differences are also obtained from the parameter estimates of the change in metropolitan area employment and population variables.

During 1980-90 a number of cities annexed substantial amounts of both area and population. Population growth within constant city boundaries implies increasing densities, while population growth with annexation can actually be associated with density declines. Given the well documented relationship between density and transit ridership, this is an important distinction. The impacts of annexations and density on transit ridership are represented in Equations 1-6 by including changes in city land area (Equations 1 and 4) or by including changes in population density (Equations 2 and 5). City gross population density, of course, is the ratio of city population and land area. Equations 3 and 6 include neither change in area or changes in density.

The signs of both the change in city area and change in city density coefficients are at variance with expectations. The change in city land area, which we expected to have a negative sign, is actually positive and significant in Equations 1 and 4, and, similarly, the change in city density, which we expected would have a positive sign, is negative. The explanation for these counter-intuitive results is undoubtedly the previously mentioned multi-collinearity among the several land use and household variables. Because of these problems, Equations 3 and 6 are probably the most defensible, at least if there is an interest in the individual regression coefficients for the control variables.

Levels and Changes of Transit Ridership: 1970-80

Total passenger boardings in the U.S. reached their historical low in 1973. As discussed previously, however, during the decade 1970-80, the nation's transit operators, aided by growing federal, state, and local subsidies, were able to halt and then reverse the steady decline in transit ridership that had been experienced nationally by the industry since the end of World War II. This reversal was achieved through large increases in capital and operating subsidies, by public takeovers of private transit systems, and by the creation of generously funded regional transit authorities in a growing number of metropolitan areas. In most instances, the new regional transit agencies had a mandate to provide service to much larger parts of the metropolitan areas than the private and public systems they replaced and were provided with substantial subsidies, often in the form of one or more dedicated sources of tax revenues. Regional transit authorities in a number of instances had huge sums at their disposal for both capital investment and operating subsidies, which they typically used to pay for the planning and construction of new rail systems and for the expansion of existing bus services. In addition to growing local and state subsidies, federal transit operating subsidies, which became available in 1974, further encouraged public transit authorities to lower real fares and to expand their systems in an effort to attract more users to the transit systems (UMTA, 1988).

The changes in service levels, real fares, and ridership that occurred during this decade are evident from the data for the 69 transit operators included in the 1970-80 linked sample shown in Table 3-9 (the same data for the individual systems are included in Appendix Table A-3). The variation in system size is greater for the 1970-80 linked sample than for the 1980-90 sample. The 1970-80 sample includes systems that vary in size from the Amarillo (Texas) Transit System (only 700,000 boardings in 1980) to New York CTA (over 2 billion boardings in 1980). As inspection of the data in Table 3-2 on membership in the 1970-80 sample indicates, this sample includes most of the major transit systems. There are, however, some regrettable omissions due to incomplete data: the Cleveland, Columbus (Ohio), St. Louis, and Washington, D.C. systems, for example, are missing from this analysis.

Table 3-9 presents the mean values of the variables for 1970 and 1980, and their absolute and percentage changes during 1970-80. Among these 69 transit systems, 46 experienced ridership increases while 23 experienced ridership declines. As these data indicate, the unweighted increase in annual passenger boardings between 1970 and 1980 for the 69 systems was 48.9 percent. Use of weighted percentage changes, which give

Table 3-9. Mean Values of Variables for the Sample of 69 Transit Operators in 1970 and 1980, and Absolute and Percentage Changes for 1970-1980

Variable	1970	1980	Absolute Change	Percentage Change Weighted	Percentage Change Unweighted
Dependent Variable					
Annual Boardings ('000)	64,398	82,015	17,617	27.4%	48.9%
Policy Variables					
Average Real Fares in 1980 $	$0.52	$0.26	($0.26)	-50.0%	-47.7%
Annual Revenue Miles ('000)	18,062	17,940	(122)	-0.7%	35.9%
Rail/Total Revenue Miles (%)	5.4	4.4	-1.0	-18.5%	NA
Exogenous Variables					
Metro Area Employment ('000)	529	635	106	20.0%	31.1%
Metro Area Population ('000)	1,537	1,631	94	6.1%	12.6%
City Employment ('000)	235	262	27	11.5%	22.3%
City Population ('000)	575	566	(9)	-1.6%	4.0%
City Land Area (sq. miles)	113	127	14	12.8%	20.5%
City Density (persons per sq. mile)	5,888	5,208	(680)	-11.5%	-10.8%
Percent City Households w/o Car (%)	23.9	20.5	-3.4	-14.2%	-16.5%

more weight to larger systems, results in a smaller increase, but even this lower figure is a healthy 27.4 percent.

As the data in Table 3-9 indicate, the 69 systems included in the 1970-80 sample made large reductions in real fares over the decade, average fares declined by -47.7 percent (unweighted) and -50 percent (weighted). In fact, only one of the 69 systems, the Savannah TA, had lower real fares in 1970 than in 1980, while 33 reduced fares by more than 50 percent over the decade. These systems also increased service by significant amounts. When unweighted means are used, the average system provided 35.9 percent more revenue service at the end of the decade than at the beginning. Since the OLS regressions reported on this chapter are unweighted, this is the more relevant of the two means shown in Table 3-9. Nonetheless, it is clear from the weighted average, which is -0.7 percent for the same period, that a number of larger systems reduced the level of service during the decade. In all 45 of the 69 systems included in the 1970-80 linked sample increased service miles during the decade, while 24 decreased service. Nine systems cut total service miles by more than 25 percent between 1970 and 1980. From Table A-3, it can be seen that the New York CTA, the nation's largest transit system, reduced its annual revenue miles of service from 431 million miles in 1970 to 320 million miles in 1980. Service cuts by the New York CTA thus account for a large part of the difference in weighted and unweighted percentage changes in total service miles in Table 3-8.

With the exception of declines in both the weighted and unweighted means of central city population density, which are not good news for transit, the mean values (both weighted and unweighted) of all of the other land use variables change over the decade were positive, which works to the advantage of transit. The number of car-less households, who tend to be transit captives, declined by 14.2 percent (weighted) and 16.5 percent (unweighted) between 1970 and 1980.

Ridership Change Equations for 1970-80

The six 1970-80 ridership change equations, shown in Table 3-10, are identical to those used for the six 1980-90 equations, except that the 1970-80 equations include two more policy variables. These are a 0,1 dummy variable for public ownership at the start of the period, and a second 0,1 dummy variable that identifies those systems that were privately owned at the start of the period but became publicly owned and operated during the period.

The coefficient for the dummy variable that identifies those systems that were publicly owned and operated in 1970 is positive in all six equations, but is not statistically different from zero. The dummy variable identifying those privately owned systems that became publicly owned during the decade was negative in all six equations, but these negative signs should be ignored because the standard error indicates that none of the coefficient estimates for this variable differs from zero.

As was true for the 1980-90 equations, the fare and service elasticities for the six 1980-90 equations are both highly significant statistically and are highly consistent across equations. Half the fare elasticities, for example, are -0.43 and the other half are -0.44. Similarly, half of the service elasticities are 0.72 and half are 0.74.

While the fare elasticities are very similar across the six 1970-80 equations, the mean value of the six 1970-80 fare elasticity estimates, which was -0.44, is a good deal larger than the mean 1980-90 estimate of the same elasticity, which is -0.34. By contrast, the mean service miles elasticity estimate for the 1970-80 sample, which was 0.73, is very close to the mean estimate obtained from the 1980-90 sample, which was 0.70.

The coefficient of the changes in the rail share of total service miles is again positive in all six equations, or not significantly different from zero in any. While this

Table 3-10. OLS Estimates of Regression Models for 1970-80 Changes in Transit Ridership for 69 Transit Operators
(Dependent variable: change in log of boardings)

Variable	Coefficient Estimate and (Standard Error)					
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6
Constant	-0.56 (0.25)	-0.56 (0.25)	-0.52 (0.24)	-0.54 (0.26)	-0.54 (0.27)	-0.51 (0.26)
Change in log of annual revenue miles	0.72 (0.08)	0.72 (0.08)	0.72 (0.08)	0.74 (0.09)	0.74 (0.09)	0.74 (0.09)
Change in log of real average fares in 1980 $s	-0.43 (0.09)	-0.43 (0.09)	-0.43 (0.09)	-0.44 (0.10)	-0.44 (0.10)	-0.44 (0.10)
Change in the rail share of annual revenue miles	0.13 (0.37)	0.13 (0.37)	0.10 (0.37)	0.18 (0.39)	0.16 (0.39)	0.13 (0.38)
Dummy: public ownership for the year of 1970	0.05 (0.13)	0.05 (0.13)	0.03 (0.13)	0.09 (0.14)	0.09 (0.14)	0.07 (0.14)
Dummy: change in ownership during 1970-80	-0.15 (0.13)	-0.15 (0.13)	-0.16 (0.13)	-0.11 (0.14)	-0.11 (0.14)	-0.13 (0.14)
Log of revenue miles for the year of 1970	0.04 (0.02)	0.04 (0.02)	0.04 (0.02)	0.04 (0.02)	0.03 (0.02)	0.03 (0.02)
Change in log of metropolitan area employment	0.43 (0.25)	0.43 (0.25)	0.43 (0.25)			
Change in log of metropolitan area population				0.59 (0.47)	0.66 (0.53)	0.57 (0.46)
Change in log of city employment				-0.05 (0.31)	-0.01 (0.30)	0.01 (0.29)
Change in log of city population	0.10 (0.19)	0.19 (0.23)	0.13 (0.18)			
Change in log of city land area	0.09 (0.19)			0.11 (0.20)		
Change in log of city population density		-0.09 (0.19)			-0.07 (0.17)	
Change in city percent households with no car	1.69 (1.47)	1.69 (1.47)	1.31 (1.23)	1.18 (1.43)	1.04 (1.40)	0.80 (1.23)
R-Squared	0.83	0.83	0.83	0.82	0.82	0.82

result is somewhat surprising, given the tendency for rail systems to have higher transfer rates than all bus systems and the greater carrying capacity of each train, the same result was obtained for the 1980-90 period.

The coefficient of the scale variable, total revenue miles in 1970, is more than twice its standard error in all six equations, and indicates that systems that were larger in 1970 had larger increases in boardings over the decade, holding constant the effects of all other explanatory variables. The magnitude of this scale effect in 1970-80, moreover, is about twice as large as it was in the 1980-90 period.

The land use and household control variables included in the 1970-80 equations are identical to those included in the comparable 1980-90 equations. They exhibit much lower levels of statistical significance than in the comparable 1980-90 equations, however. None is statistically different from zero at the five percent level using conventional tests of significance. The coefficients for the change in city area and change in city density variables also have unexpected signs. Multicollinearity may again be a factor. As the simple correlations for the 1970-80 sample shown in Table 3-11 indicate, the simple correlations among the city and metropolitan area employment and population variables are quite high.

Table 3-11. Simple Correlations among Control Variables: 1970-80 Sample

Variable (*)	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.45	1.00						
Metro Area Jobs	0.48	0.83	1.00					
City Pop	0.27	0.77	0.52	1.00				
City Jobs	0.30	0.79	0.69	0.72	1.00			
City Land Area	-0.02	0.35	0.33	0.40	0.51	1.00		
City Pop Density	0.25	0.31	0.12	0.45	0.11	-0.63	1.00	
City % 0-Car HHs	0.26	-0.16	-0.26	-0.18	-0.28	-0.58	0.42	1.00

(*) All but "City % 0-Car HHs" are changes in the logarithms of variables for 1970 and 1980.
"City % 0-Car HHs" is the change in the percentage of zero-car households in central city.

Levels and Changes in Ridership for 1960-70

During the 1960-70 period, the declines in transit ridership from their World War II peak continued, albeit at a somewhat reduced rate. As a result of these continuing declines, most transit systems, particularly privately owned and operated ones, increased real fares and reduced service miles in an ultimately unsuccessful effort to remain profitable. These trends are evident in the transit firm data included in our 1960-70 sample. This sample contains 66 transit systems ranging in size from the New York City Transit Authority (1.7 billion boardings in 1970) to the Fondy Area Bus Corporation (Wisconsin, 366,000 boardings in 1970).

