ABSTRACT

TRANSIT PRODUCTIVITY ANALYSIS IN HETEROGENEOUS CONDITIONS USING DATA ENVELOPMENT ANALYSIS WITH AN APPLICATION TO RAIL TRANSIT

by
Manuel J. Martínez

This dissertation extends transit productivity analysis by developing a new method of Data Envelopment Analysis (DEA), the linear programming approach to productivity analysis. The new model analyzes productivity of transit working under heterogeneous operating conditions. It is named Two-Farrell DEA for it applies DEA in two stages, DEA(1), that calculates the productivity frontiers at given operating conditions and DEA(2), that uses inputs adjusted by multipliers calculated in DEA(1). The model Two-Farrell DEA calculated productivity benchmarks for each rail transit agency and estimated its potential for higher revenue or lower expense improvement. Additionally, the results identify two production techniques of rail transit, the sources of increasing returns to scale, the degree of flexibility to changes in the shadow prices of the inputs, and a method to prioritize investment for expansion of operations. Its indirect contribution to transit operations planning consists of checking the consistency and feasibility of new rail projects. Moreover, this dissertation includes the first correlation analysis made between productivity and operating conditions related to network form, factor analysis of transit operating conditions, the comparison of results between the new model to four other methods, and the evaluation of the empirical accuracy of methods with cluster analysis.

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This dissertation is dedicated to my parents and to my family.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Chapter **Page**

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

Figure **Page**

LIST OF MATHEMATICAL EXPRESSIONS

LIST OF MATHEMATICAL EXPRESSIONS
(Continued)

CHAPTER 1

INTRODUCTION

1.1 Objective and Significance of the Dissertation

This dissertation presents a fairer and more accurate method of transit productivity analysis (Two-Farrell DEA) under heterogeneous conditions that improves the basis for policy decisions like public ownership, privatization, public-private partnerships, subsidy allocation, or expansion of transit operations. Transit productivity analysis studies the productive structure of the industry in order to design policies consistent with the transit goals. For example, Pucher, Markstedt, and Hirschman (1983) found evidence that subsidy increases are associated with productivity reductions. This raised concerns in States subsidizing transit, and California, New York, Michigan, and Pennsylvania linked performance to subsidy allocation to improve the use of their resources (Fielding 1987). In other examples, transit productivity analysis calculated the effect of subsidies on transit performance and estimated the impact of privatization and deregulation on transit efficiency (Chang and Kao 1992; Gómez-Ibáñez and Meyer 1990; Sakano, Azam, and Obeng 1997). Productivity analysis provides the raw materials to major decision-making processes.

Productivity analysis can contribute indirectly to transit operations planning by evaluating the consistency and feasibility of new projects. A more direct contribution to operations planning uses a route-by-route level like in the proposed redistribution of resources from less to more utilized routes of (Pucher and Brail 1984). This dissertation presents examples of consistency and feasibility evaluation of new projects but leaves route-by-route analysis to further research.

1.2 Scope of the Dissertation

Transit productivity analysis is a branch of transit performance evaluation. Transit productivity analysis measures productivity efficiency based on the theory of the firm consistently with the maximization of output subject to technological and budget constraints. Instead, performance is a more general concept that includes such variables as on-time performance, regularity, maintenance efficiency, safety and security, speed, frequency, trip length, daily service hours, air conditioning, vehicle load, etc. Frequently, transit evaluation involves the use of productivity ratios within a broader pool of measures of performance. Baker, Dornan, and Schwager (1979) presented a general measure of performance that could be decomposed into twelve performance-ratios to pinpoint sources of inefficiencies. A method to select the right indicators from a broad pool of variables was developed by (Fielding and Anderson 1983; Fielding, Babitsky, and Brenner 1985). With the proper adjustments, the new model developed by this dissertation can be extended from transit productivity analysis to transit performance evaluation in further research.

This dissertation covers some sections of productivity analysis but leaves others for further research. First, productivity analysis studies productivity efficiency and productivity growth but this dissertation is limited to the estimation of efficiency and leaves growth to further research. Second, allocation efficiency calculates the degree of success in the use of inputs relative to their prices but this dissertation is limited to the estimation of technical efficiency and leaves allocation efficiency to further research. Third, public funds for operating and capital expenditures have an impact on decisions about the scale of production while controlled fares and regulated wages have an impact on decisions about costs and direct revenues. This dissertation assumes that the transit agency maximizes outputs subject to the quantity of available resources. However, it is worthy to note that in the same scenario other authors have been preferring to assume that the transit agency minimizes cost subject to its technological constraints (Berechman 1993, Chapters 3 and 4).

In theory, productivity analysis should include social goals to evaluate the achievement of governmental funding. In the 1960's transit was thought to alleviate congestion, improve safety, and promote urban renewal. In the 1970's transit was thought to save energy, mitigate air pollution, and improve mobility of the poor, minority groups, the elderly, and the handicapped (Altshuler, Womack and Pucher 1979; Smerk 1991). However, to be completely effective transit needs to be part of comprehensive policies of urban planning beyond the control of transit managers (Berechman 1993; US-DOL-BLS 1998). Therefore, this dissertation considers that transit managers control transit service but they do not completely control the beneficial social externalities of transit.

The transit industry operates in many differentiated modes like bus transit, rail transit, and demand responsive services. This dissertation applies the new model to heavy and light rail transit because both modes attracted most of the new transit trips of the recent years and because there is electronic data available on geographic location of tracks and stations. This dissertation does not include institutional factors like subsidies or ownership nor attributes of the rail technology like signal systems, automation, right of way, train capabilities, trip length, etc. The analysis of attributes, institutional factors, and the remaining modes is left to further research.

Finally, this dissertation analyzes the three most common frontier methods; partial productivity analysis, stochastic frontier analysis, and data envelopment analysis. Other methods were excluded because they have very few applications; Free Disposal Hull (FDH), Artificial Neural Networks (ANN), and Multi-criteria Goal Programming. Some other methods were excluded because they do not consider frontiers; Total Factor Productivity (TFP), Linear Discriminant Analysis, and conventional cost functions.

1.3 Definition of Terms

Productivity analysis uses a limited number of inputs and outputs relevant to transit. Inputs are the physical resources consumed by the productive process of transit and consist primarily of labor, energy, and vehicles. Rail transit also uses tracks and stations. Transit produces a single output expressed in passenger miles. However, since passenger miles are counted using periodical surveys this dissertation chooses a pair of measures of the same output that are counted in the whole population; vehicle revenue miles (VRM) (service supplied) and unlinked passenger trips (TRIPS) (service consumed).

This dissertation uses a broad definition of operating conditions. They are those factors that are out of the control of the agency and that affect its productivity. Operating conditions include a variety of factors; (1) Socioeconomic, like personal income and population density. (2) Institutional, like union presence and ownership type. (3) Operating characteristics, like peak-to-base ratio and average speed. (4) Regulation, like fixed prices and subsidy funds. (5) Attributes like network size and fleet age. (6) Management-related factors, like autonomy and organization. (7) Firm specific conditions. Notwithstanding their variety, all operating conditions share three characteristics, they are exogenous, heterogeneous, and affect productivity.

This dissertation applies the new model to heavy and light rail transit. Heavy rail is characterized by high-speed and rapid acceleration with passenger rail cars operating singly or in multiple car trains on fixed electric rails, with separate rights-of-way from which all other traffic is excluded, with sophisticated signaling, high platform boarding and a heavy passenger volume. In 1998 there were 14 heavy rails in the US. Light rail is an electrical railway, with a lighter passenger volume, with passenger cars operating singly or in two-car trains on fixed rails in shared or exclusive right-of-way, and stops accessible through a low or high platform. The vehicle's power is drawn from an overhead electric rail. In 1998 there were 20 light rail systems in the US (US-DOT-FTA 1985-2000).

1.4 Outline of Research Procedures and Organization of the Dissertation

This dissertation makes a critical review of the literature to determine the approach and the assumptions of the new model. Chapter 2 formulates the working hypothesis after finding that transit works in heterogeneous conditions, that operating conditions affect transit productivity, and that conventional methods fail to measure efficiency in heterogeneous conditions. Chapter 3 explains three methods of transit productivity analysis to analyze heterogeneous conditions; partial productivity analysis, stochastic frontier analysis, and data envelopment analysis finding that a new method is necessary to deal with the specific reality of transit that works under heterogeneity of several operating conditions.

Chapter 4 develops the new model by explaining its assumptions, by maintaining algebraic coherence, and by interpreting the meaning of the new information. The adequacy of the new model is based on the acceptance of its assumptions and on its internal coherence. Chapter 5 applies the new model to rail transit and checks the expected signs of the results. The evaluation of empirical accuracy goes beyond the scope of this dissertation because Monte Carlo tests presume that the analyst knows the level of efficiency before its estimation and this is possible only with simulated data. Chapter 5 presents the results of transit productivity analysis, its consequences for policy making, and the consistency and feasibility of the planned figures of new projects. Finally, Chapter 6 concludes the dissertation and suggests further research.

CHAPTER 2

THE PROBLEM OF TRANSIT PRODUCTIVITY ANALYSIS

2.1 Transit Productivity Analysis

According to the theory of the firm, transit productivity analysis estimates the production function as the maximum output attainable at a given combination of inputs. The firm may maximize output subject to a budgetary constraint, or it may minimize total cost subject to a technological constraint (Intriligator 1978; Henderson and Quandt 1971). Once the production function is estimated, the distance from the observed output to the frontier indicates inefficiency as a proportion of the observed output.

The estimation of efficiency is a byproduct of the theory of duality that says that cost minimization is the dual formulation of output maximization. Shephard (1953) proved the theory of duality by using the distance function as a ratio of two distances from the origin of the output space, one distance to the observed output and the other distance to its radial projection on the production frontier. The inverse distance function applies as a ratio of two distances from the origin of the input space, one distance to the observed input and the other distance to its radial projection on the isoquant. The movement of the observed output toward the production frontier coincided with the movement of the observed input toward the isoquant, arriving simultaneously when both functions—distance and inverse of distance—took the value of 1.00 (Fuss and McFadden 1978; Berechman 1993).

Besides efficiency, there are other variables calculated by productivity analysis. The returns to the quantity of a single input are the derivative on the marginal production of the input. If the industry always faces increasing returns in one or two inputs, the industry may have a tendency to natural monopoly and it would need regulations to prevent artificially higher prices. Returns to scale are the proportional augmentation of output with respect to a given augmentation of inputs. If the agency works under increasing returns to scale it is desirable to merge or to expand. If the agency works under decreasing returns to scale it is desirable to split in more than one unit or to downsize. Elasticity of substitution estimates the proportional change of technical ratios with changes of the ratio of input prices. Inputs can be substitutable or complementary depending of the sign of the elasticity. If many inputs are complementary to each other the impact of price increase of one input will be more intense than if many inputs are substitutes to each other. Finally, the linear production frontier calculates increases in transit outputs caused by increases in transit inputs showing the most cost-effective ways to expand transit operations (Fuss and McFadden 1978; Intriligator 1978; Baumol, Panzar and Willig 1982; Berechman 1993).

Of all the aforementioned variables, efficiency scores affect transit policy in the sensitive point of the allocation of public resources to alternative ends. Latin American governments privatized their public bus and rail transit agencies because they consumed resources in productive inefficiency. In the United States, transit policy aims to alleviate externalities produced by the characteristics of the consumption of urban transportation. Externalities are costs produced by private activities that are not internalized in the price or in the cost of the service. Examples include the following, 1) Congestion caused by the common use of free public roads. 2) Pollution produced by private transportation. 3) Energy crises caused by foreign conflicts. 4) Destruction of urban neighborhoods associated with urban expressways. 5) National security concerns caused by excessive self-reliance in private automobiles. 6) Equity concerns on accessibility and mobility of large groups of the society. The support for transit to alleviate externalities does not find important opposition against its current form, which includes public ownership of most of transit agencies, minimum service, fixed fares, labor protection, safety rules, and subsidies from all governmental levels. A common approach to productivity analysis has been to leave externalities out because of the difficulties to measure the external benefits caused by transit activities. However, the most sensitive point of transit policy is productive efficiency because, in principle, the theory of the firm expects a level of inefficiency out of regulation and of public ownership. So, if the cost of inefficiency exceeds the benefits of alleviating externalities, transit policy should be modified (Altshuler, Womack and Pucher 1979; Heilbrum 1987; Berechman 1993; Naciones Unidas-CEPAL 1992).

Not all agencies are technically efficient in the use of inputs. Some agencies do not work at the frontier but at the interior of the frontier. The seminal work of Farrell in 1957 used the distance function to measure the percentage of efficiency of the observations in relation to the production possibility frontier. Other variables related to efficiency include the following. 1) The improvement path, that is the reduction of inputs and increase of outputs to reach the frontier. 2) The scale efficiency, that is the percentage of efficiency due to operations near or far from the optimal point. 3) The efficient peers, or efficient agencies technically nearer to the evaluated agency (technical nearness is understood as similar ratios between inputs and outputs). 4) Sources of inefficiency, which can be internal or external. 5) Productivity benchmarks, that indicate the efficiency goals in productivity. On the other hand, transit policies to improve overall efficiency include the following. 1) Promoting privatization and public-private partnerships. 2) Contracting out. 3) Ensuring free-entry markets. 4) Changes in the scale of production. 5) Attacking external sources of inefficiency with regulation. 6) Campaigns to emulate the efficient peers that work on the best practice frontier (Lovell 1993; Kumbhakar and Lovell 2000; Coelli, Rao and Battese 1998; Ali and Seiford 1993; Shephard 1953; Intriligator 1978). Table 1 presents the variables calculated by productivity analysis.

Table 1 Variables of Productivity Analysis

Variable	*Consequences*
Returns to quantity of a single input	Detection of sources of returns to scale
Returns to scale and scale efficiency	Supports decisions to merge or to breakdown agencies and regulation to prevent natural monopoly
Elasticity of substitution between inputs	Detect vulnerability of agencies due to input price increases
Efficiency, sources of inefficiency, improvement path, and efficient peers	Major decisions on ownership, subsidies, and regulation. Major managerial strategies of re-engineering, downsizing, expansion of operations, etc.
Production function and productivity benchmarks	Determines quantity and direction of expansion or reduction of operations by using cost effectiveness.

If efficiency is the sensitive point of transit productivity analysis, operating conditions are the difficult points of efficiency estimation. Fuss and McFadden in 1978 considered operating conditions as determinants of the production function mentioning the following examples, imperfect information, legal restrictions (patent agreements, pollution control regulations, and safety), non-transferable commodities (managerial capacity, climate, and environmental factors), and restrictions on contracts on inputs, outputs, quotas, and rationing. Therefore, a set of values of any of the mentioned variables produces a family of frontiers of production. In the transit industry some operating conditions frequently mentioned as causing productivity differentials are urban density, stop spacing, pedestrian accessibility, traffic congestion, and peaking of the demand (Pushkarev and Zupan 1977).

2.2 Contribution to Transit Operations Planning

The contribution of productivity analysis to operations planning uses coincidental data for cross-examination. The theory of the firm and productivity analysis offers indirect ways to check consistency and feasibility of new projects. On the other hand, methods of operations planning for fixed-route transit operations involves four steps; estimation of transit demand, planning of rail network and stations, fleet size design, and labor force design.

Transportation demand is the result of a two-way relationship between land use and transportation networks. The land use pattern depends on the character of the transportation network and the viability of the transportation network depends on the land use pattern (Heilbrum 1987). The activities of the individual can be modeled by the choice he or she makes at several decision levels; life-style aspirations, desired activity patterns (income, employment), locational choices (employment, neighborhood), and travel choices (short run decision). All choices are influenced by the socioeconomic characteristics of the individual and by the attributes of the transportation networks—time, cost, safety, convenience, security, etc. (Manheim 1980; Heilbrum 1987).

There are two major approaches to estimate transit demand. The first approach uses data of aggregated zones and estimates transit demand in four stages. Trip generation finds the number of trips, produced by or attracted in one zone, depending on land use, socioeconomic, and demographic characteristics. Trip distribution determines to what zones the trips are going, given travel time and distance. Modal split determines what mode of transport will be used from each zone based on trip type, characteristics of the trip maker, and levels of service. Traffic assignment assigns trips to individual transportation facilities based on travel times of the transit and highway modes of the network. So, two stages of the process include socioeconomic and demographic characteristics, while three of the stages include network attributes of time and distance (Wright and Ashford 1989; Manheim 1980; Stopher and Meyburg 1975).

The second approach uses data of individuals and applies discrete choice models to find the probability that individuals make decisions through a sequence of stages. The decision stages include work and residential location, vehicle ownership, trip versus no-trip choice, destination, time of day, and mode choice. They are embedded in a nested multinomial logit model as a function of transportation attributes and socioeconomic characteristics of the travelers (Domencich and Mcfadden 1975). Consequently, both approaches for demand models use operating conditions to determine transit demand. Since operating conditions are directly related to the number of transit trips, this dissertation proposes ratios to check consistency of the planned figures under efficient transit operations like transit trips per capita.

The second step of operations planning is routing. It designs the route and the location of stations (stops) (Pine, Niemeyer and Chisholm 1998). Consequently, a set of ratios can check consistency of the number of trips with the length of the transit network and with the number of stops. Productivity ratios include trips per route mile, and trips per station. The technical ratio stops per route mile can check the consistency of the chosen production technique.

The third step of operations planning is blocking. It designs the fleet size to supply the service. First, the demand at the maximum load point of the route is divided by the capacity of the vehicle (including the policy of load rate of passengers per vehicle) to obtain the number of vehicles desired per period. After that, the cycle times—round trip travel time plus layover/recovery time—are divided by the desired headway to set the total number of vehicles (Pine, Niemeyer and Chisholm 1998). Therefore, a set of ratios can check consistency of the planned number of trips and vehicle revenue miles with the planned fleet size. Productivity ratios include trips per vehicle. Effectiveness is the ratio of trips per vehicle revenue mile. Intensity ratios include vehicle revenue miles per unit of input. Technical ratios can check consistency of fleet size related to network length.

The fourth step of operations planning is runcutting. It calculates the number of runs or daily operators. Runcutting consists of the assignment of operators to the assignment of vehicles. It minimizes platform times and split runs (runs with long periods of idle time in the middle) given the work rules and policy of the agency (Pine, Niemeyer and Chisholm 1998). Therefore, a set of ratios can check consistency of the planned number of labor hours with the planned trips, vehicle revenue miles, network length, and fleet size of the agency. The technical ratio labor hours per vehicle is usually taken as a ratio of efficiency with productivity of trips per labor hours and intensity of use of vehicle revenue miles per labor hour. Additional procedures could check consistency of labor hours in maintenance and energy, both being a derived demand of the scale of operations, but no further examination of these inputs is considered. Table 2 presents some ratios that check the consistency of planned new rail projects at current efficiency levels.

Table 2 Ratios to Check Consistency of Transit Operations Planning

Variables	*Ratios (*)*	*Consequences*
Transit demand	Trips/operating conditions	Consistency of planned demand
Routing	Trips/route mile Trips/station stop route mile/station	Consistency of density of transit demand
Blocking	Trips/vehicles Trips/VRM VRM/vehicle VRM/route miles VRM/station	Checks technical ratios and intensity of use of inputs
Runcutting	Labor operator hours/vehicle VRM/labor operator hours	Checks labor technical ratio and intensity of use

(*) VRM = vehicle revenue miles

2.3 Heterogeneous Conditions of Transit

This section presents evidence of the degree of heterogeneity of the operating conditions of transit. In bus transit, Fielding, Brenner, and Faust (1985) chose three operating conditions for cluster analysis; size, peak-to-base ratio, and speed, because they affected transit performance. Table 3 illustrates the high variability of the chosen variables, all of them affecting bus transit performance. Moreover, the three variables have low correlation coefficients—0.15 to 0.26—indicating at least three dimensions of heterogeneity in operating conditions. Bus transit works in very heterogeneous operating conditions.

Table 3 Heterogeneous Conditions – Bus Transit

	Size (vehicles)		*Speed (mph)*		*Peak-to-base (ratio) (*)*	
Minimum	2		7.7		0.71	
Maximum	3246		34.1		7.33	
Average	122		14		1.59	
Standard deviation	280		2.9		0.72	
Group 1 (%, range)	14%	0-10	3%	0-10	18%	0-10
Group 2 (%, range)	57%	10-100	72%	10-15	37%	1.0-1.5
Group 3 (%, range)	27%	100-1000	22%	15-20	27%	1.5-2.0
Group 4 (%, range)	2%	1000+	3%	20+	16%	2.0+

(*) Ratio of peak period number of vehicles to base period number of vehicles
(US-DOT-FTA 1985-2000, Tables 26 and 28 of 1997)

Table 4 illustrates the differences in the urban form of selected heavy as well as light rail operations. Population density in New York is thirteen times higher than in Atlanta and income per capita in PATH is four times higher than in Miami. Light rail also operates in heterogeneous urban forms; population density in San Francisco is six times higher than in St. Louis while income per capita in Cleveland is three times higher than in Los Angeles.

Table 4 Heterogeneous Operating Conditions – Rail Transit – Urban Form

Mode	*Population Density(*)*			*Income per Capita ($)*		
	Value	*Ratio*	*Agency*	*Value*	*Ratio*	*Agency*
Heavy rail						
Minimum	3,532	1	Atlanta-MARTA	9,279	1	Miami-CDTA
Maximum	47,492	13	New York-NYCT	32,639	4	New York-PATH
Light rail						
Minimum	3,047	1	St. Louis-BSDA	8,301	1	Los Angeles-LACMTA
Maximum	17,576	6	San Francisco-MUNI	22,898	3	Cleveland-GCRTA

(*) Persons per square mile at the served area = within 0.3 miles around stations
National Transportation Atlas, and Bureau of Census (US-DOC-BOC 1992; US-DOT-BTS 2000)

Table 5 shows that rail transit operates in heterogeneous network forms. In heavy rail, San Francisco has five times longer stop spacing than New York while, in light rail, Los Angeles has eight times longer stop spacing than Philadelphia. Moreover, heavy rail density of service in New York is twelve times greater than that of Cleveland while light rail density of service in Boston is three times greater than that of Cleveland.

Table 5 Heterogeneous Operating Conditions – Rail Transit – Network Form

Mode	*Stop Spacing(*)*			*Density of Service(**)*		
	Value	*Ratio*	*Agency*	*Value*	*Ratio*	*Agency*
Heavy rail						
Minimum	0.48	1	New York-NYCT	108	1	Cleveland-GCRTA
Maximum	2.24	5	San Francisco-BART	1,254	12	New York-NYCT
Light rail						
Minimum	0.15	1	Philadelphia-SEPTA	71	1	Cleveland-GCRTA
Maximum	1.16	8	Los Angeles-LACMTA	236	3	Boston-MBTA

(*) Miles. (**) Annual vehicle revenue miles per line mile. National Transportation Atlas (US-DOT-BTS 2000), and National Transit Database (US-DOT-FTA 1985-2000)

2.4 Effect of Operating Conditions over Transit Productivity

This section describes the effect of operating conditions on transit productivity made by diverse authors considered as conventional wisdom of transportation research. Meyer, Kain, and Wohl (1965) considered that station spacing, speed, and frequency affected transit costs and that residential density explained variations of the construction costs of facilities. Miller (1970) estimated a bus operating cost function that included indicators of the city setting as explanatory variables. Miller found that schedule speed, density of service, and city age were relevant to explain cost per bus mile. Pushkarev and Zupan (1977) found a positive relation between higher residential density and higher vehicle productivity in regular bus service. Later, Parsons Brinckerhoff Quade & Douglas (1996) found similar relations for light rail and commuter rail. Giuliano (1981) estimated that operating characteristics were relevant to explain productivity. Size of the agency, age of firm, peak-to-base ratio, and size of the city affected vehicle revenue hours per employee while size of the city and population density affected vehicle revenue hours per vehicle. Bladikas and Papadimitriou (1985; 1986) estimated that the unproductive labor factor, defined as the ratio of total time to platform time (operating time) was affected by the peak-to-base ratio and that the number of vehicle maintenance employees correlated to vehicle size, agency size, and speed.