Table 3-12 provides weighted and unweighted means for all of the variables used in estimating the 1960-70 change regressions. During the decade, total boardings declined by 18.3 percent (weighted) and 31.8 percent (unweighted). Average real fares for these systems, moreover, increased by 14.3 percent (weighted) and 15.9 percent (unweighted). Depending on whether weighted or unweighted means are used, annual revenue miles either increased by a small amount, 1.7 percent (weighted), or declined by

Table 3-12. Mean Values of Variables for the Sample of 73 Transit Operators in 1960 and 1970, and Absolute and Percentage Changes for 1960-1970

Variable	1960	1970	Absolute Change	Percentage Change Weighted	Percentage Change Unweighted
Dependent Variable					
Annual Boardings ('000)	72,802	56,517	(16,285)	-22.4%	-33.3%
Policy Variables					
Average Real Fares in 1970 $	$0.20	$0.24	$0.03	17.3%	18.5%
Annual Revenue Miles ('000)	16,088	15,885	(203)	-1.3%	-13.5%
Rail/Total Revenue Miles (%)	8.6	3.3	-5.3	-61.6%	-11.7%
Exogenous Variables					
Metro Area Employment ('000)	433	474	41	9.5%	24.1%
Metro Area Population ('000)	1,251	1,400	149	11.9%	13.6%
City Employment ('000)	239	233	(6)	-2.5%	7.3%
City Population ('000)	553	570	17	3.1%	8.5%
City Land Area (sq. miles)	61	94	33	53.4%	87.0%
City Density (persons per sq. mile)	6,789	5,937	(852)	-12.5%	-12.8%
Percent City Households w/o Car (%)	28.2	25.5	-2.7	-9.6%	0.5%

a more substantial amount (unweighted). The modest increase in revenue service miles for the weighted sample was largely due to a decision by the New York City Transit Authority to increase total revenue miles of service from 371 million miles in 1960 to 431 million miles in 1970. All but 21 of the 73 systems in the 1960-70 linked sample cut service during the decade.

The household and land use control variables used in the 1960-70 ridership models are identical to those used in the 1980-90 and 1970-80 regressions. As the data shown in Table 3-12 indicate, metropolitan area population grew by an average of 13.6 percent and central city population grew by 8.8 percent during the decade (both of these means are unweighted). As is indicated by the fact that central city densities declined by 12 percent on average during the decade, much of the central city population growth during 1960-70 was due to annexation. An extensive discussion of this issue along with estimates of central city population growth and decline within constant central city boundaries is provided by Kain (1968).

Ridership Change Equations for 1960-70

The specifications of the six 1960-70 ridership change equations included in Table 3-13 are identical to the equations for 1980-90. The similarities do not end, however, with these common specifications. The coefficients of initial year total service miles are once again highly significant statistically, and the estimated values, which are 0.05 in all six equations, are larger than the estimates obtained for the same coefficient in the 1970-80 equations but smaller than the estimates obtained for 1980-90. The change in rail share variable is also not statistically different from zero in any of the 1960-70 equations, a result which is identical to that obtained for the 1970-80 and 1980-90 results. Finally, as was true of the estimates of the same coefficient in the previous periods, both the fare and service elasticities are highly significant statistically in all six equations.

While there are many similarities between the estimates obtained for 1960-70 and for the two earlier periods, there are also some important differences. Starting with the fare and service elasticities, the absolute values of both of these critical parameters for the 1960-70 period are significantly larger than those for the later periods. The mean fare elasticity for the six 1960-70 equations is -0.68, fifty percent larger than the mean value of the same coefficient in 1970-80, which was -0.44, and nearly twice as large as the mean for the 1980-90 period, which was -0.34.

Table 3-13. OLS Estimates of Regression Models for 1960-70 Changes in Transit Ridership for 73 Transit Operators (Dependent variable: change in log of boardings)

Variable	Coefficient Estimate and (Standard Error)						
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6	EQ. 7
Constant	-0.54 (0.12)	-0.54 (0.12)	-0.54 (0.12)	-0.48 (0.13)	-0.48 (0.13)	-0.48 (0.12)	-0.51 (0.11)
Change in log of annual revenue miles	1.06 (0.05)	1.06 (0.05)	1.06 (0.05)	1.07 (0.05)	1.07 (0.05)	1.08 (0.05)	1.06 (0.05)
Change in log of real average fares in 1970 $s	-0.68 (0.11)	-0.68 (0.11)	-0.69 (0.11)	-0.68 (0.11)	-0.68 (0.10)	-0.68 (0.10)	-0.68 (0.10)
Change in the rail share of annual revenue miles	0.04 (0.12)	0.04 (0.12)	0.05 (0.12)	0.04 (0.12)	0.04 (0.12)	0.05 (0.12)	0.05 (0.12)
Dummy: public ownership for the year of 1960	-0.09 (0.05)	-0.09 (0.05)	-0.09 (0.05)	-0.09 (0.05)	-0.09 (0.05)	-0.09 (0.05)	-0.09 (0.05)
Dummy: change in ownership during 1960-70	-0.20 (0.05)	-0.20 (0.05)	-0.20 (0.05)	-0.20 (0.05)	-0.20 (0.05)	-0.20 (0.05)	-0.20 (0.05)
Log of revenue miles for the year of 1960	0.05 (0.01)	0.05 (0.01)	0.05 (0.01)	0.05 (0.02)	0.05 (0.02)	0.05 (0.02)	0.05 (0.01)
Change in log of metropolitan area employment	0.07 (0.09)	0.07 (0.09)	0.07 (0.09)				
Change in log of metropolitan area population				-0.05 (0.21)	-0.07 (0.21)	-0.16 (0.26)	
Change in log of city employment				-0.08 (0.13)	-0.08 (0.13)	-0.08 (0.13)	
Change in log of city population	0.03 (0.11)	-0.01 (0.09)	-0.03 (0.08)				
Change in log of city land area	-0.04 (0.05)			-0.02 (0.04)			
Change in log of city population density		0.04 (0.05)			0.04 (0.05)		0.04 (0.04)
Change in city percent households with no car	0.18 (0.39)	0.18 (0.39)	0.27 (0.37)	0.06 (0.39)	0.05 (0.38)	0.15 (0.36)	0.15 (0.35)
R-Squared	0.89	0.89	0.89	0.89	0.89	0.89	0.89

The mean value for the service elasticity for 1960-70, which is 1.07, is also substantially larger than the values obtained for the earlier periods, which were 0.73 for 1970-80 and 0.70 for 1980-90. These are interesting findings that are worth more investigation. At this point, however, we can only offer some speculations. Private operators generally concentrated on central city services and used more complex fare structures that frequently entailed payment for transfers, express premium fares, zone fares, etc.. These practices may have increased the sensitivity of ridership to changes in the average fare and service level variables used in the analyses presented in this report.

None of the land use and household control variables included in the 1960-70 change equations was statistically different from zero in any of the six equations. The most optimistic interpretation of this result, and one that has considerable merit, is that the first differencing procedure used for the 1960-70 change analysis largely removed the influence of land use and household characteristics on transit use. In this regard, it should be kept in mind that the analysis would only capture the cross section variation in the changes in land use and rates of auto ownership. If there were large changes in these variables during this period, but changes that affected all metropolitan areas in a fairly uniform manner, the effects of these changes would, like the previously discussed time series changes in real gas prices, affect only the constant terms of the change equations. Moreover, the low levels of statistical significance for these variables may be explained partly by the simple correlations among them, which are shown in Table 3-14.

Table 3-14. Simple Correlations among Control Variables: 1960-70 Sample

Variable (*)	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.14	1.00						
Metro Area Jobs	0.13	0.52	1.00					
City Pop	0.09	0.38	0.33	1.00				
City Jobs	0.08	0.37	0.42	0.53	1.00			
City Land Area	0.00	0.26	0.20	0.73	0.44	1.00		
City Pop Density	0.05	-0.12	-0.08	-0.39	-0.28	-0.92	1.00	
City % 0-Car HHs	0.09	-0.19	-0.21	-0.48	-0.38	-0.51	0.41	1.00

(*) All but "City % 0-Car HHs" are changes in the logarithms of variables for 1970 and 1980.
"City % 0-Car HHs" is the change in the percentage of zero-car households in central city.

The coefficient estimate for the public ownership dummy in 1960, which is included in all three equations, is nearly twice (1.8 times) its standard error and suggests that systems that were publicly owned in 1960 carried about nine percent fewer passengers (boardings) than private firms serving markets with the same land use characteristics and with the same real fares and service levels. The coefficients of the dummy variable identifying systems that became public during the decade, moreover, were four to five times their standard errors, and their values consistently indicate that the change in ridership for these systems was about 20 percent less than would otherwise be expected.

Chapter 4

Cross-Section Analyses of Transit Ridership

Introduction

In this chapter we present cross-section analyses of transit ridership for 1960, 1970, 1980, and 1990. The samples used for the 1960, 1970 and 1980 cross-section analyses are significantly larger than both the sample of 75 large transit systems that is used for the 1990 cross section analysis in this chapter and those used for the ridership change analyses described in the previous chapter. The linked samples were limited in size by the requirement of complete operations data for both the beginning and end of the decade; the size of the 1980-90 linked sample was further limited by a decision to limit the sample, and the analyses based on it, to the largest 75 systems.

The cross-section samples used for the analyses described in this chapter total 140 systems in 1960, 97 systems in 1970, 95 systems in 1980, and 75 systems in 1990. The size and membership of the 1990 cross-section sample is thus identical to that of the 1980-90 cross-section sample. The 1980 cross-section sample includes the same 75 systems plus 20 additional systems that were included in the 1970-80, but not in the 1980-90 linked sample. The 1960 and 1970 cross-section samples consist of the systems included in the 1960-70 linked samples plus a much larger number of systems that had complete data for only one of the two years.

Characteristics of Systems and Areas

A total of 184 systems appear in at least one of the four cross-section analyses. These systems are listed from largest to smallest in Table 4-1, where system size is defined as the mean boardings for those years with boardings data. As these data reveal, the systems included in the cross-section analyses vary greatly in size. New York CTA, the largest system, averaged 1.9 billion boardings and carried more than 13,000 times as many passengers as the smallest system, Ritchey Transportation Company of New Bethlehem (PA) which had only 146,000 boardings in 1960.

These data also reveal that New York's CTA had nearly four times as many boardings as the second largest system, Chicago's CTA, which averaged 557 million

Table 4-1: List of Transit Firms Included in the Cross-Section Ridership Analyses

Transit System	Date of Public Owner-ship	Included in Cross-Section Equations (Yes=1, No=0) 1960	1970	1980	1990	Annual Total Passenger Boardings ('000) 1960	1970	1980	1990	Mean
New York CTA	32	L	L	1	1	1,781,795	1,666,570	2,021,213	2,191,757	1,915,334
Chicago-CTA	47	L	L	1	1	534,757	386,157	720,834	586,916	557,166
Philadelphia-SEPTA	70	L	L	1	1	568,070	274,462	377,065	317,503	384,275
Los Angeles-SCRTD	58	0	L	1	1		198,883	396,618	401,055	332,185
Washington, D.C.-WMATA	73	L	0	1	1	188,226	(170	299,042	357,508	281,592
Boston-MBTA	47	L	L	1	1	256,392	253,970	252,951	303,992	266,826
NYC, Surface Transit Inc	62	L	0	0	0	257,612				257,612
San Francisco-MUNI	12	L	0	1	1	201,504	(1,004	309,132	233,468	248,035
NYC, 5th Ave. Coach Lines		L	0	0	0	232,189				232,189
New Jersey Transit Corp.		L	L	1	1	268,955	193,486	113,003	122,140	174,396
San Francisco BART & AC TD		0	0	1	1			158,144	140,809	149,477
Detroit-SEMTA	71	L	L	1	1	183,022	158,610	126,887	93,852	140,593
New Orleans - RTA	83	L	L	1	1	164,075	124,105	106,668	77,913	118,190
Baltimore-MTA	70	L	L	1	1	124,784	77,894	118,772	113,039	108,622
Milwaukee County TS		L	L	1	1	173,956	99,135	85,560	64,794	105,861
Atlanta-MARTA	72	L	L	1	1	69,554	61,050	120,163	147,845	99,653
Pittsburgh-PAT	64	L	L	1	1	93,645	103,724	108,179	86,719	98,067
St Louis-Bi-State	63	L	0	1	1	127,179	(**)	84,215	44,578	85,324
Minneapolis MTC	70	L	L	1	1	87,339	63,755	105,203	69,588	81,471
Cleveland RTA	72	L	0	1	1	18,329		116,973	73,930	69,744
Miami-Dade Cnty TA	62	0	L	1	1		55,875	67,448	80,740	68,021
Honolulu DOT Service	73	L	0	1	1	38,803	(108	74,055	73,513	62,124
Houston-MTA	74	0	L	1	1		38,888	47,774	88,367	58,343
Seattle Metro	11	L	L	1	1	41,476	31,751	74,233	78,804	56,566
Buffalo-Niagra Frontier	74	L	L	1	1	87,723	64,430	34,274	30,352	54,195
Dallas DART	60	L	L	1	1	47,313	40,408	38,066	51,010	44,199
NYC, Green Bus Lines		L	0	0	0	43,345	(203			43,345
NY, Port Au. trans-Hudson	62	0	L	0	0	38,954				38,954
Denver-RTD	74	0	L	1	1		16,490	46,942	53,262	38,898
Cincinnati-SORTA	73	L	L	1	1	55,431	33,746	33,666	30,496	38,335
Orange County TD	71	0	0	1	1			28,983	44,846	36,915
Portland-Tri-County MTD	69	L	L	1	1	27,917	18,171	46,811	54,235	36,783
San Diego MTS/MTDB	67	L	L	1	1	31,784	16,296	36,009	53,677	34,441
San Antonio-VIA Metro Tr	59	L	L	1	1	30,890	25,377	36,931	42,138	33,834
Upper Darby, Phila. Transpn Co		L	0	0	0	30,095				30,095
Michigan City, South Shore Rail		L	0	0	0	29,461				29,461
Kansas City Area TA	69	L	L	1	1	50,724	22,065	25,236	18,455	29,120
Birmingham Transit Co		L	0	0	0	28,997				28,997
New York-Triboro Coach Co.		L	L	0	0	28,691	27,864			28,278
Rochester-Genesee RTA	68	L	L	1	1	40,463	27,794	25,511	15,202	27,242
Richmond, Gr Richmond TC	73	0	L	1	1		32,916	24,466	21,680	26,354
Santa Clara County TD	73	0	0	1	1		(54	31,254	45,723	25,659
Columbus-Central Ohio TA		L	0	1	1	38,376	(240	19,941	18,415	25,577
Memphis Area TA	61	L	L	1	1	33,792	28,371	24,393	13,858	25,104
New Haven-Conn Transit		L	0	1	1	46,968		18,254	9,305	24,842
Louisville-TA River City	74	L	L	1	1	34,217	18,350	22,073	21,892	24,133
Providence RI PTA	66	L	L	1	1	30,116	19,439	27,558	16,030	23,286
Indianapolis PTC	75	L	L	1	1	29,461	21,559	16,362	12,312	19,923

Table 4-1: List of Transit Firms Included in the Cross-Section Ridership Analyses

Transit System	Date of Public Ownership	Included in Cross-Section Equations (Yes=1, No=0)				Annual Total Passenger Boardings ('000)				
		1960	1970	1980	1990	1960	1970	1980	1990	Mean
San Mateo County District		0	0	1	1		(**)	18,213	18,399	18,306
Dayton Miami Valley RTA	72	L	L	1	1	28,996	16,671	9,042	16,046	17,689
Long Beach Public Trans	63	0	L	1	1		12,232	18,275	20,711	17,072
Albany-Capital Dist TA	72	1	0	1	1	20,807		16,089	12,443	16,446
Syracuse-CNY Centro	72	L	L	1	1	22,649	14,762	14,803	13,242	16,364
Phoenix TS		0	S	1	1	(145	4,020	14,297	30,046	16,121
Santa Monica Muni Bus	28	0	L	1	1		12,484	16,425	18,998	15,969
Salt Lake City-Utah TA	70	0	S	1	1		3,954	19,083	23,903	15,647
Bridgeport-Conn Railway		L	L	0	1	24,687	13,339		7,298	15,108
Nashville-MTA		L	L	1	1	19,908	13,414	17,980	8,827	15,032
Ft Lauderdale-Browrd Cnty	72	0	0	1	1		(**)	12,041	17,474	14,758
Sacramento RTD	73	L	L	1	1	11,549	7,512	16,959	19,707	13,932
Jacksonville TA		L	L	1	1	16,083	12,533	16,958	9,642	13,804
Hartford-Conn Transit		0	0	1	1		(399	21,952	19,158	13,703
VA & MD Coach Co		L	0	0	0	12,649				12,649
Omaha, TA of Omaha	72	L	L	1	1	20,910	9,583	13,289	6,745	12,632
Brmngham Transit Co		L	0	1	1	28,997	(**)	1,587	5,795	12,126
Charlotte TS		L	L	1	1	13,317	11,295	11,230	11,855	11,924
Wilmington, Delaware Bus Co		L	0	0	0	11,706				11,706
Oak Park, West Towns Bus Co		L	0	0	0	11,525				11,525
Cincinnati, Newport & Cov		L	L	0	0	15,434	7,069			11,252
Tucson, City of Tucson MTS	69	0	0	1	1	(52	(**)	8,814	13,441	11,127
Harvey, South Suburban SL		L	0	0	0	10,671				10,671
Trenton, Capital Transit		L	0	0	0	10,458	(125			10,458
San Fran-Golden Gate TD	28	0	0	1	1		(**)	10,581	10,243	10,412
Camden, Port Authority TC	69	0	L	1	1		8,656	10,890	11,405	10,317
Evanston Bus Co		L	L	0	0	11,640	8,745			10,193
Springfield Street Railway Co		L	0	0	1	16,187	(**)		3,574	9,881
N. San Diego Transit Dev		0	0	1	1		(25	8,157	11,228	9,693
Madison Metro	70	0	S	1	1		4,627	13,424	9,096	9,049
Middlesex & Boston Street Railway		L	0	0	0	8,832				8,832
Phila, Port Au. Transit Corp.		L	0	0	0	8,656				8,656
Tacoma-Pierce Cnty Trans	61	0	L	1	1		7,756	7,532	10,570	8,619
Roanoke, Safety Motor Transit Co		L	0	0	0	8,279				8,279
Fort Worth, The T-Fort Worth	72	L	L	1	1	14,120	7,372	6,090	5,404	8,246
Santa Barbara MTD	67	0	0	1	1		(12	10,630	5,655	8,142
Delaware Bus Co	69	L	0	1	1	11,706		7,405	4,685	7,932
Reading Bus Co		L	0	1	1	13,120	(**)	5,542	4,211	7,625
Hillsborough Area RTA	71	0	0	1	1		(62	4,434	10,622	7,528
Savannah TA	60	L	L	1	1	10,224	9,031	4,517	5,951	7,431
Fresno TS	61	0	S	1	1		2,746	10,459	9,074	7,426
Shreveport Area TS	72	0	L	1	1		13,527	5,144	3,504	7,392
Spokane Transit Authority	68	0	0	1	1		(66	7,290	7,293	7,292
Toledo RTA	71	0	L	1	1		5,545	8,222	6,353	6,707
Harrisburg-CAT		L	L	1	1	9,610	5,548	7,190	4,238	6,647
Worcester RTA		L	0	1	1	14,692	(152	6,285	4,968	6,448
St. Louis County Transit Co		L	0	0	0	6,429				6,429
Santa Cruz MTD	68	0	0	1	1		(**)	6,111	6,739	6,425

Table 4-1: List of Transit Firms Included in the Cross-Section Ridership Analyses

Transit System	Date of Public Owner-ship	Included in Cross-Section Equations (Yes=1, No=0) 1960	1970	1980	1990	Annual Total Passenger Boardings ('000) 1960	1970	1980	1990	Mean
Charleston, SC Electric & Gas		L	L	0	1	9,475	5,336		4,044	6,285
Pinellas Suncoast TA	73	0	0	1	1		(59	3,382	9,030	6,206
Eugene-Lane County MTD	70	0	0	1	1			6,283	5,917	6,100
Orlando TCT	72	0	0	1	1		(80	3,833	8,061	5,947
Akron-Metropolitan RTA	69	L	S	1	1	13,151	2,963	1,902	5,394	5,853
Knoxville Transit Lines	67	L	0	1	1	9,571	(**)	4,359	3,460	5,797
Albuquerque-Sun-Tran	66	L	S	1	1	6,873	2,911	6,816	6,373	5,743
Gary Railway Inc		L	L	1	1	8,024	7,521	4,773	2,641	5,740
Gary Railway Inc		L	L	0	0	8,024	7,521	4,773	2,641	5,740
New Bedford SERTA	70	L	0	1	1	6,135	(111	5,620	4,969	5,575
Allentown-LANTA	72	L	S	1	1	8,502	4,016	5,162	4,505	5,546
Shaker Height, City DOT	44	L	S	0	0	6,180	4,831			5,506
Duluth Superior Transit Co	70	L	0	1	1	7,350	(78	5,226	3,354	5,310
Little Rock-Metroplan	72	L	L	1	1	9,544	5,430	2,428	2,563	4,991
Colmbia, SC Electric & Gas		L	L	0	1	6,264	5,313		3,323	4,967
Youngstown-Western Res	70	L	0	1	1	10,039	(50	2,485	1,549	4,691
Grand Rapids Transit Au	64	L	S	1	1	7,190	2,938	4,617	3,778	4,631
DesPlaines, United Motor Coach		L	S	0	0	5,639	3,290			4,465
Charleston Transit Co	71	L	S	1	1	8,001	3,704	3,861	2,025	4,398
Columbus Transpn Co	67	L	0	0	1	6,822			1,598	4,210
Greenville City Coach Lines		S	S	0	0	4,582	3,785			4,184
Wilkes-Barre Transit Corp		L	S	1	1	5,167	3,074	5,556	2,780	4,144
Corpus Christi, Nueces Transpn Co	66	S	0	0	1	4,697	(**)		3,380	4,039
Durham, Duke Co.		L	S	0	1	5,042	4,322		2,408	3,924
Utica Transit Co		0	S	0	0		3,886			3,886
McKeesport, Penn Transit Co		S	0	0	0	3,837				3,837
Holyoke Street Railway		S	S	0	0	4,073	3,335			3,704
Fitchburg & Leo. Street Railway		S	S	0	0	3,951	3,423			3,687
Belleville-St. Louis Coach Co		S	0	0	0	3,624				3,624
Greensboro, Duke Power		S	S	0	0	4,060	3,110			3,585
Chattanooga Area RTA	72	0	S	1	1		3,628	4,332	2,708	3,556
Fondy Area Bus Corp	73	S	S	0	0	6,736	366			3,551
Detroit-Canada Tunnel Corp		S	0	0	0	3,465				3,465
Gr Lynchburg TC	74	S	S	1	1	4,697	3,827	2,409	1,617	3,137
Stockton MTD	65	0	S	1	1		2,604	2,848	3,733	3,062
Flint-MTA	64	L	S	1	1	5,586	1,865	1,303	3,367	3,030
Wheeling, Cooperative Transit Co		L	0	0	1	5,348	(23		670	3,009
St Joseph Light & Power Co		S	S	0	0	4,149	1,767			2,958
Raleigh-NC Transit Div		S	S	1	1	3,301	3,008	3,441	1,695	2,861
Springfield MTD	68	S	S	1	1	3,075	2,213	3,422	2,653	2,841
Broome Cnty Dept of PT	68	0	S	1	1		2,136	3,321	3,046	2,834
Huntington, Ohio Valley Bus Co	72	L	0	1	1	6,251	(**)	1,342	744	2,779
Warren Transport Co		S	0	0	0	2,660				2,660
City Utilities of Spr.		S	S	1	1	4,198	2,264	1,403	1,794	2,415
Manchester Transit Inc		S	0	1	1	4,951	(65	1,695	585	2,410
Colorado Springs Transit	72	0	S	1	1		1,036	2,758	3,397	2,397
Norristown, Schuylkill Valley Lines		S	0	0	0	2,274				2,274
LaCrosse Transit Co		S	0	0	0	2,229	(33			2,229