Operating conditions also affect the capacity of rail transit. Demery (1994) observed that tolerance of the public for maximum vehicle capacity varies between cities and even within the same city, depending of the time of the day, congestion, parking, and automobile costs. Vehicles carrying relatively small numbers of standees (15-20) may be "overcrowded" from the passenger perspective. Demery also observed the association between the number of standing passengers and dwell times with the consequent delays that affect schedule adherence.

The impact of the network form on transit productivity has not yet been estimated except for stop spacing and density of service. One of the most extended concepts is connectivity. It describes the extent of available routes between two nodes indicating facility of movement and the degree of continuity of flow in spite of local stoppages (Hay 1961; Schumer 1964). The connectivity index also estimates the degree of connection between all vertices and it is considered the most important structural property of a network (Taaffe and Gauthier 1973). Connectivity can tell the degree of branching of the network—used to maximize areal coverage—and the form of the network—ability of radial, diametral, or grid network to match the demand (Vuchic 1975; Fox 1978; Musso and Vuchic 1988). Connectivity is a graph theory-index used by Garrison, Berry, Marble, Nystuen, and Morrill (1959) to describe the topology (form) of a network without distance nor direction (Nystuen 1968). Two indices can describe transportation networks, the gamma index and the alpha index (Taaffe and Gauthier 1973). The gamma index of the network is the ratio of the observed number of edges to the maximum possible number of edges in a given network.

$$\gamma = \frac{actual\_edges}{maximum\_edges} = \frac{e}{3(v-2)} \tag{1}$$

In formula (1), γ is the gamma index, e the number of edges, and v the number of vertices. The alpha index—called circuitry availability—is the ratio of the number of actual circuits to the maximum number possible in a given network. The alpha index estimates the degree of alternative paths between nodes in the network. The number of alternative paths is the number of linkages added to a minimally connected network. The alpha index is defined as:

$$\alpha = \frac{actual\_circuits}{maximum\_circuits} = \frac{e-v+1}{2v-5} \tag{2}$$

The values of both indices, gamma and alpha, can describe the form of a network as indicated in the following expressions (3).

$$\begin{array}{lll} & \textit{Gamma} & \textit{Alpha} \\ \textit{spinal network}: & \frac{1}{3} \le \gamma \le \frac{1}{2}, v \ge 4 & \alpha = 0,\ v = e+1 \\ \textit{grid network}: & \frac{1}{2} < \gamma < \frac{2}{3}, v \ge 4 & 0 < \alpha < 0.5,\ v \ge 3 \\ \textit{delta network}: & \frac{2}{3} \le \gamma \le 1.0, v \ge 3 & 0.5 \le \alpha \le 1,\ v \ge 3 \end{array} \tag{3}$$

Besides the gamma and alpha indices, Morlok (1967) gathered additional network indicators that may explain performance of transportation networks. He classified network indicators in five types; access, comprehensiveness, circuitry, link length, and density of service. Access density is the number of terminals or access points of the systems per area unit as in equation (4).

$$N' = \frac{N}{A} \tag{4}$$

In equation (4), N' is the access density, N the number of access points, and A the area of the region served by the system. The comprehensive accessibility of formula (5) is a dimensionless number that indicates the fraction of the area a system serves.

$$Z = \frac{A_t}{A} \tag{5}$$

In formula (5), Z is the index of comprehensive accessibility, A_t the area around the access points of the network that can be easily reached, and A the area of the region served by the network. The circuitry index of formula (6) measures the difference between the airline distance and the network distance between nodes.

$$C^* = \frac{\sum_{i,j} L_{ij}}{\sum_{i,j} L_{ij}^*} \tag{6}$$

In formula (6), C* is the circuitry index, L_{ij} the network distance between nodes i and j, and L^*_{ij} the airline distance between nodes i and j. Additional indicators proposed by (Morlok 1967) of the network structure are the average link length also called stop spacing, and density of service—average flow of traffic through each vertex per unit of time. Tomazinis (1975) classified descriptors of urban transportation networks in areal coverage–access density and comprehensiveness—and serviceability and flexibility–gamma and alpha indices. Finally, (Musso and Vuchic 1988) included network complexity or the ratio of inter-station spacings to the number of stations, to describe the rail network.

2.5 Conventional Productivity Analysis in Heterogeneous Conditions

Productivity growth is the productivity shift produced by technological changes while productivity efficiency is the ratio of achieved to achievable production that is equal or smaller than 1.00. Figure 1 describes productivity growth and productivity efficiency. Let the axes be the production of outputs y_1 and y_2 per unit of a common input x. Curve P_1 is the piecewise-linear envelope of the maximum production of y_1/x and y_2/x during period 1. Two agencies A and B show their position relative to P_1. B is in the position of efficiency because it operates at the frontier. A is in a position of inefficiency because some observed agencies produce higher levels of outputs A' > A. The radial distance function OA'/OA > 1 (larger than one) measures the efficiency of agency A. The radial distance function is the common proportional augmentation of outputs achievable by A. Notice that y_1/x and y_2/x increase in the same proportion along the OA radius to A'. In agency B efficiency is OB'/OB = 1 (equal to one) because B is located at the frontier. In period 2 let there be a general increase in the maximum observed productivity of the industry to the new frontier P_2. Productivity growth is the average distance between both curves P_1 and P_2.

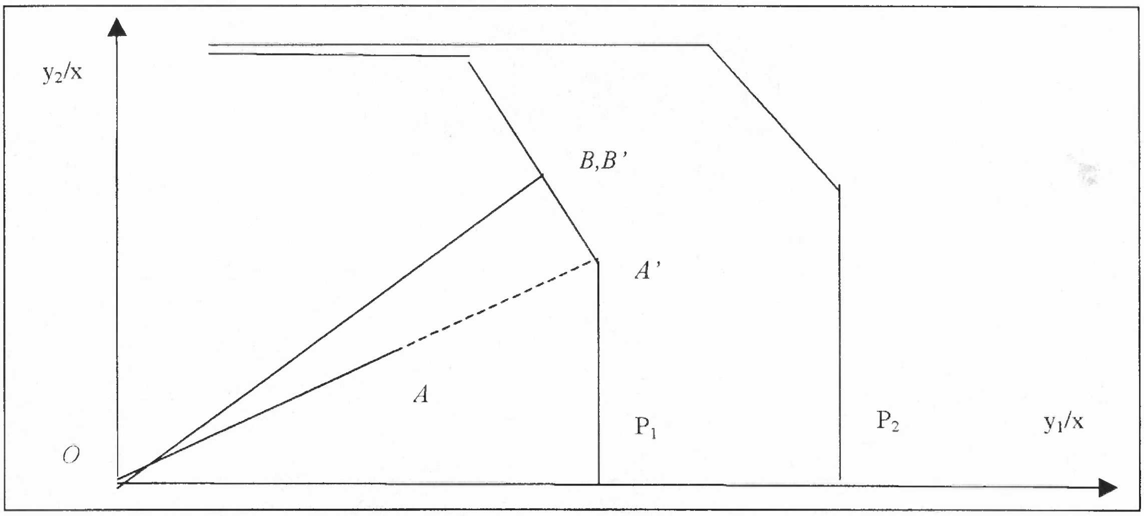

Figure 1 Efficiency versus Growth in Productivity Analysis

In Figure 2 let P_B be the production frontier operating under different conditions than P_A. That is, P_B represents operating conditions B. P_B represents agencies at better operating conditions than agencies represented by P_A. Let A work under operating conditions P_A and let B work under operating conditions P_B. The agency B is not efficient because more output is expected from B since P_B permits higher productivity. Thus, B is indeed inefficient with efficiency score OB"/OB > 1. If each agency has particular values of operating conditions, there are as many frontiers P_j as agencies and therefore heterogeneous conditions produce multiple frontiers. Moreover, Figure 2 shows that the frontier of reference for all agencies is P_B and as such it produces underestimated efficiency for A and for the industry. In Figure 2 $\frac{A''}{A} > \frac{A'}{A}$ because A refers to the farthest frontier P_B instead of P_A and A has an efficiency score overestimated by $\frac{A''}{A} - \frac{A'}{A}$, and therefore conventional methods underestimate the efficiency of A by $\frac{A}{A'} - \frac{A}{A''}$ and underestimate the efficiency of the industry by $\frac{1}{2}\left(\frac{A}{A'} - \frac{A}{A''}\right)$, in this case that the industry has only two systems. Any conventional method of transit productivity analysis underestimates efficiency in the presence of heterogeneous conditions being unfair to agencies like A because they operate in operating conditions less advantageous for transit service.

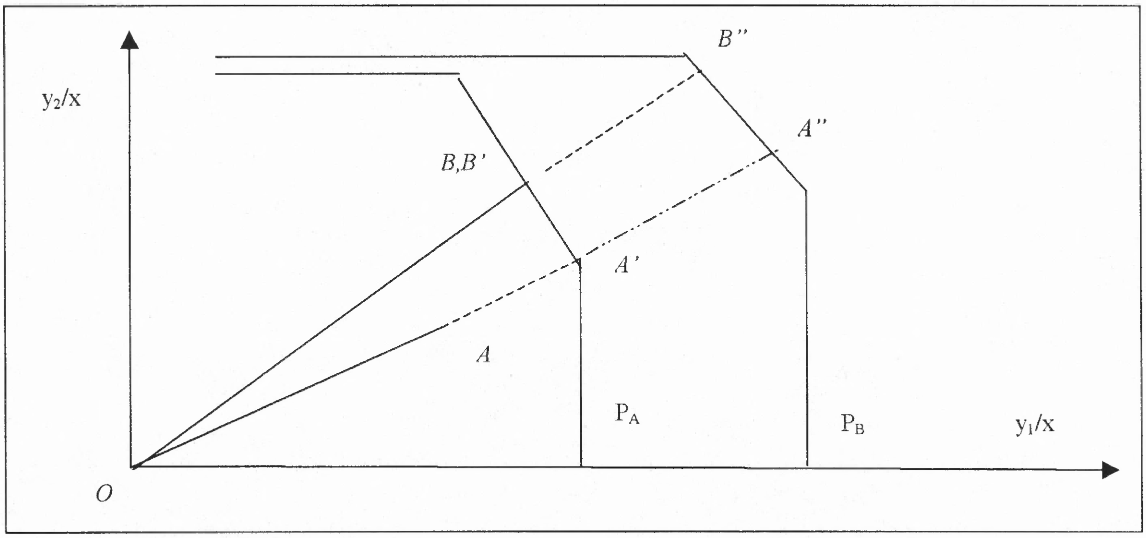

Figure 2 Heterogeneous Operating Conditions Produce Multiple Frontiers

2.6 Transit Productivity Analysis and Heterogeneous Conditions

This section shows evidence that five methods have been applied by transit productivity analysis under heterogeneous conditions, three of them refer to the frontier and are further explained in Chapter 3. The first method estimates empirical equations of productivity ratios versus operating conditions. Giuliano (1981) defined operating conditions as a group of environmental and institutional factors that can affect the supply or the demand side of transit operations. Anderson (1983) included subsidy and ownership. Systems of empirical equations permitted the analysis of operating conditions like peak-to-base-ratio, speed, and agency size that affect productivity components of bus operations and maintenance (Bladikas and Papadimitrou 1985; 1986).

The second method estimates conventional cost functions. Miller (1970) showed that scheduled speed, city age, and density of service were relevant in the estimation of the unit cost of US bus service. Wilson (1977) included subsidy source, ownership type, and weather in the estimation of cost functions of US bus agencies with the objective to forecast cost for new bus transit operations. A simpler way to estimate the effect of operating conditions was to assign a group-specific dummy as applied in (Pozdena and Merewitz 1978) for US rail transit. The firm-specific term also helps to gather the effect of all operating conditions and to isolate the effect of a single operating condition over costs like in (Karlaftis and Sinha 1997) that estimated the effect of federal subsidies in the performance of demand responsive systems. More recently, assets attributes have been included in the cost function like bus size and multi-modal operations to calculate their influence on costs per bus-kilometer in Norway (Jorgensen, Pedersen, and Solvoll 1995; Oum, Tretheway and Waters 1992). Wunsch (1996) estimated returns to operating conditions for speed, vehicle capacity, vehicle age, and peak-to-base ratio of European transit agencies.

The third method estimates frontier cost functions. Hensher (1987) included the union presence to estimate a cost frontier of bus operations, while Viton (1993) included a firm-specific dummy in the cost function to account for the operating conditions of rail transit. Gathon (1989) used the same technique in two steps in which the second one considered operating conditions as sources of inefficiency of European bus operations. More recently, (Sakano, Obeng and Azam 1997) estimated the effect of subsidies on allocative efficiency.

The fourth method estimates the total factor productivity growth. For example (Benjamin and Obeng 1990) calculated the effect of subsidies and local conditions on productivity growth for a sample of US bus agencies. With the same method, Appelbaum and Berechman (1991) included special constraints to the cost function to account for regulations (fares and minimum service) and for demand conditions (population density and income). Hensher (1992) included an additional firm-specific term in the productivity growth estimation of Australian bus transit operations.

The fifth method is data envelopment analysis (DEA). Chu, Fielding, and Lamar (1992) estimated efficiency and effectiveness of bus agencies. Estimation of effectiveness included variables as if they were additional inputs in DEA like population density, car-less household proportion, and subsidy per passenger. Furthermore, the sample used by Chu, Fielding, and Lamar came from within clusters of US bus agencies formed on the basis of peak-to-base ratio, speed, and agency size (Fielding, Brenner, and Faust 1985). More recently, Kerstens (1996) considered ownership, subsidy source, stop spacing, population density, and speed as determinants of efficiency level. Kerstens applied DEA to French bus systems and estimated a regression of the efficiency scores versus operating conditions to identify the sources of productivity inefficiency. Similarly, Nolan (1996) applied DEA for US bus agencies including some internal sources of inefficiency like the spare ratio and the share of maintenance employees. In summary, five methods have included operating conditions and therefore the transportation literature recognizes that the operating conditions are necessary for performance evaluation.

2.7 Working Hypothesis

The working hypothesis is that current methods of transit productivity analysis would not be adequate because they include a portion of the productivity difference caused by heterogeneous conditions and their results tend to favor those agencies working in more advantageous operating conditions. As a consequence, it would be necessary to develop a new method for measuring transit efficiency. Chapter 3 analyzes the adequacy of current methods to estimate efficiency scores in heterogeneous conditions, Chapter 4 develops the new model, and Chapter 5 applies the new model to productivity analysis of rail transit.

CHAPTER 3

LITERATURE REVIEW

3.1 Partial Productivity Analysis

3.1.1 Basic Features of Partial Productivity Analysis

Partial productivity is the ratio of a single output to a single input as presented in formula (7) where p is productivity, x is the quantity of input, and y is the quantity of output (Stevenson 1999).

$$p = \frac{y}{x} \tag{7}$$

3.1.2 Partial Productivity Analysis in Heterogeneous Conditions

The following text evaluates the current methods of productivity analysis in heterogeneous conditions.

3.1.2.1 Conventional Partial Productivity Analysis. Users of conventional partial productivity analysis have found that changes in productivity of the transit industry occurred because of changes in operating conditions such as population density, auto ownership, personal income, etc. Meyer and Gomez-Ibañez (1977) found that productivity in vehicle revenue miles grew by 1.05 percent per year but that productivity in revenue passengers decreased by 0.75 per year between 1948 and 1970 because of changes in operating conditions. Similarly, US-DOT-UMTA (1976) found increases in vehicle revenue miles and decreases in revenue passengers between 1974 and 1975. The Comptroller General (1981) found that, during 1973-1978, labor productivity decreased by 6 percent with respect to vehicle miles and by 4 percent with respect to passenger trips. He observed that subsidies encouraged transit expansion to less dense areas that are more costly to serve. Consistently, Pickrell (1983) traced 14 percent of the bus operating deficits to declining passenger miles per seat mile between 1960 and 1980. More recently, US-DOL-BLS (1998) found that, during 1967-1992, labor productivity declined four times faster in terms of passenger trips than in terms of vehicle revenue miles, and that expansion of service coincided with the period of expansion of public ownership and subsidies. Lyons (1995) calculated correlation coefficients between operating conditions and productivity, and found that labor and vehicle productivity in vehicle hours are significantly correlated with speed and with vehicle load in bus transit.

3.1.2.2 Cluster Analysis. Since conventional methods have had limited use to evaluate individual agencies, some States decided to use clusters to monitor performance of recipients of operating subsidies. Barbour and Zerrillo (1982) explained the way New York State Department of Transportation classified agencies by mode and by size. Simultaneously, Fielding, Mundle, and Misner (1982) proposed a cluster system on behalf of the Los Angeles County Transportation Commission to classify agencies by type of service; local/express service, fixed headway, etc. However, some clusters were too small, so that, some authors proposed nation-wide clusters to help to evaluate similar agencies by using the technique of cluster analysis.

Cluster analysis is a group of multivariate techniques whose purpose is to classify objects so that the resulting clusters maximize internal homogeneity and external heterogeneity. Cluster analysis consists of choosing the relevant variables that differentiate the groups, selecting a function to measure the distance between observations, and using an algorithm that maximizes the distance between clusters while minimizes the distance within clusters (Hair, Anderson, Tatham, and Black 1987).

Vaziri and Deacon (1983) clustered transit agencies in eleven groups by characteristics of city size (area, population, central-city population). However, some clusters were too small and census data was too aggregated. In contrast, Fielding, Brenner, and Faust (1985) opted for the use of the National Transit Database. They clustered bus agencies with four variables; peak vehicles, annual vehicle-miles, average speed, and peak-to-base ratio to describe the adjustment of the agency to its operating conditions. However, after observing Tables 1 and 5 of (Fielding, Brenner, and Faust 1985), only four out of twelve clusters are big enough for standard statistical inferences (clusters 3, 6, 7, and 8). Clusters 3, 6, 7, and 8 registered variations of operating conditions between 19 and 74 percent of the variation of the whole indicating that clusters did not eliminate heterogeneity. Moreover, groups 3, 6, 7, and 8 registered variations of productivity in labor, vehicles, and labor-maintenance between 42 and 94 percent of the variation of the population. Therefore, since operating conditions correlated to productivity ratios, operating conditions caused productivity differences within the clusters.

3.1.2.3 Empirical Equations. Empirical equations assume that the productivity ratio is a function of operating conditions. Giuliano (1981) found that fleet size, fleet age, peak-to-base ratio, and wage rate explained labor productivity while fleet size and population density explained vehicle productivity.

Bladikas and Papadimitriou (1985; 1986) found that the operating labor "unproductive" ratio has significant relations with the peaking of the demand and that personnel productivity of maintenance has significant relations with "slowness" (1/speed) and with fleet size. Pucher, Markstedt, and Hirschman (1983) related subsidies to productivity, finding that labor productivity in revenue vehicle hours has a significant relation with federal operating assistance and fleet size. Similarly, Cervero (1984) estimated regressions of labor efficiency and vehicle efficiency as a function of subsidies and time.

Empirical equations require a theoretical framework to determine the relevant set of variables in the regression (Intriligator 1978). Relevant variables could be excluded from empirical equations and the results would be biased and inconsistent. Irrelevant variables could be included in the empirical equation increasing the significance of the regression while reducing the significance of relevant variables to the point of exclusion. Without a theoretical framework, the membership of the relevant set of explanatory variables is uncertain.

3.1.3 Conclusions on Partial Productivity Analysis

Cluster analysis reduced but did not eliminate the influence of heterogeneous conditions while empirical equations lacked a theoretical framework necessary to know the relevant set of explanatory variables. In addition to its limitations in dealing with heterogeneous conditions, partial productivity analysis is limited to constant returns to scale and to single input and single output analysis (Oum, Tretheway, and Waters 1992).

3.2 Stochastic Frontier Analysis

Stochastic frontier analysis assumes that not all producers use the least possible inputs to produce the outputs they choose, and that some can operate at the interior of the frontier. The frontier is the maximum output that can be produced at a given input plus a random effect making the production frontier a stochastic one (Kumbhakar and Lovell 2000). The upper graph of Figure 3 shows the production y in the vertical axis and the observed inputs x in the horizontal axis. The square dots y_o are the observed outputs, the curve y_d is the deterministic frontier and the rounded dots y_s are the stochastic frontier. The lower graph shows two probability density functions, the truncated one describes the distribution of efficiency and the symmetric one describes the distribution of random effects.

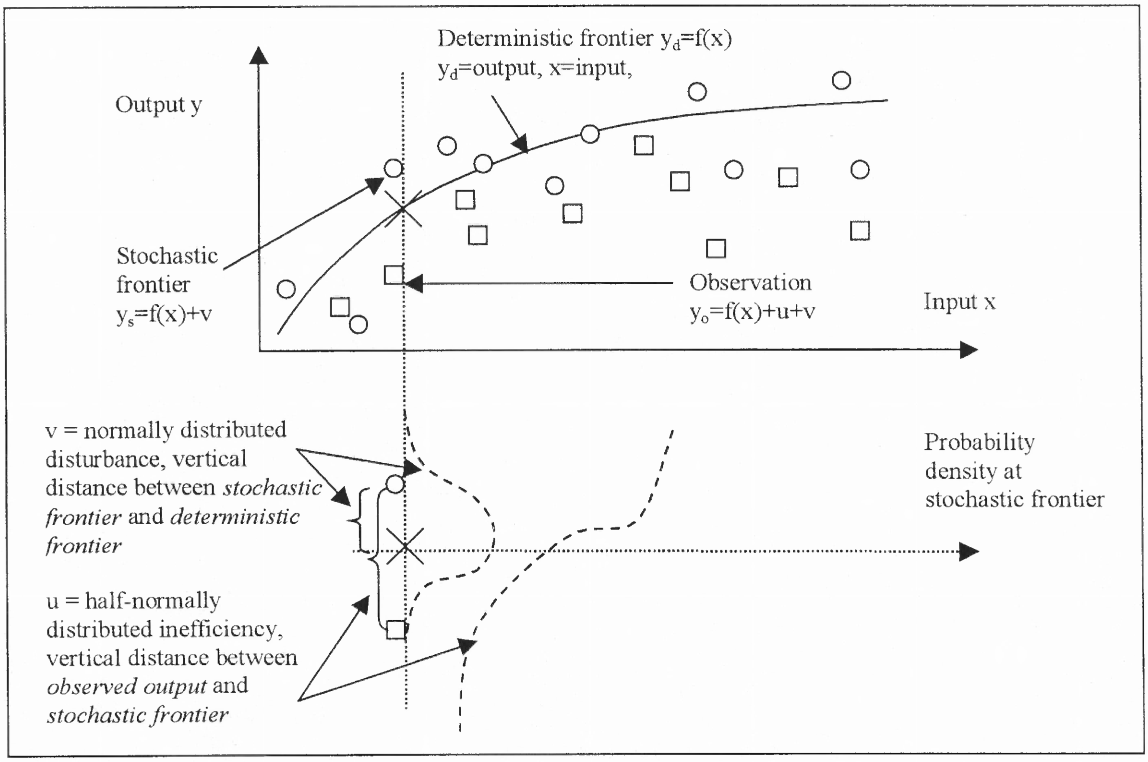

Figure 3 Stochastic Frontier and Distribution Function of Efficiency

3.2.1 Basic Features of Stochastic Frontier Analysis

Production Economics

An agency maximizes output subject to the cost constraint as in the maximization of the objective function (8) subject to constraint (9) for the case of a single output and two inputs (Henderson and Quandt 1971; Intriligator 1978).

$$\max y = f(x_1, x_2) \tag{8}$$

$$subject \quad to \qquad C = w_1 x_1 + w_2 x_2 \tag{9}$$

Where y is the output, x_1, x_2 the inputs, w_1, w_2 the input prices, and C the total cost. The production function maps the maximum output bundle *y* by using the input bundle *(x_1, x_2)*. The determinants of the production function are the state of technological knowledge, physical laws, and operating conditions. Mathematical conditions ensure that the set of input requirements is convex from below (McFadden 1978).