Table 4-1: List of Transit Firms Included in the Cross-Section Ridership Analyses

Transit System	Date of Public Owner-ship	Included in Cross-Section Equations (Yes=1, No=0) 1960	1970	1980	1990	Annual Total Passenger Boardings ('000) 1960	1970	1980	1990	Mean
Asheville TA	66	S	S	1	1	3,318	2,227	1,848	1,467	2,215
Wichita MTA	66	0	S	0	1		2,063		2,336	2,200
Berea Bus Lines		S	0	0	0	2,131				2,131
Interstate Power Co	73	S	S	1	1	3,389	2,172	1,647	707	1,979
Wilmington, Safeway Transit Co	74	S	0	1	1	2,594	(17	1,475	1,232	1,767
Mass Northeastern Transpn Co		S	0	0	0	1,667				1,667
Wheeling Public Service Co		S	0	0	0	1,659				1,659
Spartanburg, Duke Power Co		S	S	0	0	1,678	1,583			1,631
Seattle Suburban Transpn System		S	0	0	0	1,618				1,618
Galveston Island Trans		0	S	1	1		1,900	1,914	980	1,598
Newport, Transit Lines Inc		S	0	0	0	1,471				1,471
Williamsport Bus Co	69	S	0	1	1	2,005	(18	1,222	1,186	1,471
City Lines of Parkersburg		S	0	0	0	1,444				1,444
Clarksburg, City Lines of WV		S	S	0	0	1,939	827			1,383
Clarksburg, City lines of WV		S	0	0	0	1,939	827			1,383
Terminal Island Transit Co		S	0	0	0	1,345				1,345
City of Elgin, DOT	68	0	S	1	1		723	1,631	1,672	1,342
Winthrop RTC		0	S	0	0		1,332			1,332
Green Bay TS	73	0	S	1	1		1,283	1,208	1,358	1,283
Mansfield Rapid Transit Lines		S	0	0	0	1,228				1,228
Zanesville, Y-City Transit Co.		S	S	0	0	1,164	1,052			1,108
Lafayette-COLT	66	0	S	1	1		943	1,009	1,331	1,094
Oshkosh City Transit Lines		S	S	1	1	1,345	1,178	903	925	1,088
Eau Claire Transpn Co		S	0	0	1	2,427	(20		846	1,084
New Castle Area Transit	59	S	S	0	0	1,525	620			1,073
Fairmont, City Lines		S	S	0	0	1,633	510			1,072
Amarillo Transit System		0	S	1	1		1,352	700	850	967
Winona Transit Co		S	0	0	0	960				960
Massillon, Fidelity Motor Bus Lines		S	0	0	0	908				908
City of Santa Rosa	58	0	S	1	1		241	911	1,521	891
Chalottesville & Albermarle Bus Co		S	0	0	0	849				849
Newark City Rapid Transit Lines		S	0	0	0	837				837
Anderson, Duke Power Co		S	S	0	0	917	659			788
New Kensington City Lines		S	0	0	0	732				732
Muskegon Area TS		S	0	1	1	1,297	(**)	225	567	696
San Angelo City Bus Co		S	0	0	0	1,023	309			666
Everett City Lines		S	0	0	0	657				657
Greenfield & Montague Transpn Area		S	0	0	0	477				477
Beaver Meadow, Baran's Transit Lines		S	0	0	0	242				242
New Bethlehem, Ritchey Transpn Co		S	0	0	0	146				146
All Systems		140	97	95	75					
Sum						6,891,325	4,538,062	6,921,839	6,837,040	7,497,516
Mean						49,224	46,784	72,861	91,161	NA

Notes: (1) The numbers in parentheses are the numbers of revenue vehicles for the corresponding transit firms;

(2) The double astericks in parentheses identify systems that appear to have existed in that year

(3) "L" denotes included transit system with annual boardings over 5 millions, and "S", less than 5 millions.

boardings a year. In addition, two other New York City transit systems had enough boardings in 1960 to be ranked among the top ten systems in that year. These comparisons are a useful reminder of the extent to which New York City's experience tends to dominate national data on transit systems, if weighted means or national aggregates are used.

As in the comparable table in Chapter 3, Table 4-1 gives the initial year of public ownership and operation for each system, when this information was available. Similarly, the columns labeled 1960, 1970, 1980, and 1990 contain codes that indicate whether particular systems are included in each of the four cross-section samples. In the case of 1980 and 1990, sample membership is indicated by a 0, 1 dummy; systems included in the sample are coded as 1 and those that are not are coded as a zero. For 1960 and 1970 this coding convention is elaborated to distinguish between small and large systems. Large systems, which are defined as systems with more than five million annual boardings, are identified by the letter L, and small systems, which had fewer than five million annual boardings, are identified by the letter S.

Total and mean boardings for the 184 systems used in the cross-section analyses are presented at the bottom of the table. The means and sums refer to only those systems with boardings data in a particular year. As these data reveal, mean boardings for the 1980 and 1990 samples are much larger than the same statistics for the 1960 and 1990 samples. This result is hardly surprising for 1990 since the 1990 cross-section sample is the same as the 1980-90 linked sample, which was limited to the 75 largest systems with complete operations data. Mean boardings for the 1980 sample, though lower than those for the 1990 sample, are still significantly larger than for either the 1960 and 1970 sample. The 97 systems included in the 1970 sample, with an average of 46.8 million annual boardings, have the fewest annual boardings of any of the four samples.

The 1960 and 1970 samples both include larger numbers of observations and larger fractions of smaller systems. To test whether the determinants of transit ridership and the effects of critical policy variables on ridership are different for large and small systems, we estimate separate equations for large and small systems. These results are presented in the last section of this chapter after the results for the complete individual year samples have been presented.

System Characteristics

The mean values of both the dependent and independent variables for the pooled cross-section regressions are shown in Table 4-2. As noted previously, average annual ridership, as measured by total boardings, is significantly larger for the 75 systems included in the 1990 sample than for any of the other samples. This reflects the decision to use the systems included in the 1980-90 linked sample for this analysis. Average boardings for the 95 systems included in the 1980 sample are less than for 1990 as a result of the decision to add the smaller systems that were included in the 1970-80 linked sample. Even so, with a mean of 73.4 million boardings a year, the average size of systems in the 1980 sample is significantly greater than the average size of systems included in the 1970 (an average of 47.5 million annual boardings) or the 1960 samples (57.0 million annual boardings).

Table 4-2. Mean Values of Variables for the Single-Year Samples

Variable	Samples			
	1990	1980	1970	1960
Number of Transit Operators	75	95	97	140
Dependent Variable				
Annual Boardings ('000)	89,461	73,439	47,530	57,030
Policy Variables				
Average Real Fares in 1990 $	$0.51	$0.42	$0.80	$0.72
Annual Revenue Miles ('000)	22,738	16,230	13,397	12,201
Rail Revenue Miles ('000)	7,106	3,953	4,771	4,069
Rail/Total Revenue Miles	7.8%	4.3%	3.9%	8.2%
Number of Publicly-Owned Operators	75	91	52	26
Exogenous Variables				
Metro Area Employment ('000)	856	582	572	537
Metro Area Population ('000)	2,001	1,490	1,656	1,454
Central City Employment ('000)	335	236	254	228
Central City Population ('000)	621	497	633	470
City Land Area (square miles)	130	107	97	50
Central City Density (Psns./ sq. mi.)	6,071	5,451	6,088	8,938
City % Households with No Car	21.0	20.6	25.0	30.2

Note: CPI 1960$=1.31*1970$, 1970$=2.12*1980$, and 1980$=1.58*1990$.

A good case could also be made for using total annual revenue miles, one of the five policy variables shown in Table 4-2, to measure system size. When this measure is used rather than boardings, the 140 systems included in the 1960 sample are only 54 percent as large as the 75 systems included in the 1990 sample; the comparable fraction using boardings is 64 percent.

While the differences in the four samples should be kept in mind, the real fare data in Table 4-2 document the impacts of growing financial pressure on the fare setting decisions of private transit operators, the shift from private to public ownership, and finally the growing financial constraints on publicly owned systems during the 1980-90 decade. As these data indicate, average real fares increased from 72 cents in 1960 to 80 cents in 1970. Thereafter, huge infusions of federal, state, and local subsidies permitted the by then predominantly publicly owned systems to cut real fares to an average of 42 cents in 1980. In the subsequent decade, slower subsidy growth and increasing costs led system managers to increase real fares to an average of 51 cents in 1990.

The impact of streetcar abandonment during the 1960s and the implementation of modern heavy and then light rail systems in a growing number of US metropolitan areas during the 1970s and 1980s, particularly during the latter decade, are evident from the rail share data included in Table 4-2. These data demonstrate that the unweighted ratio of rail to total revenue miles first declined from 8.2 percent in 1960 to 3.9 percent in 1970, before it grew slowly to 4.3 percent in 1980 and then nearly doubled to 7.8 percent in 1990. As larger systems are more likely than smaller systems to choose rail technologies, particularly the more costly heavy rail and modern light rail technologies, it is particularly important to keep the differences in sample size and membership in mind in assessing these data.

The differences in means for the seven control variables included in Table 4-2 are smaller than might have been expected, particularly given the fact that the earlier samples include larger numbers of small systems. Even with confounding differences in sample composition and the several control variables, several previously discussed trends are, nonetheless, evident in the data in Table 4-2.

The share of total metropolitan area population residing in each city is not very different among the four samples, ranging from a high of 38 percent for the 1970 sample to a low a 31 percent for the 1990 sample. This relative constancy, in the face of widespread suburbanization over this 30 year period, no doubt reflects differences in sample composition and the extensive annexation of area and population by many cities.

The average geographic size of the cities included in the four samples increased from 50 square miles for the 1960 sample to 97 square miles for the 1970 sample, to 107 square miles for the 1980 sample, and finally to 130 square miles for the 1990 sample. This trend is the result both of some tendency for the 1990 and 1980 samples to exclude smaller systems and cities, particularly the 1990 sample, and of extensive annexations by a number of included cities (annexations were particularly pronounced during 1960-70).

Even with differences in sample membership, city densities declined in each decade between 1960 and 1980 and the fraction of households owning zero cars fell from 30.2 percent in 1960 to 25.0 percent in 1970 and then to 20.6 percent in 1980, before edging up to 21.0 percent in 1990. Like the closely related data on city density, the changes in sample membership would presumably have worked to attenuate these trends in the fractions of carless households. We now turn to a consideration of the cross-section regression equations and to a consideration of the way in which cross-section variations in both the policy and control variables affected the levels of transit ridership (boardings) during each of the years.

Functional Form

The single-year cross-section ridership models described in this chapter all employ the log-log functional form shown by Equation 1. As in chapter 3, in estimating this equation, the dependent, and all but a few of the independent variables, are transformed to natural logarithms:

(1) $\ln B = b_0 + b_1 \ln F + b_2 \ln M + \Sigma_i b_i \ln S_i + b_3 D + \Sigma_j b_j \ln X_j$;

where B denotes transit boardings; F, transit fares; M, service levels, for example, revenue miles of service provided; S_i, other measures of service characteristics; D is a dummy variable which indicates whether the system is privately or publicly owned; X_j, is a vector of various exogenous or control variables; and b_0, b_1, b_2, b_i and b_j are coefficients to be estimated.

As was true of the similar ridership change equations reported in the previous chapter, the log-log functional form used for the cross-section models provides for interactions among the several explanatory variables and has the further advantage, in those instances where both the dependent and independent variable are logarithms, of permitting the convenient interpretation of the individual regression coefficients as constant elasticities. As noted in the previous chapter, a constant elasticity gives the percentage change in the dependent variable that would result from a one percent change in a particular independent (explanatory) variable.

Results of the 1980 and 1990 Cross-Section Models

Table 4-3 presents estimates of six cross-section models for the 1990 sample of 75 large transit operators and Table 4-4 presents comparable equations for the augmented sample of 95 systems in 1980. The first thing to notice about these equations is that all 12 explain either 95 or 96 percent of the cross-section variation in annual boardings for the two samples of transit operators. This is about 20 percentage points higher than the fraction of explained variance obtained for the six 1980-90 change equations; the R^2s for those equations varied from 0.70 to 0.73. This difference was expected, as cross-section equations of this kind usually have higher R^2s than change equations; the surprise is that the R^2s for the change equations were as high as they were.

The specifications of the six 1980 and six 1990 cross-section equations are identical, except that the 1980 equations include a 0, 1 dummy variable identifying publicly owned systems. This policy variable does not appear in the 1990 cross-section equation because all 75 systems included in the sample were publicly owned and operated in that year; however, the augmented sample of 95 systems in 1980 includes four privately owned and operated systems. The logarithm of total revenue miles, the logarithm of real fares, and the rail share of total revenue miles are included in all 12 equations.

All 12 equations also include as an explanatory variable the percentage of city households that do not own a car. These equations for each year differ in terms of the land use variables that are included as controls. The first three equations in each table use metropolitan area employment to quantify differences in metropolitan area size, while Equations 4 - 6 in each table use metropolitan area population to quantify metropolitan area size. Within these two groupings, the specifications differ according to which combinations of city employment, city population, city land area, and city density are used as additional controls. We now consider the estimates obtained for the individual regression coefficients, starting with those obtained for the several policy variables.

Table 4-3. OLS Estimates of Cross-Section Ridership Models for 75 Large Transit Operators in 1990 (Dependent variable: log of annual boardings)

Variable	Coefficient Estimate and (Standard Error)					
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6
Constant	-1.85 (0.52)	-1.85 (0.52)	-2.12 (0.54)	-3.04 (0.64)	-2.20 (0.45)	-1.85 (0.48)
Log of total revenue miles	0.85 (0.06)	0.85 (0.06)	0.89 (0.07)	0.94 (0.06)	0.87 (0.06)	0.95 (0.06)
Log of real average fares	-0.51 (0.11)	-0.51 (0.11)	-0.41 (0.11)	-0.36 (0.11)	-0.46 (0.11)	-0.39 (0.12)
Rail share (%) of total revenue miles	0.29 (0.23)	0.29 (0.23)	0.30 (0.24)	0.10 (0.25)	0.14 (0.24)	0.10 (0.26)
Log of metropolitan area employment	0.17 (0.05)	0.17 (0.05)	0.20 (0.06)			
Log of metropolitan area population				0.13 (0.06)	0.11 (0.06)	0.11 (0.06)
Log of city employment				0.31 (0.10)	0.20 (0.06)	0.17 (0.06)
Log of city population	0.37 (0.10)	0.15 (0.06)	0.10 (0.06)			
Log of city land area	-0.23 (0.07)			-0.19 (0.07)		
Log of city population density		0.23 (0.07)			0.29 (0.08)	
% of city households with no car	1.63 (0.43)	1.63 (0.43)	2.21 (0.42)	1.29 (0.47)	1.28 (0.42)	1.95 (0.42)
R-Squared	0.96	0.96	0.96	0.96	0.96	0.95

Table 4-4. OLS Estimates of Cross-Section Ridership Models for 95 Transit Operators in 1980 (Dependent variable: log of annual boardings)

Variable	Coefficient Estimate and (Standard Error)					
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6
Constant	-0.94 (0.50)	-0.94 (0.50)	-1.04 (0.49)	-1.91 (0.65)	-1.79 (0.50)	-1.74 (0.50)
Log of total revenue miles	0.86 (0.06)	0.86 (0.06)	0.87 (0.06)	0.89 (0.06)	0.88 (0.06)	0.89 (0.06)
Log of average passenger fares	-0.42 (0.09)	-0.42 (0.09)	-0.42 (0.09)	-0.38 (0.09)	-0.39 (0.09)	-0.39 (0.09)
Rail share (%) of total revenue miles	-0.02 (0.29)	-0.02 (0.29)	-0.01 (0.29)	-0.03 (0.30)	-0.04 (0.30)	-0.05 (0.30)
Dummy: public ownership	-0.17 (0.18)	-0.17 (0.18)	-0.14 (0.18)	-0.21 (0.18)	-0.23 (0.18)	-0.19 (0.17)
Log of metropolitan area employment	0.07 (0.05)	0.07 (0.05)	0.08 (0.05)			
Log of metropolitan area population				0.11 (0.07)	0.09 (0.07)	0.12 (0.07)
Log of city employment				0.21 (0.10)	0.20 (0.07)	0.17 (0.06)
Log of city population	0.28 (0.11)	0.22 (0.07)	0.21 (0.08)			
Log of city land area	-0.07 (0.08)			-0.03 (0.08)		
Log of city population density		0.07 (0.08)			0.10 (0.08)	
% of city households with no car	2.65 (0.55)	2.65 (0.55)	2.85 (0.50)	2.27 (0.59)	2.15 (0.51)	2.41 (0.46)
R-Squared	0.96	0.96	0.96	0.96	0.96	0.96

Results for Policy Variables

The estimated real fare elasticities for the six 1980 cross-section equations vary between -0.38 and -0.42 while those obtained for the six 1990 equations, which range between -0.36 and -0.51, exhibit greater variation. All 12 fare elasticity estimates are highly significant statistically, with coefficients that are three to four times their individual standard errors. The mean values of the fare elasticity estimates, -0.40 for 1980 and -0.44 for 1990, are both larger in absolute value than the mean fare elasticity obtained for the six 1980-90 change equations, which was -0.33. The mean fare elasticities for 1980 and 1990 were thus also larger in absolute value than the industry rule of thumb (the so-called Simpson-Curtin rule), which it may be recalled was also -0.33. They are somewhat closer to the means of the estimates obtained by Linsalata and Pham (1991), which were -0.36 for small systems and -0.43 for larger ones.

The estimates obtained for the total revenue miles coefficient in the six 1980 cross-section equations also fall in a fairly narrow range, 0.86 to 0.89, and those for the six 1990 cross-section similarly range from 0.85 to 0.94. All 12 estimates, moreover, are more than ten times their standard errors. As was true of the mean fare elasticities reported above, the mean total service mile elasticities, which are 0.88 for 1980 and 0.89 for 1990, are significantly larger than the mean estimate of the same parameter obtained for the 1980-90 change equations., which is 0.75. While we use a single explanatory variable, total (bus plus rail) revenue miles of service in these analyses, it should be understood that increases in the amount of service provided can take the form of more route miles of service (more coverage) or of higher frequencies on the same network, or some combination of the two. These issues are examined by Liu (1993) for Portland, Oregon's transit system

All 12 equations in Tables 4-3 and 4-4 also include the rail share of total revenue miles as a policy variable. Somewhat to our surprise, the coefficient estimate of this variable was not significantly different from zero in any of the 12 equations. Indeed, the estimates exceed their standard errors in only three equations (Equations 1-3 in Table 4-3) and they are only slightly larger than their standard errors. Nonetheless, there are at least three possible reasons for including the rail share of revenue miles in the cross-section equations and for anticipating that systems with relatively more rail service miles would have more boardings, holding constant the effects of real fares, total revenue miles of service and the several control variables. First, it has been suggested that grade separated rail systems can provide faster and more reliable service because their segregated right-of-ways protect them from congestion and allow them to offer higher line-haul travel speeds. Second, multi-car trains have substantially greater carrying capacity than even large, articulated buses. This feature of the rail technology may permit bus-rail systems to provide more "effective revenue miles" of service than all-bus systems that may have to provide redundant service on some high-density routes (by redundant service we mean the provision of frequencies that exceed those that would reasonably be expected to have a significant effect on ridership).

The strongest reason to expect that bus-rail systems with extensive rail service would have more boardings than an otherwise identical all-bus system is the tendency for bus-rail systems to make greater use of feeder-line haul networks than all-bus systems. Feeder bus-line haul networks concentrate demand and permit rail systems to exploit their scale advantages. Disadvantages of such networks, of course, include greater trip circuitry and higher transfer rates. The bottom line for this analysis is that the high transfer rates associated with some rail systems may artificially inflate their boardings numbers because a higher transfer rate increases the number of boardings for the same number of linked trips.

Control Variables

As anticipated, the statistical significance of the several control variables is much greater in the 1980 and 1990 cross-section equations than in the 1980-90 change equations. This is because the first difference specification used for the change equation removed much of the impact on ridership of slowly changing land use and household variables.

The results for the percent of city households who own zero cars are particularly striking. The parameter estimates for this variable range from 1.28 to 2.21 for the 1990 equations, with a mean value of 1.66, while those obtained for the 1980 equations vary between 2.15 and 2.85 with a mean values of 2.5. In interpreting these results, it should be recognized that, unlike most of the other explanatory variables, which are represented as natural logarithms in the estimating equation, the percent of city households who do not own a car is a percentage. This coefficient gives (approximately) the percentage change in boardings that would result from a one <u>percentage point</u> change in the share of city households who own zero cars.

As the simple correlations among the 1990 contral variables in Table 4-5 reveal, metropolitan area employment and metropolitan area population are highly correlated ($r = 0.92$) and the simple correlations between city employment and city population are even

Table 4-5. Simple Correlations among Control Variables:
1990 Sample, 75 Large Transit Operators

Variable	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.54	1.00						
Metro Area Jobs	0.56	0.92	1.00					
City Pop	0.92	0.61	0.63	1.00				
City Jobs	0.90	0.62	0.65	0.98	1.00			
City Land Area	0.18	0.17	0.20	0.44	0.48	1.00		
City Pop Density	0.63	0.55	0.53	0.51	0.48	-0.28	1.00	
City % 0-Car HHs	0.49	0.33	0.23	0.32	0.31	-0.29	0.67	1.00

greater (r = 0.98). These high correlations account for the decision to alternatively use metropolitan area employment and city population as control variables in Equations 1-3 and metropolitan area population and city employment as control variables in Equations 4-6. With one exception (log of city population in Equation 3), the coefficients estimates obtained for all of these variables are 2.0 to 3.0 times as large as their standard errors.

The results obtained for the land use controls in Equation 1 are fairly representative of those obtained for all six 1990 equations. They indicate that each one percent increase in metropolitan area population led to a 0.17 percent increase in annual boardings and each one percent increase in city population resulted in a 0.37 percent increase in boardings. Equation 1, which also includes city area to account for difference in density and the effect of annexations, indicates that annual boardings decline by 0.23 percent with each one percent increase in city area, holding constant the effects of city population and the other explanatory variables. Equations 2 and 5 use city density directly rather than city area to represent the effects of annexations; the density coefficient in Equation 2, which is 0.23, is equal in magnitude but opposite in sign to that obtained for the city area variable in Equation 1, providing further evidence of the equivalence of these two measures. City density has a somewhat larger effect on boardings when it is paired with city employment in Equation 5.

The magnitudes (in absolute value) and statistical reliability of the coefficients for metropolitan area employment and population, city employment and population, city area, and city density for 1980 (Table 4-4) are generally less than those for the same equations in 1990. The fact that the regression coefficients for zero car ownership are larger in absolute value in the 1980 than in 1990 may be part of the explanation. Some support for this interpretation is provided by the fact that the simple correlations between zero car households and the other control variables, shown in Table 4-6, are consistently larger in 1980 than in 1990.

Table 4-6. Simple Correlations among Control Variables: 1980 Sample, 95 Transit Operators

Variable	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.61	1.00						
Metro Area Jobs	0.60	0.85	1.00					
City Pop	0.94	0.66	0.65	1.00				
City Jobs	0.90	0.68	0.66	0.98	1.00			
City Land Area	0.22	0.22	0.23	0.46	0.50	1.00		
City Pop Density	0.65	0.62	0.54	0.55	0.54	-0.17	1.00	
City % 0-Car HHs	0.54	0.47	0.33	0.40	0.42	-0.17	0.73	1.00

Cross-Section Regressions for 1970 and 1960

The 1970 cross-section regressions, shown in Table 4-7, are estimated for a sample of 97 transit systems and the 1960 cross-section regressions, shown in Table 4-8, are estimated for a sample of 140 transit systems. The equation specifications are the same as for the 1980 equations, which are in turn identical to those used for the 1990 regressions, except that the 1980 equations include a public ownership dummy.