Functional Forms

Production functions of the general form presented in equation (8) may have a number of functional forms. Table 6 presents three alternatives, the Cobb-Douglas form ensures constant cost shares of factors, the Constant Elasticity of Substitution form ensures constant elasticity of substitution between factors, while Transcendental Logarithmic form is the most flexible.

Table 6 Functional Forms of Production Functions

Name and Reference	*Functional form (βs = parameters to be estimated)*
Cobb-Douglas - CD (1928) (Fuss and McFadden 1978)	$\ln y = \beta_0 + \sum_{i=1}^{n} \beta_i \ln x_i \qquad \sum_{i=1}^{n} \beta_i = 1$
Constant elasticity of substitution – CES (1961) (Fuss and McFadden 1978)	$y^\rho = \beta_0 + \sum_{i=1}^{n} \beta_i x_i^\rho$
Trascendental logarithmic – Translog (1973) (Christensen, Jorgenson, and Lau 1973)	$\ln y = \beta_0 + \sum_{i=1}^{n} \beta_i \ln x_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \beta_{ij} \ln x_i \ln x_j$ $\sum_{i=1}^{n} \beta_i = 1, \sum \beta_{ij} = 0$

Traditional Estimation Methods

Two methods are used traditionally to estimate the production function through the average of the observations. They are the ordinary least squares and the maximum likelihood estimator (Intriligator 1978; Koutsoyiannis 1978). Ordinary least squares apply the formulation of equation (10)

$$\text{Calculate } \hat{\boldsymbol{\beta}} = (\mathbf{X'X})^{-1}\mathbf{X'}y \text{ to estimate parameter vector } \boldsymbol{\beta} \text{ of equation } y = \mathbf{x}\boldsymbol{\beta} + \varepsilon \quad (10)$$

In equation (10), y is the dependent variable, $\mathbf{x}$ the vector of independent variables, $\boldsymbol{\beta}$ the vector of parameters, ε the disturbance, and $\mathbf{X}$ the matrix of observations of the independent variables. The maximum likelihood estimator finds the $\boldsymbol{\beta}$ parameter vector, maximizing the probability that the sample represents the population. Hence, the maximum joint probability of production is the solution to its first order conditions.

Maximum Likelihood Estimation is a method described in equations of (11), g is the probability density function (normal) of the output y_i as a function of parameters $\boldsymbol{\beta}$ and of the variance of the disturbance σ_ε^2. L is the joint probability density of the sample, and the derivatives $\partial \ln L$ are the first-order conditions that equal zero.

$$g(y_i;\boldsymbol{\beta},\sigma_\varepsilon^2)=\frac{1}{\sqrt{2\pi\sigma_\varepsilon^2}}\exp\left(-\frac{(y_i-\boldsymbol{\beta}_i\mathbf{x}_i)^2}{2\sigma_\varepsilon^2}\right)$$, probability density function of dependent variable y_i

$$L=\prod_{i=1}^{n} g(y_i;\boldsymbol{\beta},\sigma_\varepsilon^2)$$, function of the total probability that $\boldsymbol{\beta}$ produces y_i

$$\frac{\partial \ln L(\boldsymbol{\beta},\sigma_\varepsilon^2)}{\partial \boldsymbol{\beta},\sigma_\varepsilon^2}=\mathbf{0}$$, first order conditions to maximize L (11)

Frontier Estimation Methods

Stochastic frontier formulations decompose the disturbance ε in two components, a random component "v" and an efficiency component "u" to make ε = u + v. Table 7 shows the procedures of two stochastic frontier methods, maximum likelihood estimator and modified least squares.

Table 7 Selected Methods to Estimate Stochastic Frontiers

Name *Reference* *Steps*	*Problem formulation and assumptions*	*Formula estimation*
Maximum likelihood estimator (Aigner, Lovell and Schmidt 1977) (Meeusen and van der Broeck 1977) (Battese and Corra 1977) (Jondrow, Lovell, Materov and Schmidt 1982) 1. Find ordinary least squares estimates of $\boldsymbol{\beta}, \sigma$ 2. Find log-likelihood $L(y \mid \boldsymbol{\beta}, \sigma, \gamma)$ 3. Find best γ in [0,1] 4. Find max (lnL) by applying non-linear programming method (like Davidon-Fletcher-Powell)	$y = \boldsymbol{\beta}\mathbf{x} + \varepsilon$ $y = \boldsymbol{\beta}\mathbf{x} + u + v$ $u \leq 0 \approx N(0, \sigma_u^2)$ $v \approx N(0, \sigma_v^2)$ $\sigma^2 = \sigma_u^2 + \sigma_v^2$ $\gamma = \frac{\sigma_u^2}{\sigma^2}$ $E_{(\varepsilon)} = E_{(u)} = -\frac{\sqrt{2}}{\sqrt{\pi}}\sigma_u$ $V_{(\varepsilon)} = V_{(u)} + V_{(v)} = \sigma^2$ $\sigma^2 = \left(\frac{\pi - 2}{\pi}\right)\sigma_u^2 + \sigma_v^2$	Solve the log-likelihood function: $\ln L(y \mid \boldsymbol{\beta}, \sigma, \gamma) = -\frac{n}{2}\ln\frac{\pi}{2} -$ $-\frac{n}{2}\ln\sigma^2 +$ $+\sum_{i=1}^{n}\ln[1 - \Phi(z_i)] -$ $-\frac{1}{2\sigma^2}\left(\sum_{i=1}^{n} y_i - \mathbf{x}_i\boldsymbol{\beta}\right)^2$ *where*, $z_i = \frac{(y_i - \mathbf{x}_i\boldsymbol{\beta})}{\sigma}\sqrt{\frac{\gamma}{1-\gamma}}$ $\Phi(z_i) = \int_{-\infty}^{z} (2\pi)^{-\frac{1}{2}} \exp\left(-\frac{1}{2}t^2\right)dt$
Modified least squares (Fried, Lovell and Schmidt 1993) 1. Find ordinary least squares estimates of $\boldsymbol{\beta}, \sigma$ 2. Find $\hat{\sigma}_u^2$ from m^3 3. Find $\hat{\sigma}_v^2$ from m^2 4. Find constant term $\hat{\beta}_0$	Same as above Apply theorem by which estimators of ordinary least squares are unbiased estimators of stochastic frontier except constant β_0 Moments $m^k = \Sigma(y - \hat{y})^k\ \hat{y}$ of OLS	$m^3 = \left(\frac{2}{\pi}\right)^{\frac{1}{2}}\left[1 - \left(\frac{4}{\pi}\right)\right]\sigma_u^3$ $m^2 = \left[\left(\frac{\pi}{2}\right) - 1\right]\sigma_u^2 + \sigma_v^2$ $E_{(u)} = -\frac{\sqrt{2}}{\sqrt{\pi}}\sigma_u$ $\hat{\beta}_0 = \hat{\beta}_{0\,ordinary-least-squares} - \hat{\sigma}_u\left(\frac{1}{2}\right)^{\frac{1}{2}}$

y = output, β = parameter vector, **x** = input vector, ε = disturbance, u = efficiency component of ε, v = stochastic component of ε, N = normal distribution, σ^2_ε = total variance of disturbance ε, σ^2_u = variance of efficiency, σ^2_v = variance of stochastic component, γ = efficiency component of disturbance variance, E = expected value, V = variance, L = joint density probability function of the observed outputs, n = size of sample, Φ = normal cumulative distribution function, ln = natural logarithm, z_i = normal standard value of y_i, exp = exponential function, m^k = moments k, ˆ = estimated, i = observation i.

3.2.2 Stochastic Frontier Analysis in Heterogeneous Conditions

The following text makes a critical review of the current methods of productivity analysis in heterogeneous conditions.

3.2.2.1 Conventional. Transportation studies applied conventional stochastic frontier analysis to compare methods of estimation and therefore, the operating conditions were explicitly excluded to avoid their influence over the differences between methods. For example, Kumbhakar (1987) estimated efficiency of US railroads to compare four estimation methods and Coelli and Perelman (1999) estimated efficiency of European railways to compare DEA and stochastic frontier analysis.

3.2.2.2 Two-Step. Two-Step estimates a conventional cost frontier and then uses the efficiency scores as a dependent variable that is a function of operating conditions. The second step usually estimates a Tobin regression that is a special method for those dependent variables that are bounded (efficiency should be larger or equal to zero and smaller or equal to one). The second step implicitly assumes that internal inefficiency approximates the residual, the constant term, or the parameter of a firm-specific dummy.

Gathon (1989) estimated the cost frontier of European transit agencies and found that speed explained a significant part of the variation of the efficiency score. Gathon and Pestieau (1995) estimated the production frontier of European railways, and found that regulation was significant to explain the variation of efficiency scores. Liu (1995) estimated the production frontier of British ports, and found that ownership was not significant to explain the variation of efficiency scores although location and size were significant. Sakano and Obeng (1995) estimated the cost frontier of US bus transit agencies and found that neither capital nor operating subsidies were significant to explain variations of technical efficiency. McMullen and Lee (1999) estimated the cost frontier of US motor carriers, and found that seven variables explained the variation of efficiency scores, except deregulation. In brief, Two-Step measures inefficiency and attributes it to operating conditions.

The second step usually does not consider internal inefficiency as a variable because this is unknown; therefore, a relevant variable is excluded from the regression creating a specification error in which estimators can be biased and inconsistent (Intriligator 1978). Even though the second step may assume that inefficiency was the constant term or the firm-specific dummy, the second equation is still incomplete. Dummies are used in cases where there is lack of knowledge about the model and they are limited to choose between "existence or nonexistence" of internal inefficiency (Pindyck and Rubinfeld 1998). The specification of the model improves but it cannot completely separate internal inefficiency from the effect of operating conditions because there can be an internal inefficiency in any agency caused by its culture management, employees morale, etc.

3.2.2.3 Operating Conditions as Inputs. Sarndal and Statton (1975), Sarndal, Oum, and Statton (1978), and Oum, Tretheway, and Waters (1992) demonstrated that output characteristics of the airline industry were associated to production and cost and concluded that they should be included in the production functions. Similarly, Rus and Nombela (1997) assumed that speed affected efficiency of Spanish bus agencies because it contained information about the type of routes of the firm and therefore they included it in the production function. Schmidt and Sickles (1984) estimated the production frontier of US airlines including load factor and average stage length while Cornwell, Schmidt, and Sickles (1990) included season (winter-spring), stage length, and quality of the service. Viton (1993) estimated a cost frontier function for US rail rapid transit including cars per track mile as a proxy for level of service, technological variables, and fixed factors and also he included a dummy for firm-specific characteristics.

However, this method has the caveat of correlation of inputs with operating conditions. Xu, Windle, Grimm, and Corsi (1994) estimated a cost frontier function for the US trucking industry with network variables and they proved that size and network variables are correlated and that both variables affect returns to scale in a unique but combined effect. The preceding result suggests that operating conditions do not affect productivity by themselves but that they do it through their influence on inputs; therefore, it is not possible to separate the effect of inputs from the effect of operating conditions when both appear in the same equation. Larger firms, compared to smaller systems, appeared to have advantages in increasing their length of haul and their average load size. Furthermore, if this interpretation stretches to include speed and peak-to-base ratio in the transit industry, it affects productivity through labor and vehicles causing multicollinearity that biases the parameters of inputs and operating conditions.

3.2.2.4 Operating Conditions in Additional Constraints. Additional constraints to equations (8) and (9) of page 22 transmit the effect of operating conditions to productivity by using an adequate theoretical framework. Operating conditions have been added in a demand or in a budgetary constraint attached to the original formulation of the cost minimization problem (Applebaum and Berechman 1991; Obeng and Azam 1997; Berechman 1993, Chapter 6; Sakano, Obeng, and Azam 1997).

The only problem with the additional constraints is that it is difficult to achieve comprehensiveness because one constraint is necessary to explain the effect of one operating condition while many operating conditions would reduce the degrees of freedom and complicate the estimation of the model. This method can be practical to explain the effect of few operating conditions but it becomes complicated for a large number of operating conditions.

3.2.2.5 Cost Elasticity of Operating Conditions. This method tries to simplify the inclusion of operating conditions in additional constraints. The method consists of deriving the algebraic relation between inputs and operating conditions to later use it to estimate unbiased returns to scale. The method was developed in Jara-Diaz and Cortes (1996) who related motor carrier returns to scale to several operating conditions. Savage (1997) applied this method in his estimation of returns to scale for US rail transit. Similarly Marin (1998) multiplied a linear function of operating conditions as a component of the productivity elasticity of input for airlines.

However, the cost elasticity of operating conditions seems to present only a partial view of the global relations between operating conditions, inputs, and outputs. Oum and Zhang (1997) already observed that the algebraic constructions of Jara-Diaz and Cortes (1996) assumed no relations between attributes themselves and that output had to remain constant for the relations to hold. The finding of Oum and Zhang (1997) can also be interpreted as the consequences of applying a partial empirical framework instead of a global theoretical framework to explain the relations between operating conditions, inputs, and outputs.

3.2.3 Conclusions on Stochastic Frontier Analysis

Stochastic frontier analysis may include operating conditions with additional constraints within a sound theoretical framework but additional constraints may turn too complicated if all operating conditions were included simultaneously. Therefore, this approach is adequate to measure the influence of one or two operating conditions rather than the simultaneous influence of all of them. The other methods have estimation problems like multicollinearity and specification errors derived from an inadequate theoretical formulation.

3.3 Data Envelopment Analysis (DEA)

3.3.1 Basic Features of DEA

DEA is the linear programming approach to productivity analysis developed by Charnes, Cooper, and Rhodes (1978) to evaluate regulated industries, public utilities, public services, and activities with nonexistent or regulated prices.

3.3.1.1 The Charnes, Cooper and Rhodes (1978) Model. Charnes, Cooper, and Rhodes (1978) extended the model made by Farrell (1957) from a model of single outputs to a model of multiple outputs. The formulation is presented in equations (12).

$$Charnes, Cooper, Rhodes\ 1978$$

$$\begin{array}{ll}
\textit{Primal} & \textit{Dual} \\
\max z_0 & \min \sum_{i=1}^{m} x_{i0} w_i \\
\textit{subject to}: & \textit{subject to}: \\
y_{r0} z_0 - \sum_{j=1}^{n} y_{rj} \lambda_j \le 0 & \sum_{i=1}^{m} x_{ij} w_i - \sum_{r=1}^{s} y_{rj} u_r \ge 0 \\
\sum_{j=1}^{n} x_{ij} \lambda_j \le x_{i0} & \sum_{r=1}^{s} y_{r0} u_r = 1 \qquad u_r, w_i \ge 0 \\
\lambda_j \ge 0 &
\end{array} \tag{12}$$

DEA Variables of the Primal

In the primal of model (12), z_0 is the efficiency score, if $z_0 = 1$ then agency 0 is efficient, if $z_0 > 1$ then agency 0 could augment outputs in the proportion $z_0 - 1$. There are two sets of constraints; the output set and the input set. The output set has coefficients y_{rj} describing the output r of agency j, with s outputs and n agencies. The input set has coefficients x_{ij} describing the input i of the agency j, with m inputs and n agencies. Variables z_0, λ_j are the decision variables. Variable z_0 is the maximum proportional expansion of outputs to achieve efficiency. Variables λ_j are the weights of a linear composite of the inputs of the agencies j to reproduce the inputs used by agency 0. At the optimal solution those $\lambda \neq 0$ identify those efficient agencies that are the technological reference for agency 0.

Figure 4 shows the role of the decision variables of the primal of model (12), λ and z_0. In the inputs plane (left), the input of agency A is equal to a linear composite of the inputs of B and C, Xa = λ_cXc + λ_bXb. In the outputs plane (right), the same linear combination applies to outputs B and C to build frontier BC where z_0 multiplies the output of agency A is the necessary proportional augmentation of the output to reach the frontier BC, z_0 Ya = λ_cYc + λ_bYb.

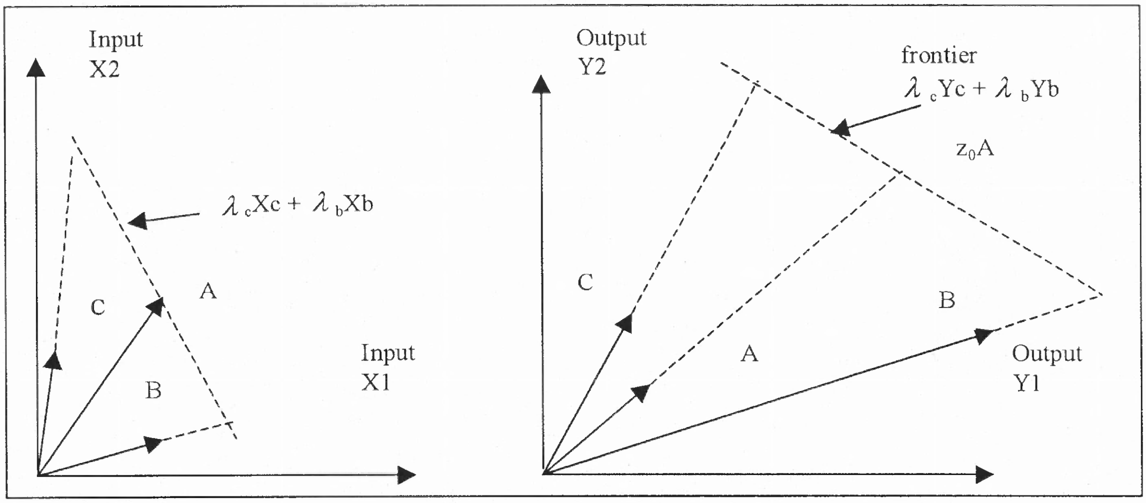

Figure 4 Decision Variables of DEA

DEA Variables of the Dual

In the dual of model (12), a set of constraints normalizes the outputs of agency 0 to 1.00 to bound the problem while the other set of constraints build several hyperplanes of linear production functions with the maximum hyperplane, the binding constraint, describing the frontier. The variable u_1 of the dual is the price associated to the slack of the primal constraint for y_1. If $u_1 = 0$ the constraint for y_1 of the primal is not binding since its slack is not zero. If $u_1 \neq 0$ the constraint for y_1 of the primal is binding since its slack is zero. As a result, if the output y_1 of agency 0 increases by one unit, efficiency increases by u_1 units.

Figure 5 shows the hyperplane built by the dual of model (12) with its equation uy – wx = 0, where u, w are the coefficients of the optimal piecewise linear production function. The value of the objective function represents the proportional distance between the hyperplane that passes through the agency and the hyperplane of the efficient frontier.

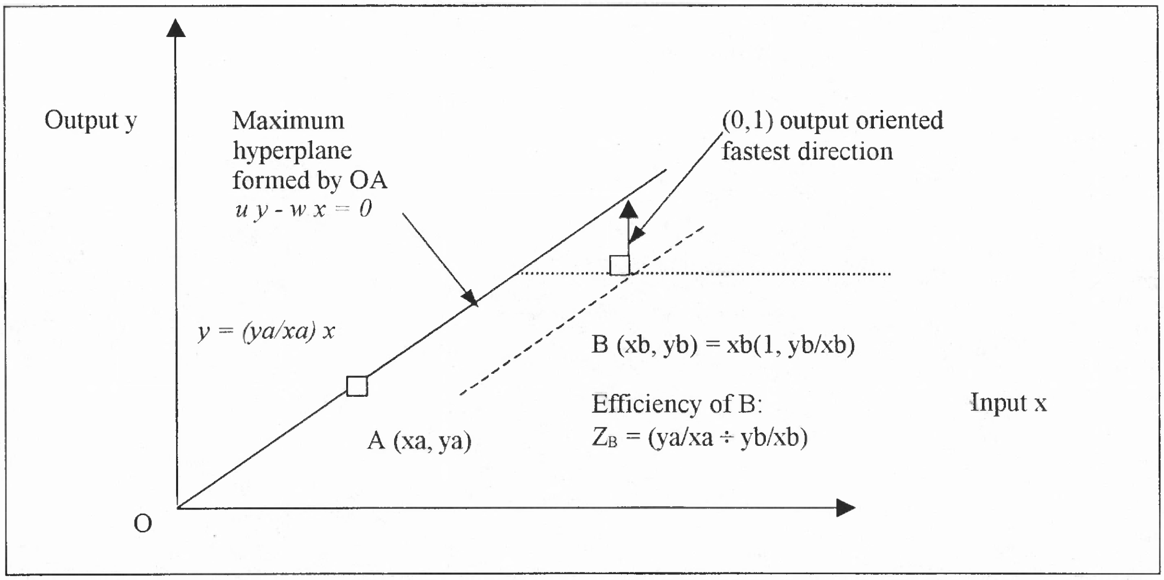

Figure 5 Optimal Hyperplane of DEA

DEA Orientation

Figure 6 illustrates that DEA is output oriented if it follows path AB to increase outputs for achieving efficiency, DEA is non-oriented if it follows path AC, and DEA is input oriented if it follows path AD to reduce inputs for achieving efficiency.