Differences in public/private ownership is one of the reasons we have grouped the discussions of the 1980 and 1990 and 1960 and 1970 results. As noted above, none of 75 systems included in the 1990 sample and all but four of the 95 systems included in the 1980 sample were publicly owned and operated. In contrast, 46 percent (45 of 97) of the systems included in the 1970 sample and 81 percent (114 of 140) of the systems included in the 1960 sample were privately owned and operated. The operations data for 1980 and 1990 compared to that for 1960 and 1970 were obtained from different sources, and this difference may also have something to do with the substantial differences in parameter estimates obtained for the two periods.

Table 4-7. OLS Estimates of Cross-Section Ridership Models
for 97 Transit Operators in 1970
(Dependent variable: log of annual boardings)

Variable	Coefficient Estimate and (Standard Error)					
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6
Constant	-1.60 (0.54)	-1.60 (0.54)	-1.67 (0.38)	-2.28 (0.48)	-2.14 (0.52)	-2.26 (0.42)
Log of total revenue miles	1.07 (0.03)	1.07 (0.03)	1.07 (0.03)	1.06 (0.03)	1.06 (0.03)	1.06 (0.03)
Log of average passenger fares	-0.64 (0.09)	-0.64 (0.09)	-0.65 (0.09)	-0.69 (0.09)	-0.69 (0.09)	-0.69 (0.09)
Rail share (%) of total revenue miles	0.09 (0.19)	0.09 (0.19)	0.09 (0.18)	-0.00 (0.18)	-0.00 (0.18)	-0.00 (0.18)
Dummy: public ownership	-0.12 (0.05)	-0.12 (0.05)	-0.12 (0.05)	-0.12 (0.05)	-0.12 (0.05)	-0.12 (0.05)
Log of metropolitan area employment	0.09 (0.04)	0.09 (0.04)	0.09 (0.03)			
Log of metropolitan area population				0.13 (0.04)	0.13 (0.04)	0.13 (0.04)
Log of city employment				-0.02 (0.07)	-0.02 (0.04)	-0.02 (0.04)
Log of city population	-0.04 (0.08)	-0.02 (0.04)	-0.02 (0.04)			
Log of city land area	0.01 (0.07)			-0.01 (0.06)		
Log of city population density		-0.01 (0.07)			-0.02 (0.06)	
% of city households with no car	1.56 (0.38)	1.56 (0.38)	1.52 (0.28)	1.36 (0.35)	1.47 (0.36)	1.38 (0.28)
R-Squared	0.98	0.98	0.98	0.98	0.98	0.98

Table 4-8. OLS Estimates of Cross-Section Ridership Models
for 140 Transit Operators in 1960
(Dependent variable: log of annual boardings)

Variable	Coefficient Estimate and (Standard Error)					
	EQ. 1	EQ. 2	EQ. 3	EQ. 4	EQ. 5	EQ. 6
Constant	-3.09 (0.44)	-3.09 (0.44)	-2.16 (0.32)	-2.58 (0.36)	-3.10 (0.44)	-2.30 (0.35)
Log of total revenue miles	1.08 (0.02)	1.08 (0.02)	1.07 (0.03)	1.06 (0.03)	1.06 (0.02)	1.05 (0.03)
Log of average passenger fares	-0.87 (0.09)	-0.87 (0.09)	-0.84 (0.09)	-0.88 (0.08)	-0.86 (0.08)	-0.84 (0.08)
Rail share (%) of total revenue miles	0.09 (0.13)	0.09 (0.13)	0.09 (0.14)	0.01 (0.13)	0.04 (0.13)	0.03 (0.13)
Dummy: public ownership	-0.08 (0.07)	-0.08 (0.07)	-0.09 (0.07)	-0.06 (0.07)	-0.08 (0.06)	-0.08 (0.07)
Log of metropolitan area employment	0.01 (0.02)	0.01 (0.02)	0.04 (0.02)			
Log of metropolitan area population				0.02 (0.03)	-0.01 (0.03)	0.02 (0.03)
Log of city employment				0.15 (0.03)	0.09 (0.03)	0.11 (0.03)
Log of city population	0.20 (0.06)	0.03 (0.03)	0.06 (0.03)			
Log of city land area	-0.17 (0.06)			-0.09 (0.04)		
Log of city population density		0.17 (0.06)			0.16 (0.06)	
% of city households with no car	-0.09 (0.28)	-0.09 (0.29)	0.38 (0.24)	0.14 (0.24)	-0.14 (0.28)	0.32 (0.23)
R-Squared	0.98	0.97	0.97	0.97	0.98	0.97

The service and fare elasticity estimates for 1970 and 1960 share high levels of statistical significance and consistency across equations for the same year with the previously discussed 1990 and 1980 estimates. Indeed, the service coefficients are 30 to 40 times their standard errors and all fall in the narrow range 1.05 to 1.08 for all 12 equations for both years. These results, however, also provide support for the view that the period of predominantly private ownership and operation was different from the period of predominantly public ownership and operation. The service elasticities obtained for the latter period were significantly lower than those obtained for the 1970 and 1960 samples; the mean service elasticity for the twelve 1990 and 1980 equations was 0.88 as compared to a mean of 1.07 for the twelve 1970 and 1960 equations.

Even larger differences between the earlier and latter period were obtained for the fare elasticities. The mean fare elasticity for 1980 and 1990 period was -0.42, which again is larger, but not enormously larger, than the -0.3 figure suggested by the Simpson-Curtin rule and is even closer to the estimates obtained by Linsalata and Pham (1991) for 52 systems. By contrast, the mean estimate for the 12 1960-70 equations, which is -0.76, is much larger in absolute value. Closer inspection of the fare elasticity estimates for 1970 and 1960 in Tables 4-7 and 4-8, however, reveals that the values for 1960, which average -0.86, are still larger than the values for 1970, which are -0.67. Within each year, however, the range is quite narrow: -0.64 to -0.69 for 1970 and -0.84 to -0.88 for 1960. Although we have no very good explanation for these differences, as we discuss in Appendix A, the more complex fare structures used by private operators may have something to do with them, or they may simply reflect genuine differences in behavior during the two periods.

The coefficient estimates obtained for the rail share variable in the 1960 and 1970 equations exhibit even less statistical significance than those obtained for the 1980 and 1990 equations. Its coefficient is not as great as its standard error in any equation and in most cases it is less than half as large.

The coefficient estimates for the public/private ownership dummy, which are identical in all six 1970 equations, indicate that holding constant the effects of the other control and all policy variables, publicly owned systems in 1970 had 12 percent fewer boardings than comparable privately owned systems. The coefficients of the public/private ownership dummy are also negative in all six 1960 equations; they vary between -0.06 and -0.09. None of these coefficients is statistically different from zero, however.

With the exception of the metropolitan employment and population variables and the zero cars variable, none of the other control variables included in the 1970 equations have coefficients that differ from zero at even the ten percent level. As Table 4-9, which presents the simple correlations among control variables for 1970, indicates, multicollinearity may be part of the explanation for their low levels of statistical significance.

Table 4-9. Simple Correlations among Control Variables: 1970 Sample, 97 Transit Operators

Variable	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.48	1.00						
Metro Area Jobs	0.49	0.94	1.00					
City Pop	0.60	0.76	0.78	1.00				
City Jobs	0.60	0.77	0.78	1.00	1.00			
City Land Area	0.23	0.28	0.29	0.46	0.46	1.00		
City Pop Density	0.52	0.80	0.75	0.78	0.79	0.07	1.00	
City % 0-Car HHs	0.43	0.51	0.44	0.58	0.60	-0.01	0.81	1.00

The control variables perform even less well in the 1960 equations. Only one of the six coefficients for the metropolitan area size is statistically different from zero. The sole exception, metropolitan area employment in Equation 3, is twice is standard error, and it indicates that metropolitan area employment had only a small impact on annual boardings. Holding constant the effects of all of the remaining variables, annual boardings increased by about four hundredths of one percent with each one percent increase in metropolitan area population in 1960. The coefficient of city population in Equation 3 is also twice its standard error and indicates that annual boardings increase by six hundredths of one percent with each one percent increase in city population. The coefficient of the zero car ownership variable in this equation is about 1.5 times its standard error. Taken at face value, it indicates that boardings would increase by about four tenths of one percent with each one percent increase in the fraction of zero car owning households.

The simple correlations among these control variables for 1960 are shown in Table 4-10. These data suggest that multicollinearity may be part of the explanation for the control variables' low levels of statistical significance.

Table 4-10. Simple Correlations among Control Variables: 1960 Sample, 140 Transit Operators

Variable	Boardings	Metro Area Pop	Metro Area Jobs	City Pop	City Jobs	City Land Area	City Pop Density	City % 0-CAR HHs
Boardings	1.00							
Metro Area Pop	0.47	1.00						
Metro Area Jobs	0.49	0.93	1.00					
City Pop	0.80	0.67	0.69	1.00				
City Jobs	0.60	0.80	0.83	0.83	1.00			
City Land Area	0.57	0.30	0.29	0.67	0.50	1.00		
City Pop Density	0.30	0.74	0.79	0.50	0.83	0.07	1.00	
City % 0-Car HHs	0.32	0.47	0.53	0.42	0.62	0.08	0.75	1.00

Estimates for Large and Small Systems

In this section we stratify the 1960 and 1970 samples into subsamples to determine whether the determinants of ridership differ for large and small systems. This stratification also allows us to explore whether the inclusion of many smaller systems in the 1960 and 1970 samples were responsible for the marked differences in fare and service elasticity estimates for the periods of private (1960 and 1970) and public (1980 and 1990) ownership and operation.

As the data in Table 4-11 reveal, we split the 1960 sample into subsamples of 88 large and 52 small systems and the 1970 sample into subsamples of 56 large systems and 47 small systems. Large systems are defined as those with more than five million annual boardings and small systems are defined as those with less than five million annual boardings. The data in Table 4-11 further reveal that the mean number of boardings for large systems in 1960 was 76.6 millions boardings per year, while the mean number of boardings for large systems in 1970 was only five percent greater, 80.4 million per year. The average number of boardings for small systems in the two years are also quite similar. Mean boardings for the sample of small systems in 1960 were 2.4 million per year and mean boardings for small systems in 1970 were 8.3 percent greater (2.6 million per year).

Table 4-11. Mean Values of Variables for the Large and Small Systems: 1960 and 1970 Samples (*)

Variable	1960 Sample Large	1960 Sample Small	1970 Sample Large	1970 Sample Small
Number of Transit Operators	88	52	56	47
Dependent Variable				
Annual Boardings ('000)	76,650	2,235	80,446	2,572
Policy Variables				
Average Real Fares in 1990 $	$0.70	$0.75	$0.86	$0.75
Annual Revenue Miles ('000)	16,167	936	22,349	1,170
Rail Revenue Miles ('000)	5,497	88	8,264	0
Rail/Total Revenue Miles	10.2%	1.7%	6.7%	0.0%
Number of Publicly-Owned Operators	18	9	31	24
Exogenous Variables				
Metro Area Employment ('000)	655	210	809	248
Metro Area Population ('000)	1,761	824	2,424	606
Central City Employment ('000)	282	55	397	58
Central City Population ('000)	588	137	999	135
City Land Area (square miles)	58	22	139	39
Central City Density (Psns./ sq. mi.)	10,467	4,934	7,726	3,850
City % Households with No Car	32.1	24.7	28.5	20.1

(*) Larger operators are those with over 5 million annual boardings, and smaller operators, with less 5 million boardings per year.

Note: CPI 1960$=1.31*1970$, 1970$=2.12*1980$, and 1980$=1.58*1990$.