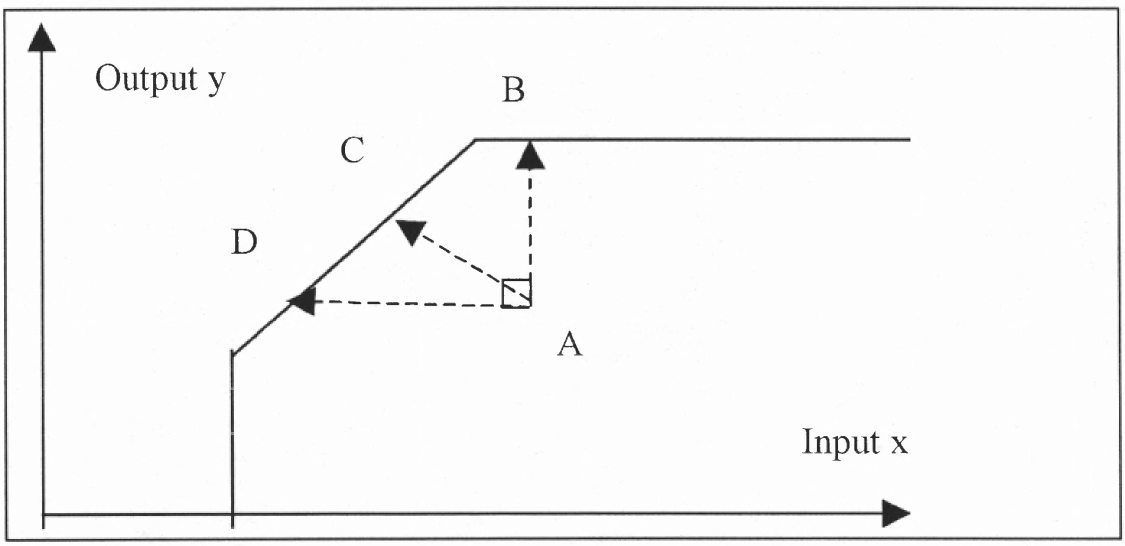

Figure 6 Orientation of DEA

Theoretical Framework of DEA

The theoretical framework of DEA is based on the radial distance function that relates observations to the frontier planes of seemingly related variables. Seemingly related variables are those already considered so by any theory. For example, the theory of the firm considers the production function as a relation between inputs and outputs where more input corresponds to more output. Thus, constraint sets of outputs and inputs of the primal of model (12) are consistent with the general agreement in the positive relation between input and output. Similarly, the planes formed in the constraints of the dual of model (12) are also consistent with the implicit linear production functions. Chang and Guh (1991) showed that the dual of DEA implies a piecewise linear envelope and that for each agency the envelope acts as a piece of a linear production function that gauges efficiency.

Information Provided by (Charnes, Cooper, and Rhodes 1978)

- *Efficiency score*. The efficiency score indicates overall efficiency. In the case of an output oriented model, a score larger than one indicates insufficient production and the proportional excess over unity indicates the proportional increase of outputs needed to achieve efficiency.
- *Efficient Peers*. Efficient peers are those efficient agencies that are technologically near the evaluated agency. They are identified as those agencies with a lambda different than zero ($\lambda \neq 0$).
- *Improvement Path*. The improvement path is the product of the outputs times the efficiency score minus one plus the output slacks. It is the actual increase of output needed to achieve efficiency.
- *Linear Production Function*. The linear production function is $uy - wx = 0$ as shown in Figure 5. The linear production function is a piecewise set of linear equations that relate outputs to inputs at the production possibility frontier. The coefficients of the inputs are the shadow prices of the agency in that they express the increase in the production of an output when the input increases in one unit. Moreover, they are the value of marginal productivity of the input when the coefficient of the output is unity and the rest of the outputs remain constant. Only those inputs whose constraints are binding in the primal show a coefficient different than zero in the primal.

- *Returns to scale*. In the case of output-oriented models, the indicator $\frac{\sum \lambda_j^{(12)}}{z_0}$ indicates returns to scale where z_0 is the efficiency score. If $\frac{\sum \lambda_j^{(12)}}{z_0} > 1$ the agency operates in decreasing returns to scale. If $\frac{\sum \lambda_j^{(12)}}{z_0} < 1$ the agency works in increasing returns to scale.

3.3.1.2 The Banker, Charnes and Cooper (1984) Model. Banker, Charnes, and Cooper (1984) assumed variable returns to scale but recommended that the decision on returns to scale be based on previous knowledge of the transit industry. They added a convexity constraint $\sum_{i=1}^{k} \lambda_j = 1$ to the primal of the model as indicated in equations (13) to adjust the frontier according to the size of the agency. The dual of the model augments the unconstrained w_0 that indicates that the implicit frontiers are locally significant to the observations.

$$Banker, Charnes, Cooper\ 1984$$

$$\begin{array}{ll}
\textit{Primal} & \textit{Dual} \\
\max h_0 & \min \sum_{i=1}^{m} x_{i0} w_i + w_0 \\
\textit{subject to}: & \textit{subject to}: \\
y_{r0} h_0 - \sum_{j=1}^{n} y_{rj} \lambda_j \leq 0 & \sum_{i=1}^{m} x_{ij} w_i - \sum_{r=1}^{s} y_{rj} u_r + w_0 \geq 0 \\
\sum_{j=1}^{n} x_{ij} \lambda_j \leq x_{i0} & \sum_{r=1}^{s} y_{r0} u_r = 1 \qquad u_r, w_i \geq 0 \\
\sum_{i=1}^{n} \lambda_j = 1 & w_0 \ \textit{unconstrained} \\
\lambda_j \geq 0 &
\end{array} \tag{13}$$

Information Provided by (Banker, Charnes and Cooper 1984)

- *Scale efficiency score.* The scale efficiency score is the ratio of efficiency scores of model (12) to model (13); $\frac{z_0}{h_0}$ where z_0, h_0 are the objective functions of the models (12) and (13) respectively indicating the degree of productivity efficiency caused by the scale of production.
- *Technical efficiency score.* The technical efficiency score is the variable h_0 of model (13). It indicates the degree of productivity efficiency caused by the technical skills of the agency.

3.3.1.3 Applications of DEA to Fields Other than Productivity Analysis. DEA has been used to estimate efficiency of site location based on travel distance and extent of coverage of sites (Desai, Haynes, and Storbeck 1994; Desai and Storbeck 1990). More recently, DEA has selected dispatching rules for scheduling problems in manufacturing and servicing systems (Braglia and Petroni 1999; Ho and Lau 1999). Haskel and Sanchis (2000) applied DEA to create a bargaining model between labor and management under certain market conditions. Reinhard, Lovell, and Thijssen (2000) extended the models that evaluate environmental efficiency with multiple environmentally detrimental inputs. Innovative contributions in transportation include (Nozick, Borderas, and Meyburg, 1998) that used parking availability and proximity to transit to evaluate travel demand programs. Also, DEA has used attributes of network links to evaluate efficiency of non-dominated paths on a road network (Cardillo and Fortuna 2000). A common feature of the innovative applications of DEA is the positive correlation of two groups of variables that measure the distance function between the observation and the frontier, a feature that can be extended to operating conditions and productivity.

3.3.2 DEA in Heterogeneous Conditions

The following text makes the critique of the current methods of productivity analysis in heterogeneous conditions.

3.3.2.1 Conventional DEA. Conventional DEA explicitly assumes an industry working in homogeneous operating conditions (Golany and Roll 1989; Boussofiane, Dyson, and Thanassoulis 1991). However, conventional DEA has been applied to transportation by authors who say that they did not consider operating conditions in order to compare different methods of DEA because they would bias the comparison of methods. For example, Forsund (1992) estimated the efficiency of Norwegian ferries to compare DEA to stochastic frontier analysis. Tofallis (1997) tested a new method to improve the discriminating power of DEA in small samples of airlines by estimating input-specific DEAs in cases of non-substitutable inputs. Therefore, conventional DEA has been applied only to compare methods of estimation and because operating conditions were not necessary.

3.3.2.2 Two-Step DEA. In 1988, Ray observed that different levels of operating conditions behave like different levels of technology because by varying their values they build productivity frontiers. He concluded that operating conditions cannot be included as inputs but that they can be related to efficiency scores in a separated Tobit regression at a second step. Tobit regression is a special Ordinary Least Squares applied to a dependent variable is bounded as efficiency is bounded between 0 and 1.00. Oum and Yu (1994) found that railways of developed countries with higher subsidies were less efficient. Good, Roller, and Sickles (1995) found that European airlines benefited from deregulation with large productivity gains. Kerstens (1996) found that ownership and subsidies were important to determine efficiency of French transit agencies. Nolan (1996) made a similar study for the US bus transit firms and he found fleet age significant in explaining technical efficiency followed by maintenance practices and operating subsidies. Gillen and Lall (1997) in their study of American airports found that reducing the movements of general aviation improved the efficiency on the airside part of the airport, while expanding the number of common gates improved terminal efficiency. Chapin and Schmidt (1999) found that mergers permitted US rail freight agencies to operate track networks more efficiently but that total productivity gains between merging firms and non-merging firms were not different. In summary, Two-Step DEA identified operating conditions with sources of inefficiency.

However, the second step does not consider internal inefficiency and therefore it produces a specification error. Also, firm-specific dummies overlap internal inefficiency with other non-controllable effects. More importantly, Two-Step DEA creates a methodological inconsistency between the deterministic efficiency score of the first step and the stochastic efficiency score of the second step.

3.3.2.3 Non-Discretionary Factors DEA. Non-Discretionary Factors DEA considers operating conditions as if they were fixed factors. Banker and Morey (1986b) developed the model presented in equations (14).

$$Banker, Morey - 1986b: \quad Non-discretionary \quad Factors, \; DEA-ND$$

$$\begin{aligned}
&Primal \\
&\max \phi_0 \\
&subject \quad to: \\
&\sum_{j=1}^{N} y_{rj}\gamma_j \le y_{r0}\phi_0 \quad r \in v_D \; discretionary\ outputs \\
&\sum_{j=1}^{N} y_{rj}\gamma_j \le y_{r0} \qquad r \in v_F \; fixed\ outputs \\
&\sum_{j=1}^{N} x_{ij}\gamma_j \le x_{i0} \\
&\sum_{j=1}^{N} \gamma_j = 1 \qquad \phi_0, \gamma_j \ge 0
\end{aligned} \tag{14}$$

In model (14), y_{rj} is the output r of the unit j, v_D the group of discretionary outputs, v_F the group of fixed (non-discretionary) outputs, x the input (m inputs), γ the matching multiplier, and ϕ_0 the efficiency score of agency 0. The factor ϕ_0 multiplies only the discretionary outputs of agency 0 because the agency is responsible for producing the discretionary outputs while maintaining the comparability of at least similar levels of non-discretionary outputs. The model can also consider non-discretionary inputs.

Cook, Kazakov, Roll, and Seiford (1991) included snowfall for winter cost increases in efficiency of highway maintenance patrols in Ontario, Canada. Obeng (1994) included subsidies to estimate the efficiency of American transit firms, but Kerstens and Eeckaut (1995) discussed his work favoring Two-Step DEA on the same issue. Cowie and Riddington (1996) used population density for the productivity efficiency of European railways. Viton (1997) included speed and fleet age to estimate the productive efficiency of American multimodal bus and demand response transit. Parker (1999) included ownership to estimate technical efficiency of British airports.

However, Non-Discretionary Factor DEA has been contested in three areas. Yu (1998) found it inaccurate because it achieved only a 25 percent correlation with the real efficiency score. Moreover, adding inputs that are unnecessary increases artificially the estimated efficiency scores (Nunamaker 1985). Additionally, operating conditions do not behave as inputs and therefore they cannot be included as fixed inputs (Ray 1988). The three problems are related because the low empirical accuracy of Non-Discretionary Factors may be caused by the overestimation caused by the inclusion of operating conditions as unnecessary inputs.

3.3.2.4 Cluster Analysis DEA. There are three models of cluster analysis DEA. The first pre-assigns the value of a categorical variable to a group and estimates DEA inside the group. The second applies cluster analysis to form the groups. The third measures efficiency differences between groups called "programs". The first model is the categorical variables model which assigns a value to each cluster and then includes the agency if it belongs to the same group of the evaluated agency. This model is represented by equations (15) (Banker and Morey 1986a).

$$
\begin{aligned}
&Banker, Morey-1986a: \quad DEA\ and\ Cluster\ Analysis,\ \ DEA-CL\\
&Primal\\
&\min z_0\\
&subject\quad to:\\
&\sum_{j=1}^{N} x_{ij}\lambda_j \geq x_{ij0} z_0\\
&\sum_{j=1}^{N} y_{rj}\lambda_j \geq y_{rj0}\\
&\sum_{j=1}^{N} \lambda_j = 1\\
&\lambda_j \geq 0\\
&\sum_{j=1}^{N} \lambda_j \delta_{m,j}^{(k)} \leq \delta_{m,j}^{(k)} \qquad \delta_{m,j}^{(k)} = 0\ or\ 1\ group\ discriminant
\end{aligned}
\tag{15}
$$

In model (15), x is the input i of a total of m, y the output r of a total of s, λ the multiplier of agency j of a total of n, and z the efficiency score, δ is a binary variable that activates the comparison of those agencies of the same cluster. The multipliers λ_j are activated by δ if agencies are in the same cluster as the evaluated agency. An extension to model (15) related the value of the categorical variable to values of operating conditions (Cook, Chai, Doyle and Green 1998). Rouse, Putterill, and Ryan (1997) applied model (15) to estimate the managerial performance of highway maintenance in New Zealand.

The second model applies cluster analysis and uses its results to estimate DEA using model (15). This model was developed in (Ruggiero, Duncombe, and Miner 1995) and applied in (Ruggiero 1996; 1998). Chu, Fielding, and Lamar (1992) used it earlier when they estimated efficiency of American bus transit agencies presented in the previous work of (Fielding, Brenner, and Faust 1985) on the basis of peak-to-base-ratio, speed, and size. Charnes, Gallegos, and Li (1996) clustered Latin American airlines in two groups depending on their environmental characteristics before applying DEA. Karlaftis (2000) clustered American bus transit agencies by size with the objective to estimate returns to scale.

The third model called "program evaluation" compares efficiency of groups working under different policy programs. This method uses tests of non-parametric statistics to determine if efficiency scores are different between groups (Charnes, Cooper and Rhodes 1981; Carrington, Puthucheary, Rose and Yaisawarng 1997; Ozcan, Watts, Harris and Wogen 1998; Bates 1997; Ozcan 1992).

Chan and Sueyoshi (1991) applied program evaluation to American airlines to measure the effect of deregulation. Chang and Kao (1992) applied program evaluation to urban bus transit agencies of Taiwan to measure the effect of ownership. Hjalmarsson and Odeck (1996) estimated productivity efficiency of trucks in road construction and maintenance in Norway identifying sources of inefficiency. Cowie (1999) applied program evaluation to Swiss private railways to estimate the effect of ownership on productivity. In all applications, program evaluation measured the simultaneous effect of *one* but not the effect of *several* operating conditions.

The caveat of the first and second models of cluster analysis DEA is that they reduce the effect of heterogeneous conditions but that they do not eliminate differences within the cluster causing inaccuracy. Moreover, since DEA applies to a smaller set of reference it raises the efficiency scores artificially. The caveat of the third model applies for cases of only one operating condition but does not apply for the case of many operating conditions.

3.3.2.5 Reversed Two-Step DEA. Reversed Two-Step DEA estimates the effect of heterogeneous conditions and uses the results to adjust the inputs and outputs to estimate DEA in the second step of the model. Fried, Schmidt, and Yaisawarng (1999) applied a Reversed Two-Step DEA to American nursing homes. The method has five stages; first, it calculates the traditional DEA to find the slacks of the inputs. Second, it estimates the parameters of input slacks as a linear function of operating conditions. Third, it uses the estimated equation to calculate the input slacks for each nursing home. Fourth, it calculates an adjusted input, that is, the observed input plus the maximum estimated slack minus the slack estimated for each nursing home. Fifth, the method runs DEA one more time using the adjusted inputs.

The combination of stochastic regression and deterministic DEA produces a methodological inconsistency when it considers that efficiency is deterministic in DEA while it is stochastic in the Tobit regression. Moreover, the regression between input slacks and operating conditions (second step) does not consider sources of internal inefficiency (unknown variable) and therefore it has a specification error.

3.3.3 Conclusions on DEA

DEA has not yet developed an adequate model for operating conditions. The Reversed Two-Step DEA could be extended with a sound but simple theoretical framework to link operating conditions and productivity. In that way, the new method would avoid the specification errors of the Two-Step DEA, the overestimation of the Non-Discretionary Factors DEA, and the overestimation and inaccuracy of the Cluster Analysis DEA.

DEA has additional benefits that make it attractive for transit productivity analysis. It does not require rigid assumptions regarding production technology or regarding efficiency distribution and it does not require market prices of inputs or outputs (Oum, Tretheway, and Waters 1992). DEA is a simple approach for the elevation of multiple outputs relative to other approaches that consider complex relations between inputs and outputs as in the case of stochastic frontier analysis (Cooper, Seiford, and Tone 2000).

However, DEA has four limitations. First, DEA does not consider stochastic events and therefore DEA cannot be tested for statistical significance. Second, DEA is sensitive to outliers, so that unusually good performance of a single unit can push the production frontier to levels that may expose DEA to inaccuracy. Third, it has been observed that the higher the number of inputs or outputs, the higher the efficiency scores. Consequently, unnecessary factors increase the general level of estimated efficiency artificially (Nunamaker 1985). Fourth, overestimated efficiency occurs after partitioning a sample because each partition has a lower number of evaluated agencies.

3.4 Conclusions of the Literature Review

After reviewing the current methods for transit productivity analysis, it was found that all methods have limitations to measure efficiency in heterogeneous operating conditions and therefore it is necessary to develop a new model. Since DEA has more advantages to be applied to transit, the new model will build on DEA. Since the Reversed Two-step DEA estimates first the effect of heterogeneous conditions and later the productivity efficiency, the new model will build on the Reversed Two-Step DEA.

CHAPTER 4

THE NEW MODEL

4.1 Objectives and Assumptions of the New Model

4.1.1 Objectives of the New Model

The new model aims to accomplish four objectives. First, to extract the effect of heterogeneous conditions from productivity efficiency by using two steps, one to estimate the effect of heterogeneous conditions and the other to estimate productivity efficiency. Second, it intends to avoid specification errors caused by absent variables by solving the apparent conflict of avoiding redundant operating conditions while including all their effect. Third, to avoid inaccuracy caused by dummy variables intended to describe internal inefficiency by isolating internal inefficiency in the last step. Finally, the new model aims to use the theory of the firm to link inputs, outputs, and operating conditions in a sound framework. The adequacy of the model is based on its assumptions and its internal coherence.

4.1.2 Assumptions of the New Model

4.1.2.1 Operating Conditions Build Multiple Production Frontiers. A technology level determines the maximum outputs achievable by a given combination of inputs. Therefore, changes in technology will shift the production frontier (Emery 1984). Similarly, a bundle of operating conditions determines the maximum outputs achievable by a given combination of inputs such as changes in operating conditions will shift the production frontier (McFadden 1978). Ray (1988) adopted this approach and applied it to DEA, and this formulation is the departing point of the development of the new model.

Let the observed production function be a multiplicative and separable function of inputs and operating conditions working at the efficient frontier. Let the industry have n agencies. The generic agency j produces $\tilde{y}_j$ observed units of a single output by using a bundle of s inputs working at a bundle of q operating conditions. Let the s-element vector $\mathbf{x}_j$ be the inputs of the firm. Let the q-element vector $\mathbf{c}_j$ be the operating conditions affecting the output. Equation (16) is the observed production as a function of inputs and operating conditions.

$$\tilde{y}_j = g(\mathbf{x}_j, \mathbf{c}_j) \qquad (16)$$

Assume that two efficient and identical agencies, j and h, have the same bundles of inputs, $\mathbf{x}_j = \mathbf{x}_h$ but produce different levels of outputs, $\tilde{y}_j \neq \tilde{y}_h$, due to differences in operating conditions, $\mathbf{c}_j \neq \mathbf{c}_h$. Equal levels of outputs $\tilde{y}_j = \tilde{y}_h$ could only be produced at equal levels of operating conditions, $\mathbf{c}_j = \mathbf{c}_h$, therefore the formulation allows for shifts in the productivity frontier caused by changes in operating conditions. Let isolate the effect of the operating conditions $\mathbf{c}_j$ in the observed production of equation (17).

$$\tilde{y}_j = \delta_b(\mathbf{c}_j) * f(\mathbf{x}_j)_b \tag{17}$$

Where $\tilde{y}$ is the observed output and $f(\mathbf{x}_j)_b$ is the production function of the equivalent output produced if agency j worked at a bundle of operating conditions called "base" expressed by "b". If $\delta_b(\mathbf{c}_j) = 1$ for all j agencies, then, the output is the same at both bundles of operating conditions, j and b. If $\delta_b(\mathbf{c}_j) \neq 1$ the effect of operating conditions acts as a proportional technical change. Expression (18) converts the observed output to an equivalent output produced at operating conditions "base".

$$\frac{\tilde{y}_j}{\delta_b(\mathbf{c}_j)} = f(\mathbf{x}_j)_b \tag{18}$$

Let $\mathbf{c}_j \in \Delta$ such as Δ is the set of all admissible vectors of operating conditions of agency j. Assume that $0 \leq \delta_b(\mathbf{c}_j) \leq M$, where M a big number, for any $\mathbf{c}_j \in \Delta$, and therefore, $\delta_b(\mathbf{c}_j)$ is bounded and positive. After that, let define $y_j = f(\mathbf{x}_j)_b$ the equivalent output of the agency j if its operating conditions were $\mathbf{c}_b$, the vector of operating condition "base". Expression (19) illustrates the meaning of multiplier $\delta_b(\mathbf{c}_j)$ in the relation between output produced at the operating conditions j and b.

$$\begin{array}{ll} \textit{If } \delta_b(\mathbf{c}_j) \geq 1 \Rightarrow y_j \leq \tilde{y}_j & \mathbf{c}_j \textit{ is more advantageous than } \mathbf{c}_b \\ \textit{If } \delta_b(\mathbf{c}_j) \leq 1 \Rightarrow y_j \geq \tilde{y}_j & \mathbf{c}_j \textit{ is less advantageous than } \mathbf{c}_b \\ \textit{If } \delta_b(\mathbf{c}_j) = 1 \Rightarrow y_j = \tilde{y}_j & \mathbf{c}_j \textit{ is as advantageous as } \mathbf{c}_b \end{array} \tag{19}$$

Let $\delta_b(\mathbf{c}_b) = 1$ and $\delta_b(\mathbf{c}_j) \neq 1$ if $j \neq b$, then, as a result of expression (19), efficient operations y_j represent productivity frontiers $\frac{y_j}{x_j} = p_j$ at levels that depend on $\mathbf{c}_j$ in an orderly manner, and therefore, different bundles of operating conditions build different production frontiers.

4.1.2.2 Effects of Operating Conditions Are Independent of Scale. This assumption ensures that the scale of the agency and the size of the city produce differentiated effects on productivity. Large agencies can benefit from centralized planning or attract more riders with a more extensive network. On the other hand, large cities have different levels of traffic congestion or downtown employment than small cities. The independence assumption ensures that the effect of operating conditions does not vary with the size of the agency and avoids a special value of $\delta_b(\mathbf{c}_j)$ for each scale of production. The following text traces the consequences of this assumption.

Let the production function be the relation of a single output to a single input in a linear function at constant returns to scale. Let two efficient agencies, j and h, work at the same operating conditions but at different scale of production. Both agencies may express their observed outputs in terms of a production at "base" operating conditions and in terms of the expression (20).

$$\begin{aligned}\tilde{y}_j &= \delta_b^j(\mathbf{c}_j) f(x_j)_b \\ \tilde{y}_h &= \delta_b^h(\mathbf{c}_h) f(x_h)_b\end{aligned} \quad \text{such as } x_j < x_h \text{ and } f(x_j)_b \leq f(x_h)_b \tag{20}$$

If expression (21) holds, the operating conditions at scale h would affect the production more intensely than at scale j.

$$\delta_b^j < \delta_b^h \text{ such as } \quad \delta_b^j, \delta_b^h > 0 \tag{21}$$

If production functions are linear with constant returns to scale, and, if "a" and "b" are technical coefficients relating inputs to outputs, the equations of expression (22) hold for the observed output $\tilde{y}$ and for its equivalent at operating conditions "base" y.

$$\tilde{y} = ax, \quad y = bx \tag{22}$$

Figure 7 shows that, if expression (21) holds, the production function $\tilde{y}$ would not be linear because $(b - a) = \delta_h > \delta_j$ by which "b" or "a" would have to vary with scale and the observed production function would not be linear and there would not be constant returns to scale. The same conclusion holds for all piecewise linear production functions in the case of variable returns to scale to maintain the same linear properties of the production function. Therefore independence of heterogeneous conditions versus scale ensures linear production functions, and that could also be proved for variable returns to scale at the vicinity of the observations.