The means of the policy variables in Table 4-11 indicate that mean real fares per boarding for large systems in 1960 (70 cents per boarding), were five cents less than the mean real fares per boarding for small systems, but by 1970, the reverse was true. The mean fares charged by small systems remained 75 cents per boarding, while the mean fare charged by large systems increased to 86 cents (an 11 cent differential). If the Simpson-Curtin rule is to be believed, something that the previously cited estimates from the 1960 and 1970 cross-section equations cast some doubt upon, the 23 percent increase in fares charged by large systems would have caused an 8 percent decline in boardings.

Not surprisingly, the data on total revenue miles in Table 4-11 indicate that the average large system provided many times as much service as the average small system. In addition, both small and large systems on average increased their revenue miles of service over the decade. These data also confirm earlier observations that larger systems are much more likely to operate rail service than smaller ones. None of the small systems operated any rail service in 1970, and rail service miles in 1960 accounted for less than two percent of the total revenue miles of service offered by small systems in that year. The small amounts of rail service provided by small systems in 1960 were no doubt the remnants of streetcar and street railway service, which were common in both large and small cities before World War II.

Public ownership and operation of both large and small systems was the exception in 1960. As the data in on public ownership in Table 4-11 reveals, only 17 percent (9 of 52) of the systems included in the 1960 small systems subsample were government owned. Public ownership was only slightly more common among large systems in 1960; only 20 percent (18 of 88) of large systems were government owned in that year.

There are similarly few, if any, surprises in the mean values of the control variables for the samples of large and small systems. Small systems tend to serve smaller markets in smaller metropolitan areas and cities. The cities they serve, moreover, have significantly lower gross population densities than the cities served by large systems, and the fractions of carless households are also significantly lower in the areas served by small systems.

The 1970 Regressions for Large and Small Systems

As can be seen from Table 4-12, we present three 1970 equations each for large and small systems. Identical equation specifications are used for large and small systems, with one minor exception. Equations L1 and S1, L2 and S2, and L3 and S3 thus refer to equations with identical specifications for both large and small systems. The exception, of course, is the omission of the rail share variable from all of the 1970 small system equations. Since no small systems operated any rail service in 1970. The R^2s for both the large and small systems are in excess of 0.91, although the those obtained for the large systems, which were 0.97 in all three equations, were also significantly larger.

The 1970 estimates of the service mile elasticity for large and small systems are almost identical, ranging from 1.00 and 1.01 for the three large system equations and from 0.99 and 1.02 for the three small system equations. The mean values, moreover, which were essentially one for both large and small systems, are only about seven percent less than the mean value for the pooled sample in 1970, which was 1.07.

Table 4-12. OLS Estimates of Cross-Section Ridership Models by Firm Size for 97 Transit Operators in 1970
(Dependent variable: log of annual boardings)

	Coefficient Estimate and (Standard Error)					
	56 Large Firms (> 5 million boardings)			41 Small Firms (< 5 million boardings)		
Variable	EQ. L1	EQ. L2	EQ. L3	EQ. S1	EQ. S2	EQ. S3
Constant	-1.97 (0.52)	-2.41 (0.64)	-2.27 (0.59)	-0.13 (0.75)	-1.15 (0.85)	-0.91 (0.72)
Log of total revenue miles	1.00 (0.04)	1.01 (0.04)	1.01 (0.04)	1.02 (0.06)	1.00 (0.06)	0.99 (0.06)
Log of average passenger fares	-0.87 (0.11)	-0.90 (0.12)	-0.89 (0.11)	-0.38 (0.13)	-0.45 (0.14)	-0.43 (0.13)
Rail share (%) of total revenue miles	0.31 (0.17)	0.25 (0.18)	0.24 (0.18)			
Dummy: public ownership	-0.05 (0.06)	-0.06 (0.06)	-0.06 (0.06)	-0.11 (0.08)	-0.12 (0.08)	-0.11 (0.07)
Log of metropolitan area employment	0.06 (0.04)			0.09 (0.04)		
Log of metropolitan area population		0.07 (0.05)	0.08 (0.04)		0.14 (0.05)	0.15 (0.05)
Log of city employment		0.10 (0.08)	0.05 (0.04)		-0.06 (0.11)	-0.11 (0.06)
Log of city population	0.06 (0.04)			-0.11 (0.06)		
Log of city land area		-0.04 (0.06)			-0.06 (0.10)	
% of city households with no car	0.91 (0.32)	0.70 (0.42)	0.87 (0.32)	2.45 (0.47)	2.05 (0.58)	2.23 (0.47)
R-Squared	0.97	0.97	0.97	0.91	0.91	0.91

In contrast to the results obtained for the service elasticities, the fare elasticity estimates obtained for the large and small systems were quite different. The estimates obtained for the three large system equations, which ranged between -0.87 and -0.90, were larger in absolute value than even the rather large estimates previously reported for the pooled 1970 equations, which had a mean value of -0.67. However, the fare elasticity estimates obtained for the three small system equations, which ranged between -0.38 and -0.45 and had a mean of -0.42, were significantly smaller (in absolute value) than the mean estimate obtained for the pooled 1970 equation

The rail share coefficient is positive in all three large system equations and is nearly twice its standard error in Equation L1. As noted previously, the rail share is not included in the small system equation because none of the small systems offered any rail service in 1970.

The coefficient of the public ownership dummy is negative in all six equations, but exhibits very low statistical significance. Its coefficient is both larger in absolute value and more statistically significant in the small system equations than in the large system equations.

The coefficient estimates for the control variables are generally plausible. Only the city population and employment variables for the small system equations have unanticipated signs; they are negative in all three equations and statistically different from zero in two of them. The coefficients for the percent of city households who do not own a car were positive in all six equations and generally had high statistical significance. The size of the coefficient estimates for this variable, however, were more than twice as large in the small system equations as in the large system ones. The most likely explanation is that the fraction of carless households does a better job than the other control variables of accounting for the land use and other differences among the areas served by small systems.

The 1960 Regressions for Large and Small Systems

The fractions of explained variance for the 1960 large-system equations, $R^2 = 0.98$ for all three equations, exceeds even the previously noted very high fractions ($R^2 = 0.97$), obtained for the three 1970 large system equations. However, the R^2s obtained for the small-system equations in 1960, $R^2 = 0.80$ for all three equations, are significantly smaller than those obtained for the three 1970 small system equations (which were $R^2 =$ 0.91).

As the data in Table 4-13 reveal, the service elasticity estimates obtained for the three large system equations fall in the narrow range 1.02 to 1.05 and are similar to, but slightly larger, than those obtained for the three small-system equations, which varied between 0.96 and 1.01. In contrast to the 1970 real fare elasticity estimates, which were quite different for large and small systems, the 1960 real fare elasticity estimates were very similar; the mean value for large systems was -0.82 and the mean value for small systems was -0.80. None of the rail share coefficients in 1960 were statistically different from zero; indeed, none were as large as their standard errors. Similarly, none of the remaining control variables exhibited a statistically significant effect on transit use among either large or small systems in 1960.

All of the control variables in the three large system equations had the expected signs, although none of the metropolitan area population, city land area, or city fraction of carless household variables were statistically different from zero. The most likely explanation is multicollinearity, particularly between the city land and fraction of carless household variables. In contrast to the results obtained for 1970, the coefficients for the fraction of carless households variable in the three 1960 small system equations were negative, although none was as large as its standard error. In general, the control variables in the 1960 small system equations performed poorly, particularly by comparison to the more recent analyses.

Table 4-13. OLS Estimates of Cross-Section Ridership Models by Firm Size for 140 Transit Operators in 1960
(Dependent variable: log of annual boardings)

	Coefficient Estimate and (Standard Error)					
	88 Large Firms (> 5 million boardings)			52 Small Firms (< 5 million boardings)		
Variable	EQ. L1	EQ. L2	EQ. L3	EQ. S1	EQ. S2	EQ. S3
Constant	-1.77 (0.35)	-2.35 (0.39)	-1.93 (0.39)	-1.26 (1.01)	-1.29 (1.00)	-1.20 (0.94)
Log of total revenue miles	1.03 (0.03)	1.05 (0.03)	1.02 (0.03)	1.01 (0.08)	0.96 (0.08)	0.96 (0.08)
Log of average passenger fares	-0.79 (0.10)	-0.87 (0.10)	-0.79 (0.10)	-0.78 (0.16)	-0.81 (0.16)	-0.80 (0.16)
Rail share (%) of total revenue miles	0.09 (0.10)	0.02 (0.09)	0.05 (0:10)	-0.31 (0.75)	-0.12 (0.76)	-0.14 (0.74)
Dummy: public ownership	-0.00 (0.06)	-0.02 (0.06)	-0.01 (0.06)	-0.17 (0.16)	-0.08 (0.16)	-0.09 (0.16)
Log of metropolitan area employment	0.07 (0.02)			-0.01 (0.05)		
Log of metropolitan area population		0.01 (0.03)	0.05 (0.03)		0.01 (0.05)	0.00 (0.04)
Log of city employment		0.16 (0.04)	0.07 (0.03)		0.11 (0.07)	0.10 (0.06)
Log of city population	0.03 (0.03)			0.08 (0.08)		
Log of city land area		-0.11 (0.04)			-0.03 (0.09)	
% of city households with no car	0.52 (0.19)	0.14 (0.21)	0.47 (0.19)	-0.44 (0.86)	-0.45 (0.84)	-0.46 (0.83)
R-Squared	0.98	0.98	0.98	0.80	0.80	0.80

Appendix A

Boardings vs. Linked-trips

Boardings vs. Linked-Trips

At several points in the body of the report we noted the superiority of linked-trips over boardings as a measure of transit ridership. The problem is that many systems do not prepare estimates of linked-trips and those prepared by some systems are not published. There are two explanations. First, the estimation of linked-trips can be quite difficult, particularly for large and complex multi-modal systems. These systems, of course, are the very ones for which the distinction between boardings and linked-trips is likely to be the most important. Second, and more importantly, FTA does not require systems to provide linked-trip data for their Section 15 data submissions. Instead, systems are required to provide only estimates of total annual boardings and passenger miles, both in total and by mode.

Before FTA implemented its Section 15 reporting system, data on system ridership were collected by APTA from members and were distributed to them as APTA's annual "Operating Statistics" report. As Table A-1, which presents detailed ridership statistics for six systems in 1960 and 1970, indicates, APTA asked its members to provide more detailed ridership information than FTA currently obtains for its "Section 15" reports. The table also makes clear that not all systems provided ridership data for all of the categories requested by APTA. The most likely explanations are that the system's fare structure did not include a particular fare, the system used these fares but did not collect these data, or the system collected the data but did not report them to APTA.

The data in Table A-1 include ridership measures that are similar, if not identical, to boardings and linked-trips. Passengers carried, shown in the first row of Table A-1, is essentially the same as the FTA Section 15 definition of boardings while revenue passengers, shown in the second row, is very close, if not identical, to linked-trips. The principal difference between the two measures is transfers, and the third line in Table A-1 provides estimates of the transfer rates for each of the five systems in 1960 and 1970. The transfer rate in this instance is defined as transfers as a percentage of revenue passengers (boardings).

Table A-1. Number of Transit Passengers by Type for Selected Systems in 1960 and 1970

Type of Passengers	San Diego		Seattle		Twin City		Portland (Oregon)		Philadelphia	
	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970
Total Passengers Carried	31,740	15,923	N.R.	31,751	87,339	63,755	27,917	18,171	568,070	274,462
Revenue Passengers	26,180	13,111	41,476	31,751	67,202	50,557	23,479	15,395	328,013	191,542
Transfer Rate	21.4%	21.4%	NA	NA	30.0%	26.1%	18.6%	17.4%	73.2%	43.3%
Base Fare Passengers										
Cash	12,637	9,348	24,807	25,344	18,507	44,637	2,918	13,207	185,365	168,835
Ticket or Token	8,693	1,964	10,285	2,386	38,367	N.R.	16,626	524	120,229	N.R.
Weekly Pass	0	0	0	N.R.	0	0	1,055	0	0	N.R.
Weekly Permit	0	0	0	N.R.	0	0	0	0	0	N.R.
Child Fare Passengers	723	208	2,015	N.R.	0	N.R.	752	465	0	N.R.
Student Fare Passengers	4,128	1,592	4,369	4,022	10,327	5,919	2,129	1,199	22,420	22,706
Rev. Transfer Passengers	0	0	0	N.R.	0	0	0	0	5,378	82,920
Free Transfer Passengers	5,604	2,812	N.R.	N.R.	20,138	13,198	4,362	2,675	234,680	N.R.
Free Passengers	0	N.R.	N.R.	N.R.	N.R.	N.R.	75	102	0	N.R.
Charter Passengers	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.

Inspection of the data in Table A-1 both indicates the potential value of the more detailed APTA ridership data and points to possible errors in the APTA ridership data used in the analyses included in this report. Of the five systems included in Table A-1, all but Seattle reported both the number of transfers and estimates of revenue passenger trips (approximately linked-trips) and passengers carried (boardings). Seattle also apparently provided APTA with estimates of revenue passengers for both 1960 and 1970, but since the estimates of both total passengers carried and revenue passengers are identical for 1970, it would seem that one, or possibly both, of them must be wrong. Transfer rates, for the four systems that did provide sufficient data to estimate them varied from a low of 17.4 percent for Portland in 1970 to a high of 73.2 percent for Philadelphia in 1960. It is perhaps significant that among the five systems, only Philadelphia offered rail service in either year.

With the exception of Philadelphia, the 1960 and 1970 transfer rates for the same system are similar with a hint of a downward trend. In the case of Philadelphia, moreover, there is every reason to believe that the marked decline in its systemwide transfer rate between 1960 and 1970 is the result of reporting differences or errors. The APTA reports distinguish between revenue transfer passengers (passengers who were required to pay something for a transfer) and free transfer passengers (the system did not charge users for the transfer). The data indicate that users of the Philadelphia system made 5,378 revenue transfers and 234,680 free transfers in 1960. However, the 1970

APTA report contains no information on free transfers and the number of revenue transfers increased dramatically from 5,378 in 1960 to 82,920 in 1970. The most likely explanation of these data is that Philadelphia simply did not supply APTA with information on the number of free transfers in 1970 and, most likely, did not include them in their estimate of total trips (boardings) either. One implication of this line of thinking is that the estimated 1960-70 and 1970-80 change in boardings data for Philadelphia used in estimating the ridership change models reported in Chapter 3 are incorrect. By the same logic, the 1970 levels of ridership for Philadelphia would have been seriously understated and this fact would have adversely affected the estimates of the 1970 cross-section models. The same data error, if it is an error, would also explain the abrupt decline in the estimated transfer rates for the Philadelphia system, from 73.2 percent in 1960 to 43.3 percent in 1970. If more time and resources had been available for this research, we might have been able to catch this and similar errors and to correct at least some of the errors by consulting other published data or through direct contact with transit officials or others in Philadelphia.[1]

APTA, in its data collection activities, also asked its members to provide information on whether their passengers used cash, tickets, or tokens to pay for their trips, or used a weekly pass or permit. Among the five systems included in Table A-1, only Portland provided any information on pass or permit use and it provided these data for only 1960. According to the Portland data, weekly passes were used for less than four percent of all boardings in 1960. Pass use has grown on many systems, however, and they create particularly serious problems in preparing linked-trip estimates. They are frequently used for both first boardings and for subsequent ones (transfers) and the numbers of transfers and linked-trips by pass users can not be determined without careful surveys. Of the remaining transit operators, except for Seattle and Philadelphia, pass and permit use in 1970 were reported as zeros rather than as non-reported. This information suggests that those reporting zeros did not use passes, but we would not want to put too much faith in this conclusion

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[1] While careful examination of the total passenger, revenue passenger, and transfer data for the individual systems included in the study might have enabled us to catch more errors of this type, it is far from certain that we would have been able to correct them. In our experience, transit operators have very little interest in historical data and particularly those for systems that preceded them. There is a very good chance that 1960 and 1970 data that could be used to resolve this and other issues no longer exist for many systems, if it ever did. In the Philadelphia case, for example, it is likely that the system changed its fare collection procedures between 1960 and 1970 and simply stopped keeping information on free transfers. Still, correcting these and other errors would presumably produce more accurate parameter estimates and would be worth making some effort, if time and resources permitted.

All but the Twin Cities and Philadelphia in 1970, which were coded as not reported in the APTA "Operating Statistics" report, provided separate estimates of cash and ticket or token boardings. There is an argument for obtaining further data on the types of fares charged, the fare/price schedule, and data on total farebox revenues and boardings for each type of fare as part of the Section 15 reporting process. APTA also used to publish a quarterly survey of fare structures, which could provide an example for how to collect and report these data as part of Section 15. While asking systems to provide data on the types of fares, they would somewhat increase the complexity of the Section 15 data collection process, such a step is nonetheless worth considering. There is an even stronger argument for requiring systems to prepare estimates of the number of linked-trips and for requiring these systems to include these linked-trip estimates in their Section 15 reporting.

Table A-1 also includes data on the number of trips made with student and child fares. Since average fares per boarding estimates which are used in the ridership equations are calculated as the ratio of farebox revenues to total boardings, changes or cross-system differences in the fractions of discounted and undiscounted fares obviously create problems for the estimation of fare elasticities from these data and for their interpretation. While we have no systematic evidence, our sense is that public transit operators have been less aggressive in competing for school trips in the past decade or two than in previous periods. If so, this may reflect changes in funding sources for school transportation that have encouraged school systems to provide their own yellow school buses for trips to school or, more likely, to contract directly with private operators for these services. These school bus trips are not included in the estimates of public transport trips considered in this report. If there has been a shift in the provision of some or part of these trips from public transport operators to others, the change would explain some of decline in transit ridership (boardings) that occurred during the 30 year period covered by this study. This is an issue that is worth considering in future analyses.

In Table A-2 we have provided estimates of the fractions of children and student fares of total boardings in 1960 and 1970 for those systems reporting this data to APTA. If we consider only the fractions of boardings that were made using children and student fares for these systems, there is no evidence for the view that trips using children and student fares became proportionately less important over the 1960 to 1970 period. The numbers of boardings using children and student fares declined between 1960 and 1970, but in percentage terms the decline was smaller than for all transit boardings. At the same time, it is worth noting that 66 percent of the 140 systems included in our 1960

Table A-2:. Selected Transit Operating Statistics for Firms That Either Reported or Did Not Reported Children and Student Fare Passengers, 1960 and 1970

Item	Year 1960			Year 1970		
	All	Reported	Not Reported	All	Reported	Not Reported
Number of Firms	140	92	48	97	57	40
Average Total Boardings (in Thousands)	49,010	67,169	14,205	47,530	52,068	41,064
Average Revenue Passengers (in Thousands)	NA	57,483	NA	NA	47,023	NA
Average Children & Student Fare Passengers	NA	4,916	NA	NA	4,515	NA
Weighted % of Children & Student Fare Passengers over Total	NA	7.3%	NA	NA	8.7%	NA
Unweighted % of Children & Student Fare Passengers over Total	NA	11.8%	NA	NA	13.2%	NA
Weighted Average Fares in 1970 Dollars	$0.20	$0.20	$0.19	$0.29	$0.28	$0.30
Unweighted Average Fares in 1970 Dollars	$0.21	$0.21	$0.23	$0.24	$0.23	$0.26

Note: 1960 $ = 1.31 * 1970 $

cross-section sample reported children and student trips, while only 59 percent of the 97 systems in our 1970 cross-section sample reported them. Thus, it is possible that a growing number of systems between 1960 and 1970 relinquished the school bus market to other providers. In addition, it is possible that these shifts tended to occur after 1970 and were related to the public takeover of private transit firms.

Transfer Rate Regressions

Table A-3 presents exploratory regression analyses of the variation in transfer rates for those systems that reported both total passenger trips (boardings) and revenue passenger trips (linked-trips) in 1960 and 1970. In all 122 systems reported these data in 1960 and 83 in 1970.

Table A-3. Estimates of Transit System Transfer Rate Equations for 1960 and 1970

	Coefficient Estimate and (Standard Error)					
	Year 1960 (Obs.=122)			Year 1970 (Obs.=83)		
Variable	Eq. 60-1	Eq. 60-2	Eq. 60-3	Eq. 70-1	Eq. 70-2	Eq. 70-3
Constant	-0.169 (0.07)	-0.168 (0.07)	-0.177 (0.07)	-0.144 (0.07)	-0.147 (0.07)	-0.146 (0.07)
Natural Logarithm of Total Revenue Miles	0.042 (0.009)	0.042 (0.008)	0.045 (0.008)	0.040 (0.009)	0.040 (0.009)	0.041 (0.009)
Share of Rail Revenue Miles over Total (%)	-0.004 (0.08)			0.041 (0.08)		
Dummy for Public Ownership	0.069 (0.03)	0.068 (0.03)		0.005 (0.02)	0.006 (0.02)	
R-Squared	0.22	0.22	0.19	0.21	0.21	0.21

Included in Table A-3 are three equations for 1960 and three for 1970. The natural logarithm of system-wide transfer rates (total transfers/revenue passengers) is used as the dependent variable in all six equations. These equations perform much less well in terms of overall explanatory power than the cross-section ridership rate equations presented in Chapter 4. None of the six equations in Table A-3 has an R^2 that exceeds 0.22, and the range of explained variance for the six equations is between 19 and 22 percent. This result is not particularly surprising since the dependent variable used in the transfer rate equation is a rate and thus does not benefit from the service area size effects that account for some of the very high R^2 obtained for the cross-section regressions on total boardings.[2]

As is evident from Table A-3, identical specifications were used for the three 1960 and 1970 transfer rate equations. The first equation in both years includes three explanatory variables: a system size variable (the natural logarithm of total revenue miles); a measure of rail's importance in a multi-mode system (the rail share of total revenue miles); and a dummy for public ownership. This equation explains 22 percent of the variance in transfer rates in 1960 and 21 percent in 1970. The estimates of both total revenue miles and the public ownership dummy coefficients are both highly significant statistically, while the statistical significance of the rail share variable coefficient is

2 A comparable cross-section ridership equation would use per capita ridership as the dependent variable rather than total boardings. We chose not to estimate per capita ridership models for a variety of reasons; the most important of them is that no reliable service area measures were available.

nonexistent in the 1960 equation. In the 1970 equation, however, the coefficient of the rail share variable is five times its standard error and indicates that that the system-wide transfer rate increases by 0.04 percent for each one percentage point increase in the rail share, a result that is consistent with the notion that bus-rail systems have higher transfer rates than all-bus systems of the same size.

The estimated coefficients of total revenue miles, which appears in all six equations, is not affected much by the inclusion of the other two variables. Its coefficient, which varies between 0.042 and 0.045 in 1960 and between 0.040 and 0.041 in 1970, does not change much with the addition of the two other explanatory variables. It is, moreover, highly significant statistically in all six equations. The estimates indicate that the transfer rate increases with system size as measured by total revenue miles of service, a quite reasonable result, although the effect is fairly small. As system and network size increases the number of origins and destinations that can be reached using the system increases as well, and there are both more opportunities and reasons to transfer. It is also likely that the transfer rate depends on the nature of a system's network (e.g. whether it is primarily radial in character or more of a grid), but we know of no source that would provide this kind of information on network characteristics. If we had more time and resources, it would have been possible to consider how the transfer rate is affected by system size measured by route miles as well as by total revenue miles.

The final explanatory variable, the public ownership dummy, appears in four of the six equations and is statistically significant in all four. The public ownership dummy indicates that publicly owned systems had higher transfer rates than privately owned ones in both 1960 and 1970. The public ownership effect, however, differs substantially between the two years; its effect is tiny in 1970, but in 1960 it suggests that transfer rates for publicly owned systems were about seven percent higher than for privately owned systems, holding constant the total number of revenue miles of service and the rail share of total revenue miles. However, we very much doubt that the public-private differences in transfer rates is due to public ownership; it is more likely that the public ownership dummy in these equations are proxying the effects of omitted system characteristics.

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