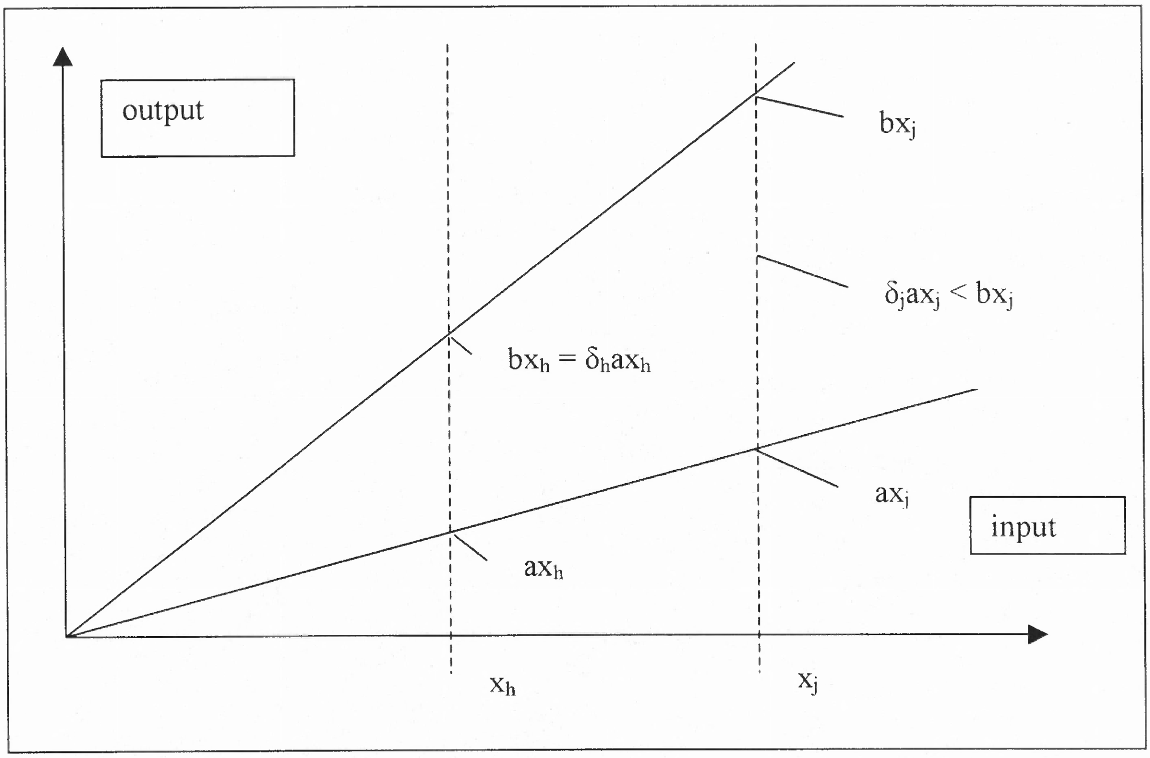

Figure 7 Scale and Operating Conditions

4.1.2.3 Effects of Operating Conditions Are Independent of the Level of Efficiency. The assumption of independence between efficiency and the effects of operating conditions ensures the fairness of the analysis because the evaluated agency does not control operating conditions. Let two agencies operate at the same scale and at the same operating conditions but at different levels of efficiency, j at 100% efficiency and h at θ*100% of efficiency; $0 \le \theta \le 1$. Even though efficiency levels were different the multipliers that convert the outputs to operating conditions "base" are identical $\delta_b^j = \delta_b^h$.

4.2 Formulation of the New Model

4.2.1 Selection of Operating Conditions

Factor analysis is a mutltivariate statistical method whose primary purpose is data reduction and summarization. It addresses the problem of analyzing the interrelationships among a large number of variables and explains these variables in terms of their common underlying dimensions called factors. By using factor analysis the analyst can identify the separate factors being measured by a survey and determine a factor loading for each variable on each factor. All variables are simultaneously considered. Each variable is a linear function of an hypothetical set of factors and each factor is a linear function of the original variables (Karson 1982; Hair, Anderson, Tatham and Black 1987). The selection of operating conditions follows three steps; collecting operating conditions correlated with transit productivity, applying factor analysis, and selecting those conditions that represent factors which are not correlated with other selected operating conditions.

4.2.2 Data Envelopment Analysis Number One—DEA(1)

Model (23) presents the first DEA model relating transit productivity to operating conditions.

$$DEA(1)$$

Primal

$$\max \phi_0$$

subject to:

$$p_{k0}\phi_0 - \sum_{j=1}^{n} p_{kj}\lambda_j \leq 0$$

$$\sum_{j=1}^{n} c_{tj}\lambda_j \leq c_{t0}$$

Dual

$$\min \sum_{t=1}^{q} c_{t0}w_t$$

subject to:

$$\sum_{t=1}^{q} c_{tj}w_t - \sum_{k=1}^{L} p_{kj}u_k \geq 0$$

$$\sum_{k=1}^{L} p_{k0}u_k = 1 \qquad (23)$$

Variables of DEA(1)

In the primal of model (23), j is one of the n agencies that evaluate the agency 0, 0 is the evaluated agency that prior formulations associated to operating conditions “base”. In this model “base” is replaced by the subscript 0 to describe the evaluated agency. k is one of L productivity ratios such as *TRIPS/loper* or

VRM/cars (see Appendix B for variable abbreviations), L is the product of m and s, m being the number of inputs and s the number of outputs, t is one of q operating conditions, and ϕ_0 is the distance function between the observation and the productivity frontier at operating conditions similar to 0, $\phi_0 \geq 1.00$ because the frontier cannot exist below observed productivity. DEA maximizes ϕ_0 because it expresses the radial extension from the observation to the frontier. λ_j is the contribution of j to reproduce the operating conditions and productivity ratios of agency 0 with one linear composite of operating conditions and one of productivity ratios of efficient agencies, respectively. p_{k0}, p_{kj} are the productivity ratios k of agencies 0 and j, respectively, c_{t0}, c_{tj} are the operating condition t of 0 and j, and $p_{k0}\phi_0$ is the productivity benchmark achievable at operating conditions similar to 0. In the dual of model (23), u_k and w_t are the dual prices associated with the slacks of constraints of productivity k and of operating condition t of the primal, respectively.

Constraints of DEA (1)

The set of constraints $\sum_{j=1}^{n} c_{tj}\lambda_j = c_{t0}$ reproduces the operating condition t of agency 0. The constraint $\sum_{k=1}^{L} p_{k0}u_k = 1$ normalizes the productivity of agency 0 to unity. The set of constraints $\sum_{k=1}^{L} p_{kj}u_k - \sum_{t=1}^{q} c_{tj}w_t = 0$ is the binding constraint that builds the frontier plane of operating conditions with productivity benchmarks, and $\sum_{t=1}^{q} c_{t0}w_t$ is the objective function that measures the distance from the productivity of 0 to the productivity benchmark.

Information Provided by DEA (1)

- *Productivity Benchmark, $p_{k0}\phi_0$ in the primal of model (23).* It is the maximum productivity achievable by agency 0 working at operating conditions 0.

- *Distance to the Frontier,* ϕ_0 *in the primal of model (23).* It multiplies the productivity of 0, p_0, to reach the frontier at the operating conditions of agency 0.

- *Productivity Peers, those agencies* j *such as* $\lambda_j > 0$ *in the primal of model (23).* Those agencies j that achieve the maximum productivity at operating conditions similar to 0.

- *Linear Observed Relations Productivity-Operating Conditions,* $\sum_{k=1}^{l} p_{kj}u_k - \sum_{t=1}^{q} c_{tj}w_t = 0$ *from the dual of model (23).* It is the binding constraint that calculates productivity benchmarks at given operating conditions.

- *Transforming Multiplier,* $\delta_j = \dfrac{\phi_0 \tilde{p}_{k0}}{\phi_j \tilde{p}_{kj}}$. It is the ratio between the productivity benchmarks of two agencies working at different operating conditions When the $\tilde{y}_j$ multiplies δ_j it transforms the observed output $\tilde{y}_j$ into the equivalent output y_j produced at operating conditions 0. If $\delta_j > 1$, agency j is working at less advantageous operating conditions than agency 0. If $\delta_j < 1$ then j is working at more advantageous operating conditions than agency 0.

- *Advantage Factor of Operating Conditions,* $\bar{\delta}_0 = \dfrac{\sum_{j=1}^{n} \delta_{j/0}}{n}$. It indicates the advantage of operating conditions of agency 0 relative to the operating conditions of the transit industry. If $\bar{\delta}_0 > 1$, agency 0 is working in more advantageous conditions than the industry. If $\bar{\delta}_0 < 1$, 0 is working at less advantageous conditions than the industry.

Connection Between DEA(1) and DEA(2) by using Transforming Multiplier δ_{ij}

Let one observed output be $\tilde{y}_j = \tilde{y}_j(\mathbf{x}_j, e_j, \mathbf{c}_j)$, where $\mathbf{x}_j$ is the input vector of agency j, e_j is the efficiency level of agency j, and $\mathbf{c}_j$ is the vector of operating conditions of agency j. In expression (24) let the observed output of j be a composite of three parts $(\mathbf{x}_j, e_j, \mathbf{c}_j)$ that are separable and multiplicative. The first component depends on the level of inputs $y_j^{frontier\ of\ j}(\mathbf{x}_j)$, the second depends on the level of efficiency $y_j^{efficiency\ of\ j}(e_j)$, and the third depends on the operating conditions of agency j relative to agency 0 $y_j^{conditions\ of\ j/0}(\mathbf{c}_j)$.

$$\tilde{y}_j = y_j^{frontier\ of\ j}(\mathbf{x}_j) * y_j^{efficiency\ of\ j}(e_j) * y_j^{conditions\ of\ j/0}(\mathbf{c}_j)$$

$$y_j = y_j^{frontier\ of\ j}(\mathbf{x}_j) * y_j^{efficiency\ of\ j}(e_j)$$

$$\delta_j = \frac{1}{y_j^{conditions\ of\ j/0}(\mathbf{c}_j)}$$

$$y_j = \tilde{y}_j \delta_j \qquad (24)$$

4.2.3 Data Envelopment Analysis Number Two—DEA(2)

Model (25) is the primal of model (12) incorporating expression (24). Since the first set of constraints includes the term $y_j^{conditions\ of\ j/0}$ the linear composite of outputs would not reproduce the output of the evaluated agency and therefore the model cannot estimate efficiency properly. Note that $y_0^{conditions\ of\ 0/0}(\mathbf{c}_0) = 1$ and it does not appear in model (25). The objective function θ_0 is the efficiency score of agency 0.

$$\begin{aligned}
&\max \theta_0 \\
&\textit{subject to}: \\
&y_0\theta_0 - \sum_{j=1}^{n} y_j * y_j^{conditions\ of\ j/0}(\mathbf{c}_j)\lambda_j \le 0 \\
&\sum_{j=1}^{n} x_{ij}\lambda_j \le x_{i0} \qquad i = 1,\dots,m\ \textit{inputs} \\
&\sum_{j=1}^{n} \lambda_j = 1 \qquad j = 1,\dots,n\ \textit{agencies} \\
&\textit{one output } y
\end{aligned} \qquad (25)$$

Since model (25) still has the unknown components $y_j, y_j^{conditions\ of\ j/0}(\mathbf{c}_j)$, its first set of constraints can not be used. Instead, model (25) is replaced by model (26) by including δ_j the multiplier that transforms observed outputs of j to equivalent quantities of outputs produced at operating conditions 0.

In other words, the observed outputs of model (25) are replaced with equivalent outputs as if they were produced at operating conditions of agency 0. Model (26) replaces model (25) with a formulation that considers all equivalent outputs at operating conditions of agency 0. One more time, notice that $\delta_0 = 1$ by definition of the transforming multiplier.

$$DEA(2)$$

$$\begin{aligned}
&\max \theta_0 \\
&\textit{subject to}: \\
&\tilde{y}_0\theta_0 - \sum_{j=1}^{n} \tilde{y}_j \delta_j \lambda_j \le 0 \\
&\sum_{j=1}^{n} x_{ij}\lambda_j \le x_{i0} \qquad i = 1,\ldots,m \textit{ inputs} \\
&\sum_{j=1}^{n} \lambda_j = 1 \qquad j = 1,\ldots,n \textit{ agencies} \\
&\textit{one output } y
\end{aligned} \tag{26}$$

The Meaning of Transforming Multiplier δ_j

In expression (24) the multiplier δ_j eliminated the productivity difference between j and 0 caused by heterogeneous conditions. Instead, in equation (27) δ_j is the proportional distance between productivity frontiers at operating conditions 0 and j. In other words, it expresses the difference between the observed output $\tilde{y}$ and its equivalent produced at "base" operating conditions 0. In equation (28) the difference between the equivalent outputs produced at different operating conditions is indeed the difference between productivity ratios caused by heterogeneous conditions.

$$\delta_j = \frac{y_j}{\tilde{y}_j} = \frac{y_j^{\textit{frontier of } j}(\mathbf{x}_j) * y_j^{\textit{efficiency of } j}(e_j)}{y_j^{\textit{frontier of } j}(\mathbf{x}_j) * y_j^{\textit{efficiency of } j}(e_j) * y_j^{\textit{conditions of } j/0}(\mathbf{c}_j)} \tag{27}$$

$$= \frac{y_j^{frontier\ of\ j}(\mathbf{x}_j)}{y_j^{frontier\ of\ j}(\mathbf{x}_j) * y_j^{conditions\ of\ j/0}(\mathbf{c}_j)} = \frac{y_j^{frontier\ of\ j}(\mathbf{x}_j) * y_j^{conditions\ of\ 0/j}(\mathbf{c}_0)}{y_j^{frontier\ of\ j}(\mathbf{x}_j)} =$$

$$= \frac{\dfrac{y_j^{frontier\ of\ 0}(\mathbf{x}_j)}{x_j}}{\dfrac{y_j^{frontier\ of\ j}(\mathbf{x}_j)}{x_j}} = \frac{p_j^{frontier\ of\ 0}}{p_j^{frontier\ of\ j}} \tag{28}$$

In expression (29) the effect of operating conditions does not depend on scale and the optimal productivity is unique at a given bundle of operating conditions. Therefore, the productivity of j at the frontier at operating conditions of agency 0 equals the productivity of 0 at the frontier at the same level of operating conditions.

$$p_j^{frontier\ of\ 0} = p_0^{frontier\ of\ 0} \qquad \textit{uniqueness of DEA}(1)\ \textit{solution} \tag{29}$$

In expression (30) δ_j equals the proportional distance between the frontier projections of productivity, ϕ the objective function of DEA(1) of model (23), and $p^{frontier\ of\ 0}$, $p^{frontier\ of\ j}$ the efficient productivity at operating conditions of agencies 0 and j, respectively.

$$\delta_j = \frac{p_{ij}^{frontier\ of\ 0}}{p_{ij}^{frontier\ of\ j}} = \frac{p_{i0}^{frontier\ of\ 0}}{p_{ij}^{frontier\ of\ j}} = \frac{\phi_0 \tilde{p}_0}{\phi_j \tilde{p}_j} \tag{30}$$

Figure 8 illustrates the concept of equation (30) of a unique difference of productivity ratios between two agencies with independence of scale.

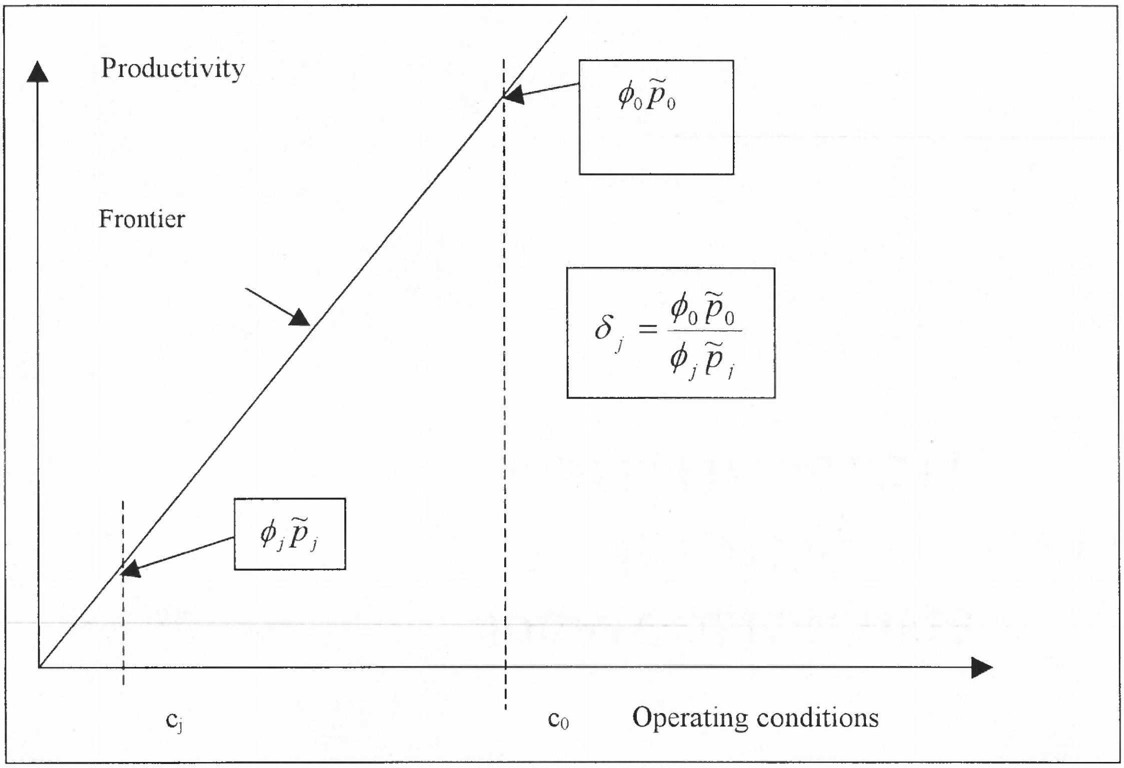

Figure 8 Productivity Frontier versus Operating Condition

4.2.4 The Multiple Factor Industry

Case of Single Output and Multiple Inputs

Let the transforming multiplier δ_j express the productivity differences between the operating conditions of agency j and agency 0. Let be a single output and two inputs 1 and 2. In expression (31) assume that the transforming multiplier δ_j applies for both inputs.

$$\delta_j = \frac{\phi_j \tilde{p}_{1j}}{\phi_0 \tilde{p}_{10}} = \frac{\phi_j \tilde{p}_{2j}}{\phi_0 \tilde{p}_{20}} \tag{31}$$

In expression (32) productivity is expressed in ratios of output to inputs.

$$\delta_j = \frac{\phi_j \dfrac{y_j}{x_{1j}}}{\phi_0 \dfrac{y_0}{x_{01}}} = \frac{\phi_j \dfrac{y_j}{x_{j2}}}{\phi_0 \dfrac{y_0}{x_{02}}} \tag{32}$$

In expression (33) the level of output disappears from the equation.

$$\frac{\frac{1}{x_{j1}}}{\frac{1}{x_{01}}} = \frac{\frac{1}{x_{j2}}}{\frac{1}{x_{02}}} \tag{33}$$

Equation (34) describes the particular case of a unique technique of production for both agencies and therefore, it is a contradiction that δ_j holds for all techniques.

$$\frac{x_{01}}{x_{j1}} = \frac{x_{02}}{x_{j2}} \tag{34}$$

Thus, δ_j would hold only for one input at a time unless δ_j changes to be input-specific δ_{ij} and that it changes place from the output set of constraints to the input set of constraints using the value of its inverse δ_{ij}^{-1} as seen in the adjusted DEA(2) of model (35).

$$\begin{gathered} \textit{Adjusted} \quad DEA(2) \end{gathered}$$

$$\begin{aligned} &\max \theta_0 \\ &\textit{subject to}: \\ &\tilde{y}_0\theta_0 - \sum_{j=1}^{n} \tilde{y}_j\lambda_j \le 0 \quad i = 1,\ldots,m \quad \textit{inputs} \\ &\sum_{j=1}^{n} x_{ij}\delta_{ij}^{-1}\lambda_j \le x_{i0} \quad j = 1,\ldots,n \quad \textit{agencies} \\ &\textit{one} \quad \textit{output} \quad y \end{aligned} \tag{35}$$

Case of Multiple Outputs and Multiple Inputs

Let expression (36) formulate a multiplier δ_{ij} that is common for two outputs, 1 and 2 of agency j, and two bundles of operating conditions, 0 and j.

$$\delta_{ij} = \frac{\phi_j p_{ji1}}{\phi_0 p_{0i1}} = \frac{\phi_j p_{ji2}}{\phi_0 p_{0i2}} \tag{36}$$

Expression (37) presents the productivity as ratios of outputs to inputs

$$\delta_{ij} = \frac{\dfrac{y_{j1}}{x_{ji}}}{\dfrac{y_{01}}{x_{0i}}} = \frac{\dfrac{y_{j2}}{x_{ji}}}{\dfrac{y_{02}}{x_{0i}}} \tag{37}$$

In expression (38), the transforming multiplier δ_{ij} holds for the two outputs only in the particular case of fixed joint production of outputs as in expression (38) and therefore it is a contradiction that δ_{ij} holds for all output bundles. As an approximate alternative, let the transforming multiplier approximate the average of the outputs and bounded to the observed range of productivity ratios, as in expression (39) and expression (40). This dissertation chooses the simple approximation because any alternative for approximation will not fix the inaccuracy of the model in the multiple output case.

$$\frac{y_{j1}}{y_{01}} = \frac{y_{j2}}{y_{02}} \tag{38}$$

Approximate Solution for two outputs

$$\hat{\delta}_{ij} = \frac{1}{2}\left(\frac{\phi_j p_{ji1}}{\phi_0 p_{0i1}} + \frac{\phi_j p_{ji2}}{\phi_0 p_{0i2}}\right) = \frac{1}{2}\frac{\phi_j}{\phi_0}\left(\frac{p_{ji1}}{p_{0i1}} + \frac{p_{ji2}}{p_{0i2}}\right) \tag{39}$$

$$\min_{j=1,\dots,n} \tilde{p}_j \le \hat{\delta}_{i0}\tilde{p}_0 \le \max_{j=1,\dots,n} \tilde{p}_j \tag{40}$$

Detailed Formulation of the New Model

Model (41) presents the new model with the expressions (39) and (40).

NEW MODEL

$$\max \phi_0$$
$$\textit{subject to:}$$
$$\phi_0 \tilde{p}_0 - \sum_{j=1}^{n} \tilde{p}_j \lambda_j \leq 0 \qquad \text{DEA(1)} \qquad (41)$$
$$\sum_{j=1}^{n} c_j \lambda_j \leq c_0$$

$$\delta_{ij} = \frac{\phi_j}{\phi_0} \frac{p_{ji}}{p_{0i}} \qquad \hat{\delta}_{ij} = \frac{\sum \delta_{ij}}{s} \qquad \max \frac{\tilde{y}_{rj}}{x_{ij}} > \frac{y_{r0}}{x_{i0}} > \min \frac{\tilde{y}_{rj}}{x_{ij}}$$

$$\max \theta_0$$
$$\textit{subject to:}$$
$$\tilde{y}_{r0}\theta_0 - \sum_{j} \tilde{y}_{rj} \lambda_j \leq 0 \qquad \text{DEA(2)}$$
$$\sum_{j=1}^{n} \hat{\delta}_{ij}^{-1} x_{ij} \lambda_j \leq x_{i0}$$
$$\sum_{j=1}^{n} \lambda_j = 1$$

Variables of DEA(2)

In model (41), θ_0 is the efficiency score of 0, $\tilde{y}_{r0}, \tilde{y}_{rj}$ are the observed outputs r of 0 and j, and λ_j is the multiplier used to reproduce the inputs of 0 with a linear composite of the inputs of j. x_{i0}, x_{ij} are the observed input i of 0 and j, respectively, and $\hat{\delta}_{ij}^{-1}$ the transforming multiplier that adjusts outputs to their equivalent at operating conditions 0.

The Global Effect of the Transforming Multiplier $\hat{\delta}_{ij}^{-1}$

So far the transforming multiplier $\hat{\delta}_{ij}^{-1}$ has been applied to pairs of individual agencies, the following text traces the global effect of the multiplier $\hat{\delta}_{ij}^{-1}$ on DEA with the matrix formulation of model (42).

$$\begin{aligned} &\min \theta_0 \\ &\textit{subject to}: \\ &\begin{bmatrix} \mathbf{Y} & 0 & -\mathbf{I} & \mathbf{0} \\ -\mathbf{X} & \mathbf{X}_0 & \mathbf{0} & -\mathbf{I} \\ \mathbf{e}^T & 0 & \mathbf{0} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \boldsymbol{\lambda} \\ \theta_0 \\ \mathbf{s}^+ \\ \mathbf{s}^- \end{bmatrix} = \begin{bmatrix} \mathbf{Y}_0 \\ \mathbf{0} \\ 1 \end{bmatrix} \end{aligned} \tag{42}$$

Model (42) simplifies to model (43) where $\mathbf{Q}$ is the production matrix, $\boldsymbol{\lambda}$ the variable vector, and $\mathbf{q}_0^y$ the output vector of agency 0.

$$\begin{aligned} &\min \theta_0 \\ &\textit{subject to}: \\ &\mathbf{Q}\boldsymbol{\lambda} = \mathbf{q}_0^y \end{aligned} \tag{43}$$

Let $\boldsymbol{\lambda}_B$ be the vector of basic variables that excludes those variables whose basic solution is zero. $\mathbf{Q}_B$ is the production matrix formed by the columns of those variables present in the basis of comparison, and $\boldsymbol{\delta}$ the transforming multiplier of DEA(1). $\mathbf{Q}_B = \boldsymbol{\delta}_B \hat{\mathbf{Q}}_B$, and $\mathbf{Q}_B^{-1} = \hat{\mathbf{Q}}_B^{-1} \boldsymbol{\delta}_B^{-1}$. Where $\hat{\mathbf{Q}}_B^{-1}$ is the inverse of the basic matrix, the multiplier matrix of the observed inputs and outputs.

Let $\mathbf{v}_j$ be the comparison weights with those product columns not in the basis, transformed as in the following expression $\mathbf{v}_j = \mathbf{Q}_B^{-1}\mathbf{q}_j$; $\hat{\mathbf{v}}_j = \mathbf{Q}_B^{-1}\boldsymbol{\delta}_B^{-1}\mathbf{q}_j$. The new dual prices are also modified by $\mathbf{u}^T = \mathbf{c}_B^T \mathbf{Q}_B^{-1}$; $\hat{\mathbf{u}}^T = \mathbf{c}_B^T \mathbf{Q}_B^{-1} \boldsymbol{\delta}_B^{-1}$, where $\mathbf{c}_B = (0 \;\; 1_{\theta_0} \; 0)$.

Therefore, the efficiency function of (44) says that $\boldsymbol{\delta}$ is an additional multiplier of the output vector of agency 0. Since intuitively $\boldsymbol{\delta}_{\mathbf{B}}^{-1}$ would make all agencies closer to agency 0 it is expected that there will be a reduction of differences in productivity with a general increase of the estimated efficiency.

$$\theta_0 = \mathbf{c}_B^T \mathbf{Q}_B^{-1} \boldsymbol{\delta}_B^{-1} \mathbf{q}_0^y \tag{44}$$

4.2.5 The Name of the New Model

A special name will facilitate the reference to the new model henceforth. Since the new model applies two sequential DEAs and applies accurately to a single output, the model can be named Two Farrell DEA (2F-DEA) in reference to the single output model developed by Farrell (1957).

4.3 Algorithm of 2F-DEA

1) Let x_i be the input i, y_r the output r, c_t the operating condition t, and p_k the productivity k.

2) Calculate $p_{kj} = \dfrac{y_{rj}}{x_{ij}}$ and select c_{tj} such as correlation $\rho_{p_t c_k} > 0.5$ for all agencies j.

3) Apply factor analysis to reduce the number of operating conditions to the most significant ones.

4) Estimate DEA(1) with model (41), calculate benchmarks $\phi_j \widetilde{p}_{ij}$, repeat [s (outputs) times n (agencies)] times.

5) Calculate transforming multiplier $\delta_{ij}^{-1} = \dfrac{\phi_0 p_{i0}}{\phi_j p_{ij}}$ and calculate $x_{ij}\,\hat{\delta}_{ij}^{-1}$ described in model (41)

6) Bound the results with $\max\limits_j \dfrac{\widetilde{y}_{rj}}{x_{ij}} > \dfrac{y_{r0}}{x_{i0}} > \min\limits_j \dfrac{\widetilde{y}_{rj}}{x_{ij}}$.

7) Estimate DEA(2) with model (41), repeat [n (agencies) times n (agencies)] times.

4.4 Conclusions on the New Model

The new model, 2F-DEA, consists in the application of DEA in two steps with accurate results for single output and approximate results for multiple outputs. The model is the first that links both steps of DEA by using the theory of the firm. The model 2F-DEA requires the additional work of running (s times n) more simplex algorithms than the conventional DEA. Theoretically, the model DEA(2) includes the effect of operating conditions as a separable multiplier that reduces the productivity differences between agencies to those attributed only to productivity efficiency.

CHAPTER 5

THE RESULTS

5.1 Data and Software

5.1.1 National Transit Database

The National Transit Database is the primary source of data for inputs and outputs. It gathers the data of the annual reports submitted by transit agencies to the Federal Transit Administration in compliance with the Section 15 reporting system (US-DOT-FTA 1985-2000; US-DOT- UMTA 1989). This database provides information for the following variables.

Outputs

Annual Vehicle Revenue Miles (000's) (*VRM*) measures the service supplied.

Annual Unlinked Passenger Trips (000's) (*TRIPS*) measures the service utilized.

Inputs

Annual Labor Hours (000's) used in transportation and general administration (*loper)* and in maintenance (*lmain*).

Annual Consumption of Energy (000's Kilowatt Hours) (*ener*) expresses the electricity consumed by the rail system.

Vehicles available for maximum service (*cars*) is the number of revenue vehicles at the maximum season of the year, on the week and day that this maximum occurs, not taken at special event or extreme circumstances. It includes spares, out of service vehicles, and vehicles awaiting maintenance. It does not include vehicles for sale or emergency contingency use. For 1984 the figure is the active fleet.

Track length (miles) (*rails*) is the directional track length.

Stations (*stats)* is the number of stations, considered only for heavy rail.

5.1.2 National Transportation Atlas and Census Tracts Data

A complementary source of data is the National Transportation Atlas. It provides the geographic layout of rail transit as presented in the example of Figure 9 that shows Chicago's heavy rail network (US-DOT-BTS 2000). Appendix A contains the list of modifications made to the Atlas for this dissertation.

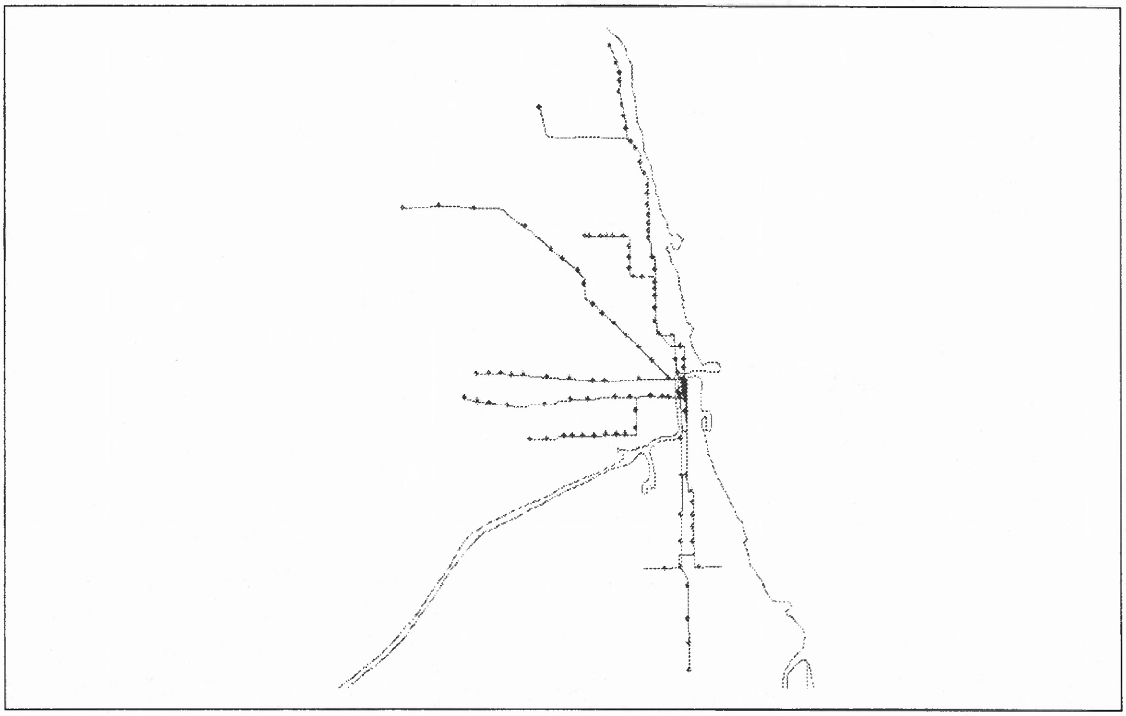

Figure 9 Heavy Rail Network of Chicago-CTA

Operating Conditions of the Urban Form

The operating conditions of the urban form refer to those socioeconomic variables describing the environment at the vicinity of the rail stations. They are calculated by combining of the National Transportation Atlas with the 1990 Census Tract Data within 0.3 miles of the stations, the served area of rail systems. The following is the list of the variables obtained.

Population is the population residing in the served area.

Household income is the average household income in the served area.

Income per capita is the average income per capita in the served area.

Population density is population per square mile of the served area.

Household size is the average household size in the served area.

Household density is the number of households per square mile in the served area.

Vacant houses is the proportion of vacant houses in the served area.

Autos per household is the number of autos divided by the number of households in the served area.

Autos per capita is the number of autos divided by the population residing in the served area.

Rush hour concentration is the proportion of workers leaving for work, using a motorized mode (transit or auto), during rush hour in the served area. One variable corresponds to people going out to work from 6 to 9 a.m. and the other from 8 to 8:30 a.m.

Transit market share is the proportion of people choosing transit to go to work in the served area among those that use motorized modes.

Population employment is the number of employed persons residing in the served area.

Density of employees is the population employment density of the served area.

Minority population is the number of Blacks and Hispanics living in the served area.

Poor population is the number of people below the line of poverty living in the served area.

Operating Conditions of the Network Form

The operating conditions of the network form are those that describe the graphical form of the network and its spatial coverage. They are calculated from the National Transportation Atlas with operations available in the GIS software. The following is the list of the variables related to the network form.

Comprehensive access is the proportion of metropolitan area served by rail.

Density of access is the metropolitan area per access point.

Density of network is the network length per square mile of metropolitan area.

Connectivity index is the observed number of links divided by the maximum possible number of links. It indicates if network is spinal (1/3 to ½), grid (1/2 to 1/3), or delta grid (2/3 to 1).

Density of service is the number of vehicle revenue miles per track mile. It measures frequency and capacity of the network.

Available circuits index measures the redundancy of the system. It is the ratio of the number of circuits in a graph to the maximum possible circuits. It indicates if network form is spinal (0), grid (0 to ½), or delta grid (1/2 to 1).

Network complexity is the ratio links to vertices in the network.

Stop spacing is the average length of the links of the network.

Circuitry index is the ratio of network distance to airline distance among access points.

5.1.3 The State of the Nation's Cities

The State of the Nation's Cities is a database of the Center for Urban Policy Research at Rutgers, the State University of New Jersey (Glickman, Lahr, and Wyly 1998). The collected variables may refer to the metropolitan area (m) or to the center-city (c) and they can be expressed in absolute or in density units. This database provides information for the following variables.

Population is the number of persons residing in the area.

Population employment is the employed population residing in the area.

Jobs is the total number of jobs located in establishments at center city.

Minority population is Black and Hispanic population residing in the area.

5.1.4 Annual Urban Mobility Study

The Urban Mobility Study, published by the Texas Transportation Institute of Texas A&M University System, analyzes the nation's highway transportation system by using data from several sources. The report evaluates travel conditions and operations of the freeway and principal arterial street networks in 68 urbanized areas from 1982 to 1997. The source of data is primarily the Federal Highway Administration's Highway Performance Monitoring System (HPMS) database with supporting information from various state and local agencies (Texas A&M University System 2000). The following is the definition of the congestion index.

Congestion Index is the Travel Rate Index (TRI), that is the average travel time in peak period divided by the travel time in off peak period, in other words, the amount of extra travel time during the peak period compared to free-flow travel. This measure considers days without crashes or vehicle breakdowns calculating delay due to high traffic volumes on freeways and principal arterials.

5.1.5 Absent Connectivity Data

Absent connectivity data refers to those variables that describe the degree of connection of the rail system with other modes and agencies that are not included in this dissertation. Absent connectivity data at rail stations includes the following. (1) Parking spaces, (2) street parking spaces, (3) rail transit connections, (4) bus and shuttle-bus connections, (5) Dial-a-Ride and taxi-cabs, and (6) operating conditions of additional connected zones.

5.1.6 Selection of Data Points

Some data points were not used in the analysis. Some systems did not report some of the variables for a given year, reported them as zero, or recorded unusual productivity levels linked to tourism, opening years, or major renovation years. Table 8 presents the non-selected data points.

Table 8 Non-selected Data Points

Heavy Rail	*Light Rail*
Boston 1984	Boston 1984, 1987 and 1989
PATH 1992	New Orleans 1984 to 1997
Atlanta 1984, 1985, 1993	Newark 1985, 1986, 1987
Los Angeles 1993	San Diego 1986
	Sacramento 1987
	Baltimore 1992
	Denver 1994
	San Jose 1988
	Dallas 1996
	St. Louis 1994
Total Data Points Used 179	*Total Data Points Used 152*

5.1.7 Software, Degrees of Freedom, and Algorithm

Commercial software was developed by researchers in the field of DEA with the following capabilities; maximum number of observations: 200, maximum number of variables: 15, maximum number of cells: 1500. To maintain an adequate degree of freedom, the minimum number of observations for the application of DEA should be higher than the sum of the number of inputs plus the number of outputs (Ali 1990; Golany and Roll 1989). The algorithm consists of the application of the simplex algorithm n times, one per agency. For each simplex, the initial feasible solution is λ_0 = 1.00 and z_0 = 1.00 (Sueyoshi and Chang 1989; Ali 1993; Pitaktong, Brockett, Mote, and Rousseau 1998).

5.2 Results of 2F-DEA

5.2.1 Rail Transit Systems

The application of 2F-DEA involved seventeen light and fourteen heavy rail systems. Table 9 shows that light rails serve 1 million persons at walking-distance, 55 percent of them served by three systems; Boston, San Francisco, and Philadelphia. Light rails produce 258 millions of passenger trips per year, 50 percent of them produced by the aforementioned three systems. Henceforth, the short names of the second column will represent the full names of the agency.

Table 9 Population and Ridership - Light Rail

System	*Short name*	*Population (*) (1990)*	*TRIPS (000's) (1997)*
Boston-MBTA	bos	165,771	67,000
San Francisco-MUNI	sfr	191,753	36,738
Philadelphia-SEPTA	phi	234,999	25,003
Los Angeles-LACMTA	lan	92,621	22,659
San Diego Trolley	sdi	56,002	18,287
St. Louis-Bi-State	slo	13,895	14,486
Portland Tri-County MTD	por	28,722	10,432
Dallas-DART	dal	21,293	7,972
Sacramento-RTD	sac	27,695	7,862
Pittsburgh-PAT	pit	53,592	7,421
Buffalo-Niagara Frontier	buf	20,037	6,919
Baltimore-Maryland MTA	bal	28,949	6,772
Santa Clara County TD	sjo	33,160	6,728
New Orleans Public Svc	nor	40,977	5,605
Cleveland-RTA	cle	33,168	5,337
Denver-RTD	den	10,300	4,428
Newark-NJT	new	32,918	4,294
Hudson-Bergen Light Rail	HB	96,258	31,200
TOTAL (**)		*1,085,132*	*257,940*

(*) Served area within 0.3 miles of a station or a stop. (**) It does not consider Hudson-Bergen

Table 10 presents the population served and annual ridership of heavy rails. They serve 5.3 million persons at walking distance, 84 percent of them served by three systems; New York, Washington, and Chicago. Heavy rails transport 2,429 million passenger trips per year, 79 percent of them transported by the three aforementioned systems. Henceforth, the short names represent the full names of the agencies.

Table 10 Population and Ridership - Heavy Rail

System	*Short name*	*Population(*) (1990)*	*TRIPS (000's) (1997)*
New York-CTA	nyo	3,732,428	1,579,783
Washington-WMTA	was	155,623	198,003
Chicago-CTA	chi	512,234	151,010
Boston-MBTA	bos	168,775	113,715
Atlanta MARTA	atl	37,686	90,991
Philadelphia-SEPTA	phi	247,894	86,245
San Francisco-BART	sfr	112,617	80,490
New York-PATH	path	99,990	67,998
Miami-Dade Cnty TA	mia	41,699	14,020
Baltimore-MTA	bal	41,142	12,600
Los Angeles-LACMTA	lan	52,235	11,628
Lindenwold-PATCO	patco	33,927	10,660
Cleveland-RTA	cle	33,797	7,695
Staten Island Rapid Trans	sta	44,799	4,618
San Juan Heavy Rail	SJ		31,300
TOTAL (**)		*5,314,846*	*2,429,456*

(*) Served area within 0.3 miles of a station.
(**) It does not include San Juan Heavy Rail

5.2.2 Inputs, Outputs, and Operating Conditions

This application considers the following inputs, annual labor hours dedicated to operation and administration in (*loper*) in thousands, annual labor hours dedicated to maintenance in (*lmain*) in thousands, annual kilowatt-hours of electricity in (*ener*) in thousands, number of rail cars (*cars*), track length (*rails*), and number of stations (*stats*). This application considers two measures of outputs, annual vehicle revenue miles in (*VRM*) in thousands, and annual unlinked passenger trips (*TRIPS*) in thousands, they measure the same output from different approaches, *VRM* the capacity offered and *TRIPS* the capacity utilized. The list of inputs and outputs is presented in Table 11.

Table 11 Inputs and Outputs

Factor	*Short name*	*Units*
Outputs		
1 Vehicle revenue miles	*VRM*	Annual vehicle miles (000's)
2 Unlinked passenger trips	*TRIPS*	Annual passenger boarding (000's)
Inputs		
1 Labor in operations	*loper*	Annual labor hours in operation and administration (000's)
2 Labor in maintenance	*lmain*	Annual labor hours in maintenance (000's)
3 Energy	*ener*	Annual kilowatt hours of electricity (000's)
4 Vehicles	*cars*	Number of rail cars
5 Track length	*rails*	Directional track miles
6 Stations (only heavy rail)	*stats*	Number of stations

Light Rail Operating Conditions

The selection of operating conditions consists of correlation analysis, factor analysis, and planning of the estimation of DEA(1). Table 12 shows the correlation of productivity with twenty-one operating conditions with values larger than or equal to 0.5. *VRM* productivity correlates with stop spacing and rush half-an-hour concentration and *TRIPS* productivity correlates with density of service. Note that, contrary to the popular belief that congestion is associated with higher productivity of rail transit, the congestion index is absent.

Table 12 Correlation between Operating Conditions and Productivity (*) - Light Rail

Operating Conditions(**)		*VRM per*				*TRIPS per*		
	loper	*lmain*	*ener*	*cars*	*loper*	*ener*	*cars*	*rails*
1 Access density								.58
2 Network density								.58
3 Comprehensive accessibility			-.51			.51		.53
4 Employment density						.53		.69
5 Housing density						.60		
6 Population density						.58		.65
7 Transit share						.55		.67
8 Employment	-.52							.53
9 Stop spacing	.69	.74		.78				
10 Density of service					.54	.63	.63	.81
11 Employment density (m)			.51					
12 Jobs density			.51					
13 Population (c)			.55					
14 Employment (c)			.56					
15 Population density (c)						.56		
16 Employment density (c)						.59		.52
17 Auto per household					-.54	-.59		
18 Auto per capita						-.52		
19 Income per household			-.52	-.53				
20 Income per capita	-.50		-.54					
21 Rush half-an-hour Concentration	-.66	-.61	-.50	-.63				

(*) Significant correlation is $\rho \geq 0.50$ (**) (m) = metropolitan area, (c) = center city

Table 13 shows the results of factor analysis. Four factors explain 89 percent of the total variance of the twenty-one operating conditions; served area conditions describing environment near the rail stations, metropolitan area conditions describing the general environment of the city, car factor, and income and rush hour concentration. From Tables 12 and 13 served area conditions associate with productivity of *VRM* and *TRIPS*, metropolitan area conditions relate to productivity of *VRM* and *TRIPS* with *ener* and *rails*, car factor correlates with *TRIPS* productivity only, and income and rush hour concentration factor associates with *VRM* productivity only.

Table 13 Factor Analysis of Operating Conditions - Light Rail(*)

Operating conditions(**)	*(1) Served area conditions(***)*	*(2) Metropolitan area conditions)*	*(3) Car factor*	*(4) Income and rush hour concentration*
(89% of variance)	*(34%)*	*(26%)*	*(15%)*	*(13%)*
1 Access density	**.95**	.16		.15
2 Network density	**.95**	.16		.15
3 Comprehensive accessibility	**.90**	.31		.14
4 Employment density	**.78**	.12	.45	.27
5 Housing density	**.77**	.18	.54	.21
6 Population density	**.73**	.32	.52	.13
7 Transit share	**.71**		.63	.19
8 Employment	**.71**	-.15	.47	.27
9 Stop spacing	**-.61**		-.19	-.38
10 Density of service	**.66**	.24		-.28
11 Employment density (m)	.19	**.97**		
12 Jobs density	.24	**.96**		
13 Population (c)		**.95**	.12	-.23
14 Employment (c)		**.95**	.11	-.24
15 Population density (c)	.55	**.75**	.31	.12
16 Employment density (c)	.63	**.69**	.28	.12
17 Auto per household	-.29	-.24	**-.80**	.25
18 Auto per capita	-.13	-.49	**-.72**	.37
19 Income per household	.23		-.28	**.88**
20 Income per capita	.20	-.28		**.87**
21 Rush half-an-hour concentration	.35		.54	**.66**

(*) Shows significance larger or equal than 0.1 (smaller or equal to –0.1)
(**) (m) = metropolitan area, (c) = center city
(***) Served area = within 0.3 miles of stops

Table 14 presents the selected seven operating conditions that are highly correlated with productivity, with one operating condition per factor, and with no correlation between selected operating conditions.

Table 14 Selected Operating Conditions - Light Rail

Selected operating condition	*Output*	*Input*	*Factor*
9 Stop spacing	*VRM*	*loper, lmain, cars*	(1) Served area
13 Population (c)	*VRM*	*ener*	(2) Metropolitan area
20 Income per capita	*VRM*	*ener*	(4) Income and concentration factor
21 Rush half-an-hour concentration	*VRM*	*loper, lmain, cars*	(4) Income and concentration factor
10 Density of service	*TRIPS*	*loper, ener, cars, rails*	(1) Served area
16 Employment density (c)	*TRIPS*	*ener, rails*	(2) Metropolitan area
17 Auto per household	*TRIPS*	*loper, ener*	(3) Auto factor

Table 15 re-orders Table 14 to present the estimation plan for eight DEA(1) models, four of *VRM* productivity and four of *TRIPS* productivity. Note that *VRM* per *rails* and *TRIPS* per *lmain* do not appear to be affected by operating conditions of light rail.

Table 15 Estimation Plan for DEA(1) - Light Rail

Output	*Input*	*Operating condition*	*Short name*
VRM	*loper*	Stop spacing	*Stopsp*
		Rush half-an-hour concentration	*Rushalf*
	lmain	Stop spacing	*Stopsp*
		Rush half-an-hour concentration	*Rushalf*
	ener	Population cc	*PopCC*
		Income per capita	*IncoPC*
	cars	Stop spacing	*Stopsp*
		Rush half-an-hour concentration	*Rushalf*
TRIPS	*loper*	Density of service	*Denserv*
		Autos per households	*AutoPH*
	ener	Density of service	*Denserv*
		Autos per households	*AutoPH*
		Employment density (c)	*EmpCCD*
	cars	Density of service	*Denserv*
	rails	Density of service	*Denserv*
		Employment density (c)	*EmpCCD*

Heavy Rail Operating Conditions

The selection of operating conditions of heavy rail follows the same process followed for light rail. Table 16 shows that productivity correlates with twenty-seven operating conditions with coefficients larger than or equal to 0.5. Productivity of the inputs *rails* and *stats* correlates with several operating conditions, both are the fixed inputs of the rail network. Productivity of *cars* does not correlate with any of the operating conditions, and density of service correlates with several *TRIPS* productivity ratios.

Table 16 Correlation between Operating Conditions and Productivity (*) - Heavy Rail

Operating conditions(**)	*VRM per*			*TRIPS per*				
	loper	*rails*	*stats*	*loper*	*lmain*	*ener*	*rails*	*stats*
1 Jobs Density (c)		.53						
2 Employment (c)		.53						
3 Employment density (m)		.53						
4 Population (c)		.52						
5 Employment density (c)		.55					.52	
6 Population (m)		.53					.52	
7 Jobs		.55					.54	
8 Employment (m)		.52					.52	
9 Transit share		.83	.51				.81	.76
10 Population		.77					.69	
11 Employment		.78					.69	
12 Density of network		.76					.73	
13 Density of service				.54	.50	.60	.88	.77
14 Population density		.88					.82	.58
15 Comprehensive accessibility		.63					.68	
16 Housing density		.88					.82	.68
17 Employment density		.89					.83	.71
18 Household size			-.56					-.64
19 Rush half-an-hour Concentration		.65		.63		.51	.65	.67
20 Income per capita								.68
21 Network complexity		.76	.76	.50		.52	.65	.80
22 Connectivity index			.52					.59
23 Auto per capita		-.65					-.65	
24 Auto per household		-.72					-.70	-.63
25 Circuit availability		.61	.74				.53	.81
26 Density of access	.59							
27 Stop spacing	.61		.50					

(*) Significant correlation is $\rho \geq 0.50$

(**) (m) = metropolitan area, (c) = central city

Table 17 shows the results of factor analysis. Five factors explain 94 percent of the total variance of operating conditions; metropolitan area conditions, served area conditions, income and rush hour concentration, car factor, and stop spacing. From Tables 15 and 16, metropolitan area conditions associate with *rails* productivity while the served area conditions relate with *rails* and *stats* productivity, although density of service associates also with other *TRIPS* productivity. Income and rush hour concentration correlates with productivity of both outputs and several inputs, car factor relates with *rails* and *stats* productivity, and stop spacing factor associates with *VRM* productivity.

Table 17 Factor Analysis of Operating Conditions - Heavy Rail

Operating conditions(*)	*(1) Metropolitan area*	*(2) Served area (**)*	*(3) Income and rush hour concentration*	*(4) Car factor*	*(5) Stop spacing*
(94% of variance)	*(30%)*	*(24%)*	*(15%)*	*(13%)*	*(11%)*
1 Jobs Density (c)	**.91**	.29		.18	
2 Employment (c)	**.91**	.28		.21	.15
3 Employment density (m)	**.91**	.30		.19	
4 Population (c)	**.91**	.28		.20	.15
5 Employment density (c)	**.85**	.30	.21	.13	.11
6 Population (m)	**.79**	.22	.26	.12	.42
7 Jobs	**.77**	.21	.33		.39
8 Employment (m)	**.73**	.20	.32		.44
9 Transit share	**.56**	.43	.47	.45	.17
10 Population	.25	**.95**			.13
11 Employment	.26	**.95**			.13
12 Density of network	.32	**.82**		.12	.37
13 Density of service	.29	**.78**	.42	.26	
14 Population density	.43	**.76**	.18	.41	.17
15 Comprehensive accessibility	.34	**.73**	-.14	.10	.52
16 Housing density	.45	**.63**	.32	.52	.14
17 Employment density	.50	**.60**	.34	.50	.12
18 Household size			**-.91**	-.27	.13
19 Rush half-an-hour concentration	.14	.33	**.87**		.13
20 Income per capita	.45	-.12	**.83**	.19	
21 Network complexity	.37	.31	**.56**	.27	-.27
22 Connectivity index	.38	-.21	.26	**.80**	-.19
23 Auto per capita	-.14	-.51		**-.79**	-.24
24 Auto per household		-.47	-.40	**-.73**	-.18
25 Circuit availability	.44		.49	**.62**	-.28
26Density of access	-.22	-.20			**-.88**
27 Stop spacing	-.25	-.26			**-.87**

(*) (m) = metropolitan area, (c) = center city.
(**) Served area is within 0.3 miles of stations

Table 18 selects four operating conditions using three criteria; (1) highest correlation index, (2) one operating condition per factor, and (3) no correlation between selected operating conditions. Since the operating conditions of factor (1) correlated with factor (2), none of factor (1) was selected.

Table 18 Selected Operating Conditions - Heavy Rail

Operating condition	*Output*	*Input*	*Dimension*
27 Stop spacing	*VRM*	*loper, stats*	(5) Stop spacing
17 Employment density	*VRM*	*rails*	(2) Served area
21 Network complexity	*VRM*	*stats*	(3) Income and concentration factor
13 Density of service	*TRIPS*	*loper, lmain, ener, rails, stats*	(2) Served area

Table 19 presents the plan to estimate eight DEA(1) models for heavy rail, three with *VRM* and five with *TRIPS* productivity. Density of service is the surrogate of operating conditions related to all *TRIPS* productivity ratios. Note that the productivity of cars is not present and it may indicate that the observation of Demery (1994) that vehicle loading varies with socioeconomic conditions is not detected by the considered operating conditions.

Table 19 Estimation Plan for DEA(1) - Heavy Rail

Output	*Intput*	*Operating condition*	*Short name*
VRM	*loper*	Stop spacing	*Stopsp*
	rails	Employment Density	*EmpDen*
	stats	Network Complexity Stop spacing	*NetCom* *Stopsp*
TRIPS	*loper*	Density of service	*Denserv*
	lmain	Density of service	*Denserv*
	ener	Density of service	*Denserv*
	rails	Density of service	*Denserv*
	stats	Density of service	*Denserv*

5.2.3 Results of DEA(1)

Light Rail Productivity Benchmarks

Productivity benchmarks are the projections of the frontier estimated in DEA(1) after the application of the plan of Table 19. Table 20 shows that Boston can produce 8.3 *VRM/loper,* Philadelphia 6.6, and Los Angeles 28.5. *VRM* productivity benchmarks are lower for Boston, San Francisco, and Philadelphia; but higher for San Diego and Los Angeles.

Table 20 Productivity Benchmarks for *VRM*– 1997 - Light Rail

VRM per	*Loper*	*lmain*	*ener*	*cars*
Condition	*(Stopsp & Rushalf)*	*(Stopsp & Rushalf)*	*(PopCC & IncoPC)*	*(Stopsp & Rushalf)*
bos	8.3	6.9	0.14	32.1
sfr	7.1	6.7	0.15	28.0
phi	6.6	8.2	0.21	26.3
lan	28.5	27.0	0.25	88.8
sdi	28.5	27.0	0.21	88.8
slo	22.3	24.3	0.15	83.9
por	24.1	16.3	0.19	60.3
dal	24.2	24.8	0.21	84.8
sac	26.5	19.7	0.19	68.2
pit	13.2	11.1	0.15	36.4
buf	15.4	12.7	0.10	48.5
bal	15.4	15.8	0.17	66.1
sjo	24.9	18.8	0.17	64.1
cle	13.7	12.4	0.07	48.1
den	21.7	14.9	0.20	49.2
new	22.3	13.7	0.28	50.1
VRM per ...	*Labor hour*	*Labor hour*	*Kw-h*	*000's per car*

Table 21 shows the productivity benchmarks in *TRIPS*. This time Boston, San Francisco, Philadelphia, and Newark have higher benchmarks than Los Angeles or San Diego. Productivity benchmarks have similar extreme differences in *TRIPS* productivity as in *VRM* productivity suggesting that operating conditions have a balanced incidence on *VRM* and *TRIPS*.

Table 21 Productivity Benchmarks for *TRIPS* – 1997 - Light Rail

TRIPS per	*loper*	*ener*	*cars*	*rails*
Condition	*(Denserv & AutoPH)*	*(Denserv, AutoPH & EmpCCD)*	*(Denserv)*	*(Denserv & EmpCCD)*
bos	88.6	2.8	520.9	1915
sfr	75.6	1.7	461.3	1145
phi	83.5	1.5	398.8	675
lan	70.1	1.2	420.1	772
sdi	68.3	1.0	442.7	686
slo	77.5	1.4	471.3	839
por	72.9	1.1	409.8	575
dal	64.0	0.5	391.9	472
sac	70.7	1.2	412.2	653
pit	69.4	1.1	402.8	606
buf	80.7	1.8	461.8	1045
bal	77.5	1.5	420.8	785
sjo	35.8	0.4	403.2	611
cle	66.0	1.0	378.8	424
den	88.6	0.9	422.5	425
new	88.6	2.2	476.7	1290
TRIPS per...	*Labor hour*	*Kw-h*	*000's per car*	*000's per mile*

First Observation of DEA(1) for Multiple Outputs

This observation confirms the adequacy of estimating individual productivity ratios rather than estimating a group of productivity ratios in DEA(1). If DEA(1) includes all operating conditions in one model, some of them would associate with productivity ratios that they do not affect. Figure 10 illustrates this observation by showing the values of productivity benchmark *VRM/loper* found in three different estimations. The lowest curve corresponds to the estimate of *VRM/loper* when DEA(1) includes eight productivity benchmarks (four *VRM* productivity ratios and four *TRIPS* productivity ratios of Table 15), the intermediate curve is the result of DEA(1) when it includes two productivity benchmarks (*VRM/loper* and *TRIPS/loper*), and the highest curve is the productivity ratio *VRM/loper* when DEA(1) includes only that ratio. Since the plateaus of productivity of the highest curve have more stable values corresponding to relevant operating conditions and since the other curves show variability unrelated to the value of operating conditions, the highest curve renders more realistic results. The corollary of a single productivity estimation of DEA(1) is that benchmarks apply for single-output to single-input relations but the agency may not necessarily reach all benchmarks simultaneously.

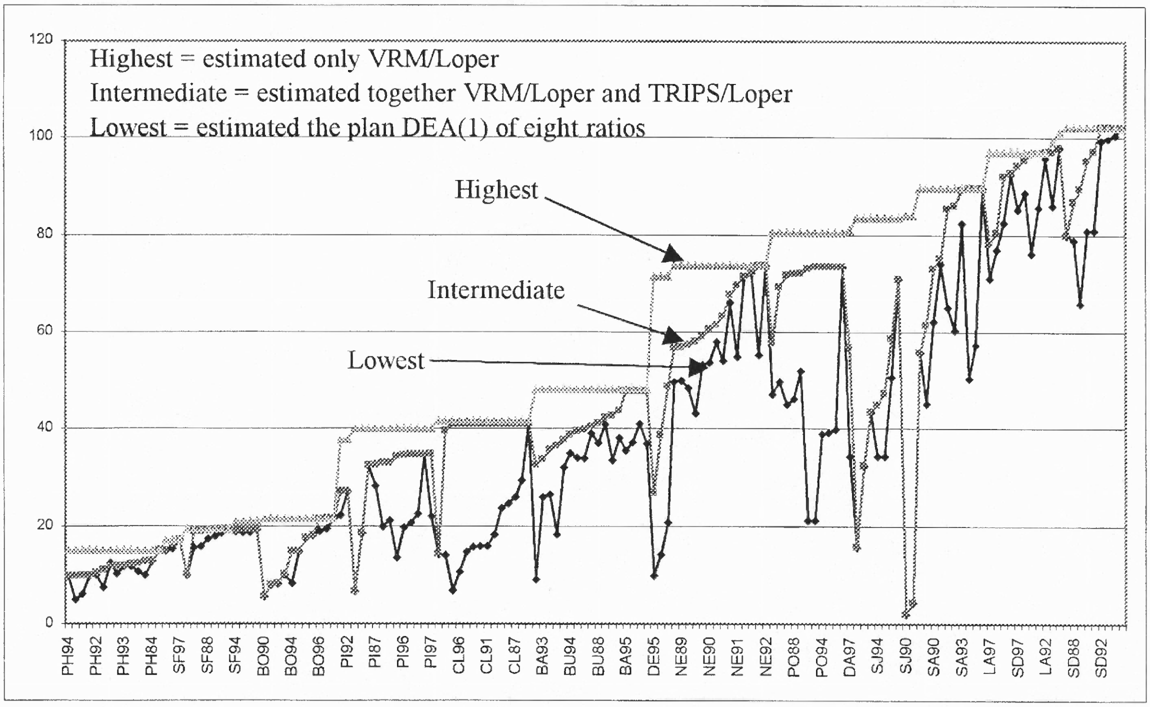

Figure 10 Ascending Profile of Benchmarks by DEA(1) - *VRM/loper* (maximum=100%) - Light Rail

Light Rail Advantage Factor

The advantage factor indicates the higher (or lower) proportion of productivity achievable at the operating conditions of the agency with respect to the average of the industry. Table 22 shows the advantage factor of the evaluated light rail $\bar{\delta}_{i0}$, the average of the transforming multipliers of DEA(1) $\bar{\delta}_{i0} = \frac{\sum_{j=1}^{n} \delta_{ij/0}}{n}$. The factor $\bar{\delta}_{i0}$ indicates how advantageous are the operating conditions of 0 to produce high productivity. If the index is greater than 1.00, like $\bar{\delta}_{Loper\ Sacramento}$ = 1.20, the operating conditions allow 20 percent higher productivity of *loper* in Sacramento. If the index is less than 1.00, say $\bar{\delta}_{Ener\ Buffalo}$ = 0.97 operating conditions allow 3 percent below average of productivity of *ener* in Buffalo.

Boston, San Francisco, and Philadelphia have operating conditions with lower advantage factors in the productivity of *loper*, *lmain* and *cars* although they have a better potential for *ener* and *rails*. Two systems, Pittsburgh and Cleveland have all advantage factors below 1.00 indicating low advantage in all inputs. On the other hand, four systems have all advantage factors greater than one, so that they have high advantage in all inputs; Los Angeles, St. Louis, Baltimore, and Newark. The advantage factor summarizes the effect of operating conditions on productivity.

Table 22 Advantage Factor of Operating Conditions - Light Rail

Agency	*loper*	*lmain*	*ener*	*cars*	*rails*
bos	*0.69*	*0.61*	1.03	*0.78*	1.07
sfr	*0.61*	*0.65*	1.15	*0.83*	1.37
phi	*0.53*	*0.71*	1.22	*0.65*	*0.92*
lan	1.36	1.37	1.42	1.38	1.15
sdi	1.34	1.39	1.05	1.38	*0.93*
slo	1.27	1.32	1.07	1.42	1.14
por	1.25	1.12	1.04	1.11	*0.90*
dal	1.14	1.33	*0.45*	1.26	*0.84*
sac	1.20	1.22	*0.95*	1.16	*0.80*
pit	*0.85*	*0.90*	*0.83*	*0.83*	*0.91*
buf	1.08	*0.98*	*0.97*	1.07	1.22
bal	1.02	1.10	1.08	1.17	1.01
sjo	*0.48*	1.20	*0.35*	*0.90*	*0.72*
cle	*0.88*	*0.97*	*0.60*	*0.96*	*0.80*
den	1.37	1.07	*0.98*	1.00	*0.75*
new	1.39	1.03	1.87	1.11	1.31

Second Observation for Multiple Outputs

The second observation refers to the inaccuracy tolerated by the transforming multipliers $\hat{\delta}_{ij}$ in the case of multiple outputs. The value of $\hat{\delta}_{ij}$ holds for two outputs and therefore DEA(1) estimates two multipliers per input, $\delta_{ij\,VRM}, \delta_{ij\,TRIPS}$, described by the average of two productivity-ratios $\hat{\delta}_{ij} = \frac{\delta_{ij\,VRM} + \delta_{ij\,TRIPS}}{2}$. A weighted average or a ratio of *TRIPS* per *VRM*, would not improve the approximation. Consequently, $\hat{\delta}_{ij}$ is an approximation with three possibilities; (1) both partial deltas are either greater than one or both are smaller than one, (2) one is greater than one and the other is smaller than one, or (3) both are near one. Figure 11 shows that the transforming multiplier $\hat{\delta}_{ij}$ conceals different effects for each output.

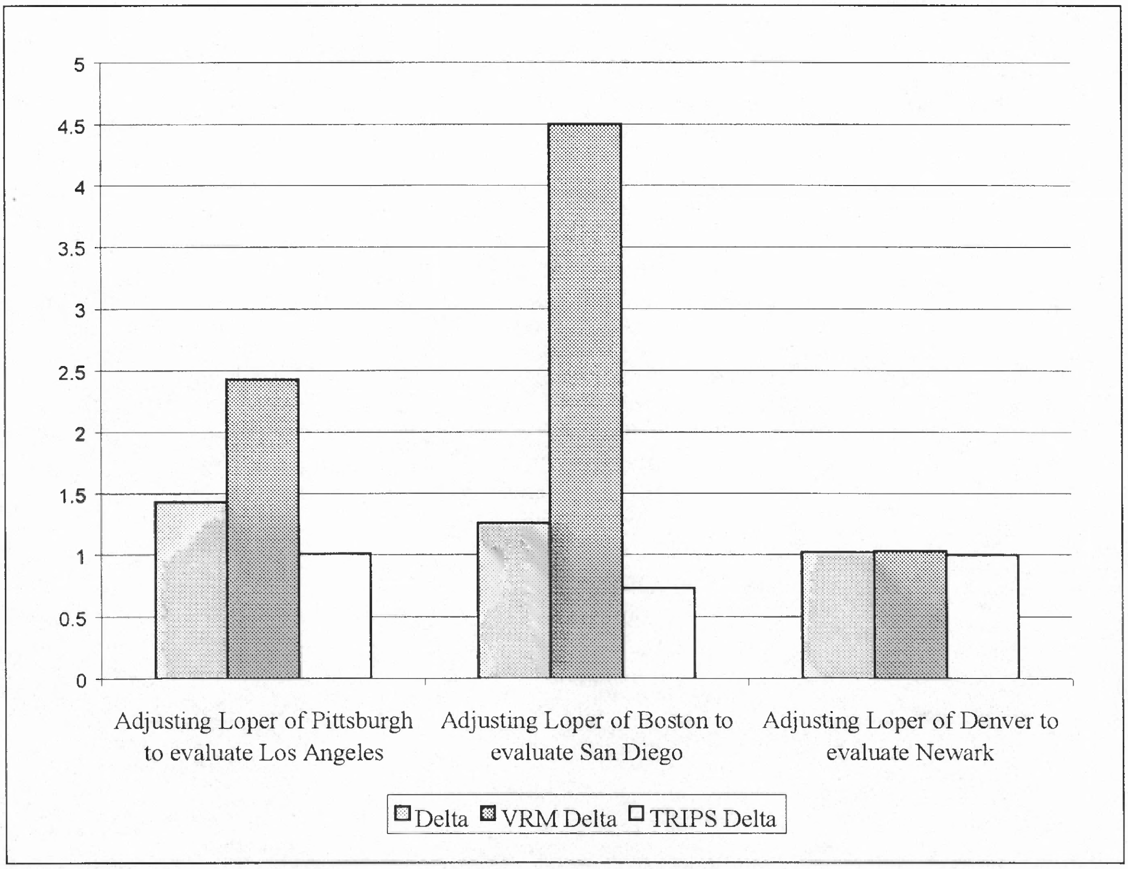

Figure 11 Consequences of the Approximation of δ_{ij} in the Multiple Output Case - Light Rail

Heavy Rail Productivity Benchmarks

Productivity benchmarks determine the upper limits of productivity achievable at the operating conditions of individual agencies. For example, Table 23 shows that Philadelphia can produce 13.7 *VRM/loper* that is only 72 percent of the benchmark of San Francisco, 18.9 *VRM/loper*. San Francisco and PATCO are better suited for high *VRM* productivity than New York and Philadelphia. In terms of *VRM/loper*, the highest benchmarks correspond to BART and PATCO, in *VRM/rails* the highest benchmarks correspond to New York and PATH, while in *VRM/stats* the highest benchmarks correspond to San Francisco and PATH. The lowest benchmarks correspond to Philadelphia and Staten Island.

Table 23 Productivity Benchmarks for *VRM* - 1997 - Heavy Rail

VRM per	*loper*	*rails*	*stats*
Condition	*(Stopsp)*	*(EmpDens)*	*(Stopsp & NetCom)*
nyo	12.9	638	673
was	17.2	350	862
chi	15.9	402	752
bos	16.0	390	661
atl	16.9	299	895
phi	13.7	373	227
sfr	18.9	359	1264
path	16.7	611	1023
mia	17.0	320	676
bal	17.0	342	621
lan	16.1	476	319
patco	18.6	371	636
cle	17.0	311	665
sta	15.9	333	502
VRM per ...	*Labor hour*	*000's per mile*	*000's per station*

Table 24 shows the *TRIPS* productivity benchmarks for heavy rail. They are lower for both Cleveland and Staten Island while higher for both New York and PATH.

Table 24 Productivity Benchmarks for *TRIPS* - 1997 - Heavy Rail

TRIPS per Condition	*loper (Denserv)*	*lmain (Denserv)*	*ener (Denserv)*	*rails (Denserv)*	*stats (Denserv)*
nyo	47.7	107.1	1.27	3421	5440
was	43.1	101.0	1.06	2047	3228
chi	46.1	106.2	1.16	2267	3714
bos	46.8	107.1	1.26	2477	4177
atl	46.8	107.1	1.24	2429	4071
phi	42.6	100.4	1.05	2024	3176
sfr	46.7	106.8	1.20	2357	3912
path	47.2	107.1	1.27	2892	5440
mia	33.7	73.5	0.81	1580	2195
bal	35.6	80.2	0.86	1675	2406
lan	38.9	91.8	0.95	1839	2767
patco	35.1	78.4	0.84	1650	2350
cle	19.0	42.0	0.35	400	638
sta	23.0	50.0	0.55	1049	1306
TRIPS per...	*Labor hour*	*Labor hour*	*Kw-h*	*000's per mile*	*000's per station*

Heavy Rail Advantage Factor

The advantage factor summarizes the effect of operating conditions on productivity benchmarks. Table 25 shows that some factors are larger than one (higher productivity) and some smaller than one (lower productivity). Four systems have all advantage factors smaller than one, Miami, Baltimore, Cleveland, and Staten Island. Five systems have all advantage factors larger than one, Washington, Chicago, Boston, San Francisco, and PATH. The application of DEA(2) finds efficiency levels by taking into account the individual differences in operating conditions.

Table 25 Advantage Factor of Operating Conditions - Heavy Rail

Agency	*loper*	*lmain*	*ener*	*rails*	*stats*
nyo	*0.90*	1.14	1.19	1.94	1.43
was	1.17	1.11	1.11	1.08	1.35
chi	1.07	1.13	1.16	1.24	1.24
bos	1.07	1.13	1.16	1.20	1.25
atl	1.17	1.12	1.12	*0.97*	1.33
phi	*0.97*	1.10	1.09	1.10	*0.46*
sfr	1.28	1.13	1.15	1.15	1.82
path	1.18	1.14	1.19	1.74	1.91
mia	*0.94*	*0.89*	*0.90*	*0.86*	*0.90*
bal	*0.98*	*0.94*	*0.94*	*0.93*	*0.88*
lan	*0.85*	*0.89*	*0.89*	1.03	*0.39*
patco	1.02	*0.97*	*0.97*	*0.99*	*0.95*
cle	*0.56*	*0.55*	*0.41*	*0.30*	*0.32*
sta	*0.65*	*0.71*	*0.67*	*0.69*	*0.56*

5.2.4 Results of DEA(2)

Light Rail Efficiency

The model DEA(2) adjusts the value of inputs to calculate scores of overall, technical, and scale efficiency. Table 26 shows that San Francisco and St. Louis are overall efficient. The least efficient agencies are Los Angeles, Sacramento, Pittsburgh, and Cleveland with less than 80 percent efficiency. Most of the inefficiency of Los Angeles is scale inefficiency. Most of the inefficiency of Sacramento, Pittsburgh, and Cleveland is technical inefficiency. Light rail is 88.7 percent overall efficient, and it reaches 95.4 percent of the possible scale efficiency and 93.2 percent of the technical efficiency. In general, the results show mild levels of inefficiency equally balanced between scale and technical.

Table 26 Efficiency Level - 1997 - Light Rail

Agency	*Efficiency (%)*		
	Overall	*Scale*	*Technical*
bos	99.6	99.6	100.0
sfr	100.0	100.0	100.0
phi	94.3	99.1	95.2
lan	78.1	78.9	99.0
sdi	93.5	93.5	100.0
slo	100.0	100.0	100.0
por	93.5	100.0	93.5
dal	89.3	96.4	92.6
sac	75.2	99.2	75.8
pit	70.9	96.5	73.5
buf	90.9	93.6	97.1
bal	86.2	96.6	89.3
sjo	90.1	93.7	96.2
cle	79.4	100.0	79.4
den	90.9	90.9	100.0
new	87.7	88.6	99.0
Average	*88.7*	*95.4*	*93.2*

Heavy Rail Efficiency

The levels of efficiency are similar in the case of heavy rail. Table 27 shows that the most efficient agencies are New York, Atlanta, San Francisco, and PATH. The least efficient agencies are Washington (88.5 percent), Chicago (75.8 percent), Los Angeles (88.5 percent), and Staten Island (84 percent). The inefficiency of Los Angeles and Staten Island is mostly scale inefficiency, while the inefficiency of Philadelphia, Boston, Washington, and Miami is mostly technical inefficiency. Heavy rail is 92.4 percent overall efficient and it reaches 94.8 percent of the possible scale efficiency, and 97.5 percent of the technical efficiency. Levels of inefficiency are mild and similarly distributed between technical and scale.

Table 27 Efficiency Level - 1997 - Heavy Rail

Agency	*Efficiency (%)*		
	Overall	*Scale*	*Technical*
nyo	100.0	100.0	100.0
was	88.5	97.3	90.9
chi	75.8	81.1	93.5
bos	89.3	99.1	90.1
atl	100.0	100.0	100.0
phi	92.6	100.0	92.6
sfr	100.0	100.0	100.0
path	100.0	100.0	100.0
mia	98.0	100.0	98.0
bal	90.1	90.1	100.0
lan	88.5	88.5	100.0
patco	92.6	92.6	100.0
cle	94.3	94.3	100.0
sta	84.0	84.0	100.0
Average	*92.4*	*94.8*	*97.5*

5.2.5 Efficiency in Absolute Figures

Efficiency in absolute terms indicates the dollar amount in improvement achievable in the hypothetical case of total efficiency. Table 28 summarizes the potential for improvement in higher revenues and in its equivalent in savings of resources. At 55 cents per trip, as the average revenue published in (APTA 2001), light rail can improve efficiency by $ 2 million of revenue per year, mostly in Los Angeles, Sacramento, and Pittsburgh. From the resources point of view the potential improvement is equivalent to 585 thousand labor hours in operations and administration, 89 vehicles, and 70 track miles, totaling $ 55 million per year. Of the $55 million only $ 14 millions correspond to expenses per year while the rest is annual capital cost, sometimes considered as sunk cost.

Table 28 Potential for Improvement - Light Rail

Agency	*Revenue ($ 1M)*	*loper*	*cars*	*rails*	*Cost ($ 1M)*
bos	0.012	4	1		0.160
sfr					
phi	0.096	36	8	4	3.380
lan	0.534	205	15	18	15.025
sdi	0.181	22	6	3	2.410
slo					0
por	0.056	18	2	2	1.570
dal	0.105	25	4	4	2.865
sac	0.253	43	9	9	6.115
pit	0.275	86	17	11	8.670
buf	0.045	10	2	1	0.870
bal	0.174	40	5	6	4.300
sjo	0.103	26	5	4	2.950
cle	0.134	52	10	6	4.900
den	0.032	10	2	1	0.870
new	0.044	8	3	1	0.880
Total	*2.045*	*585*	*89*	*70*	*54.965*

Prices / Unit Cost	
Output	
TRIPS	*$ 0.55 per trip*
Input	
loper	*$ 50,000 per person-year*
lmain	*$ 50,000 per person-year*
ener	*$ 63.70 per thousand of KW-h*
cars	*$ 1.5 M per car*
rails	*$ 20 M per track mile*

Sources of Prices / Unit Cost: (APTA 2001; CUTA 1993, Vuchic 1981)

Table 29 presents the potential for improvement for heavy rails. Revenues could improve in $ 79 million per year at an average fare of 96 cents per trip, as published by (APTA 2001), mostly by Washington, Chicago, and Boston. From the resources point of view the inefficiency level of heavy rail is equivalent to 2,161 thousands of labor hours in operations and administration, 474 vehicles, 99 track miles, and 63 stations, summarized in $ 189 million per year. A total of $ 54 million correspond to annual expenses while the rest is usually considered sunk cost.

Table 29 Potential for Improvement - Heavy Rail

Agency	*Revenue ($ 1M)*	*loper*	*cars*	*rails*	*stats*	*Cost ($ 1M)*
nyo						
was	21.859	428	88	21	9	38.105
chi	35.083	1192	278	50	34	100.730
bos	11.681	238	44	8	6	17.340
atl						
phi	6.127	126	26	6	6	11.460
sfr						
path						
mia	0.269	7	3	1	1	1.355
bal	1.197	41	10	3	1	4.750
lan	1.284	37	3	1	1	2.230
patco	0.757	23	9	2	1	3.240
cle	0.421	22	3	2	1	2.855
sta	0.709	47	10	5	4	7.275
Total	*79.388*	*2,161*	*474*	*99*	*63*	*189.340*
			Price / Unit Cost			
Output						
TRIPS						*$ 0.96 per trip*
Input						
loper						*$ 50,000 per person-year*
lmain						*$ 50,000 per person-year*
ener						*$ 63.70 per thousand of KW-h*
cars						*$ 1.5 M per car*
rails						*$ 40 M per track mile*
stat						*$ 5 M per station*

Sources for Price / Unit Cost: (APTA 2001; CUTA 1993, Vuchic 1981)

5.3 Comparison of 2F-DEA to Other Methods

5.3.1 Accuracy of Cluster Analysis

Clusters of Rail Transit

Cluster analysis is currently used to compare transit productivity in heterogeneous conditions because it reduces the bias in favor of the agencies working at more advantageous conditions. Cluster analysis can be adequate at given levels of accuracy and therefore the levels of accuracy should be presented to the reader during the application of 2F-DEA. This dissertation uses cluster analysis with a hierarchical algorithm to build four groups based on similarities and differences in operating conditions affecting productivity. Table 30 shows that cluster 2, Southern Californian systems, and cluster 4, Newark, are so small that they do not support standard statistical analyses within the clusters. Accuracy should be calculated as the difference due to operating conditions within clusters 1 and 3.

Table 30 Typology of Light Rail

Cluster	*1*	*2*	*3*	*4*
Stop spacing (miles)	0.24	0.99	0.54	0.41
Rush concentration (%)	17	8	13	13
Income per capita ($)	16,700	9,400	15,600	9,500
Car ownership (per household)	0.9	1.2	1.2	0.7
Density of service (000' VRM per track mile)	121	115	92	151
Employment density (workers per square mile)	5,900	2,300	2,400	10,200
Members	bos, sfr, phi, den	lan, sdi	slo, por, dal, sac, pit, hub, cle	new
Observations	41	20	80	11

Table 31 presents the typology of heavy rail transit. The tests of empirical accuracy consist of the estimation of productivity differences due to operating conditions within clusters 2 and 3.

Table 31 Typology of Heavy Rail

Cluster	*1*	*2*	*3*	*4*
Stop spacing (miles)	0.7	1.0	0.8	2.0
Density of service (000' VRM per track mile)	1040	210	480	530
Employment density (workers per square mile)	20,300	4,100	5,500	5,400
Members	nyo, path	sta, cle, patco, lan, bal, mia	bos, phi, chi, atl, was	sfr
Observations	27	73	65	14

Test of Clustering in Partial Productivity Analysis

Table 32 shows that stop spacing and density of service have statistically significant correlation with productivity within the cluster.

Table 32 Trends of Productivity versus Operating Conditions within Selected Clusters

Mode	*Cluster*	*Productivity*	*Operating condition*	*Trend*	*(t-statistics)*
Light rail	*1*	*VRM/loper*	Stop spacing	2.9	(1.9, 94%)
Light rail	*3*	*VRM/loper*	Stop spacing	6.7	(5.2, 99%)
Light rail	*3*	*TRIPS/loper*	Density of service	0.45	(10.5, 99%)
Heavy rail	2	*VRM/loper*	Stop spacing	9.1	(4.7, 99%)
Heavy rail	3	*VRM/loper*	Stop spacing	5.3	(6.5, 99%)
Heavy rail	2	*TRIPS/rails*	Density of service	1.6	(4.9, 99%)

Table 33 shows that operating conditions caused a productivity difference of 5 to 36 percent of inaccuracy to be accepted by the user of cluster analysis.

Table 33 Productivity Difference due to Operating Conditions within Selected Clusters

Sample	Cluster	*Operating condition difference (z)*	*Rate of change (a)*	*Maximum productivity difference ($p_z = a*z$)*	*Maximum (best) productivity (p)*	*Productivity difference owed to "z" ($T = p_z/(2*p)$)*
Light rail	1	Stop spacing 0.19	2.9	*VRM/loper* 0.54	5.72	5 %
Light rail	3	Stop spacing 0.84	6.7	*VRM/loper* 5.64	15.51	18 %
Light rail	3	Density of service 118	0.45	*TRIPS/loper* 53	73	36 %
Heavy rail	2	Stop spacing 0.50	9.1	*VRM/loper* 4.53	16.53	14 %
Heavy rail	3	Stop spacing 0.68	5.3	*VRM/loper* 3.59	14.68	12 %
Heavy rail	2	Density of service 254	1.6	*TRIPS/rails* 460	1278	18 %

Test of Clustering in Data Envelopment Analysis (DEA)

DEA was estimated at the interior of clusters 1 and 3 of light rail and clusters 2 and 3 of heavy rail using the outputs *VRM* and *TRIPS* and the inputs *loper, lmain, ener, cars, rails,* and *stats*. Table 34 shows that efficiency scores are correlated with operating conditions in both modes, light rail and heavy rail.

Table 34 Correlation of DEA Efficiency Score versus Operating Conditions within Selected Clusters

Sample	*Cluster*	*Operating condition*	*Correlation with Efficiency score(*)*
Light rail	*1*	Stop spacing	-0.51
		Density of service	-0.51
Light rail	*3*	(Income per capita)$^{-1}$	-0.75
		Density of service	-0.62
Heavy rail	*2*	Density of service	-0.60
Heavy rail	*3*	Density of service	-0.58
		Stop spacing	-0.56

(*) signs are correct, the larger the DEA score the larger the augmentation of outputs necessary to be efficient

Table 35 shows that there exists significant correlation between operating conditions and productivity within the clusters, all are statistically different from zero.

Table 35 Trends of DEA Efficiency Score versus Operating Conditions within selected Clusters

Sample	*Cluster*	*Dependent variable*	*Operating condition*	*Trend*	*(t-statistics)*
Light rail	*1*	Efficiency score	Stop spacing	-0.64	(-3.6, 99%)
			Density of service	-0.00079	(-3.5, 99%)
Light rail	*3*	Efficiency score	(Auto per household)$^{-1}$	-7,550	(-7.6, 99%)
			Density of service	-0.0024	(-5.1, 99%)
Heavy rail	*2*	Efficiency score	Density of service	-0.00118	(-6.3, 99%)
Heavy rail	*3*	Efficiency score	Density of service	-0.00083	(-7.7, 99%)
			Stop spacing	-0.205	(-7.5, 99%)

Finally, Table 36 estimates that operating conditions caused 13 to 27 percent of the differences of productivity to be accepted by the user of cluster analysis.

Table 36 Efficiency Difference due to Heterogeneous Operating Conditions in Selected Clusters

Sample	*Operating condition difference (z)*	*Rate of change (a)*	*Maximum score difference ($p_z = a*z$)*	*Maximum (best) score (p)*	*Efficiency % difference owed to "z" ($T = 1 - 1/(p_z/2+1)$)*
Light rail *cluster 1*	Stop spacing 0.25	-0.64	0.16	1.00	13 %
	Density of service 192	-.00079	0.15		
Light rail *cluster 3*	(Auto per household)$^{-1}$ 0.00006	-7,550	-0.45	1.00	27 %
	Density of service 118	-0.0024	-0.28		
Heavy rail *cluster 2*	Density of service 254	-.00118	-0.30	1.00	13 %
Heavy rail *cluster 3*	Density of service 236	-.00083	-0.20	1.00	14 %
	Stop spacing 0.68	-0.205	-0.14		

5.3.2 Comparison of DEA-C (Conventional) to 2F-DEA

Light Rail

The conventional DEA (DEA-C) underestimates efficiency because it compares productivity against the best practice at the most advantageous operating conditions. The amount of overestimation can be calculated by the difference of efficiency between the scores of DEA-C and the scores of 2F-DEA. Table 37 shows that DEA-C underestimated 41 percent of Cleveland's efficiency, 43 percent on San Jose's, 28 percent in Pittsburgh's, and 30 percent in San Francisco's. DEA-C underestimated 17.6 percent of the efficiency of light rail on the average.

Table 37 2F-DEA versus DEA-C (Conventional) (%) - Light Rail

Agency	*Difference DEA-C minus 2F-DEA*			*DEA-C (conventional)*		
	Overall	*Scale*	*Technical*	*Overall*	*Scale*	*Technical*
bos	-7	-6.1	-1	92.6	93.5	99.0
sfr	-29.6	-2.8	-27.5	70.4	97.2	72.5
phi	-39.4	-10.6	-33.1	54.9	88.5	62.1
lan	-2.9	-3.7	1	75.2	75.2	100.0
sdi	0.8	0.8		94.3	94.3	100.0
slo				100.0	100.0	100.0
por	-12.9	-2.4	-10.9	80.6	97.6	82.6
dal	-36.4	1	-38.3	52.9	97.4	54.3
sac	-5.8	0.1	-5.9	69.4	99.3	69.9
pit	-28.3	0.5	-29.6	42.6	97.0	43.9
buf	-6.2	2.2	-8.6	84.7	95.8	88.5
bal	-15.8	-5.8	-11.8	70.4	90.8	77.5
sjo	-42.9	0.6	-46.2	47.2	94.3	50.0
cle	-40.8	-4.2	-39.1	38.6	95.8	40.3
den	-23.3	-17.9	-7.4	67.6	73.0	92.6
new	9.4	8.5	1	97.1	97.1	100.0
Average	*-17.6*	*-2.5*	*-16.1*	*71.2*	*92.3*	*77.1*

Heavy Rail

Table 38 shows that DEA-C underestimated the efficiency level of Philadelphia by 13 percent, Baltimore's by 18 percent, PATCO's by 14 percent, Cleveland's by 54 percent, and Staten Island's by 40 percent. On the average, DEA-C underestimated heavy rail efficiency by 11 percent.

Table 38 2F-DEA versus DEA-C (Conventional) (%) - Heavy Rail

Agency	*Difference DEA-C minus 2F-DEA*			*DEA-C (conventional)*		
	Overall	*Scale*	*Technical*	*Overall*	*Scale*	*Technical*
nyo				100	100	100
was	-4	3	-6	85	100	85
chi	-2	-2		74	79	93
bos	-1		-1	88	99	89
atl				100	100	100
phi	-13	-1	-13	79	99	80
sfr	-1	-1		99	99	100
path				100	100	100
mia	-5	-5	-1	93	95	97
bal	-18	-18		72	72	100
lan	-4	-4		85	85	100
patco	-14	-14	-1	78	79	99
cle	-54	-54		40	40	100
sta	-40	-40		44	44	100
Average	*-11*	*-10*	*-2*	*81*	*85*	*96*

5.3.3 Comparison of DEA-CL (Cluster Analysis) to 2F-DEA

Light Rail

Besides the reduction of the effect of operating conditions in cluster analysis, DEA-CL may overestimate efficiency by considering a smaller sample for the comparison. Table 39 shows that DEA-CL underestimates the efficiency of six agencies and overestimates the efficiency of four agencies. Overall, the total efficiency of light rail was overestimated by 4.7 percent.

Table 39 2F-DEA versus DEA-CL (Cluster Analysis) (%) – Light Rail

Agency (cluster number)	*Difference DEA-CL minus 2F-DEA*			*DEA-CL (cluster analysis)*		
	Overall	*Scale*	*Technical*	*Overall*	*Scale*	*Technical*
bos (1)	0.4	0.4		100.0	100.0	100.0
sfr (1)	-8.3	-0.9	-7.4	91.7	99.1	92.6
phi (1)	-11.0	-0.8	-10.5	83.3	98.3	84.7
lan (2)	13.6	12.8	1.0	91.7	91.7	100.0
sdi (2)	0.8	0.8		94.3	94.3	100.0
slo (3)				100.0	100.0	100.0
por (3)	6.5		6.5	100.0	100.0	100.0
dal (3)	-28.3	-8.6	-23.2	61.0	87.8	69.4
sac (3)	4.2	0.0	4.2	79.4	99.2	80.0
pit (3)	-11.7	-7.7	-6.8	59.2	88.8	66.7
buf (3)	-1.6	-4.3	2.9	89.3	89.3	100.0
bal (3)	-6.8	-6.9	-0.8	79.4	89.7	88.5
sjo (3)	-25.2	-4.7	-23.2	64.9	89.0	73.0
cle (3)	-29.1		-29.1	50.3	100.0	50.3
den (1)	9.1	9.1		100.0	100.0	100.0
Average	*-4.7*	*0.0*	*-5.3*	*84.0*	*95.5*	*87.8*

Heavy Rail

Table 40 shows that DEA-CL model overestimates efficiency of almost all agencies because the cluster implies a lower number of observations. For example, clusters 1 and 4 (New York and San Francisco) will always be efficient in their corresponding clusters because they are composed of one or two systems. Cluster 2 (systems in medium-size cities) charges all overestimated efficiency to apparent "scale efficiency". DEA-CL overestimated the overall efficiency of heavy rail by 3 percent.

Table 40 2F-DEA versus DEA-CL (Cluster Analysis) (%) - Heavy Rail

Agency (cluster number)	*Difference DEA-CL minus 2F-DEA*			*DEA-CL (cluster analysis)*		
	Overall	*Scale*	*Technical*	*Overall*	*Scale*	*Technical*
nyo (1)				100	100	100
was (3)	4	-5	9	93	93	100
chi (3)	7	2	6	83	83	99
bos (3)	11	1	10	100	100	100
atl (3)				100	100	100
phi (3)	-9	-3	-7	83	98	85
sfr (4)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
path (1)				100	100	100
mia (2)				98	100	98
bal (2)	10	10		100	100	100
lan (2)	12	12		100	100	100
patco (2)	7	7		100	100	100
cle (2)	2	2		96	96	100
sta (2)	-4	-4		80	80	100
Average	*3*	*2*	*1*	*95*	*96*	*99*

5.3.4 Comparison of DEA-ND (Non-Discretionary Factors) to 2F-DEA

Light Rail

DEA-ND may overestimate efficiency caused by the inclusion of operating conditions as if they were "inputs" or it may underestimate efficiency caused by the remaining effect of heterogeneous conditions in DEA. The final result is unpredictable. Table 41 shows that DEA-ND did not find any technical inefficiency in light rail and that DEA-ND overestimates technical efficiency, although it overestimates the overall efficiency by 3.7 percent. This is due to the increase in the number of "inputs" from five to twelve including stop spacing, density of service, rush-half-an-hour concentration of demand, income per capita of served area, and employment density of center-city.

Table 41 2F-DEA versus DEA-ND (Non-Discretionary Factors) (%) - Light Rail

Agency	*Difference DEA-ND minus 2F-DEA*			*DEA-ND (non-discretionary factors)*		
	Overall	*Scale*	*Technical*	*Overall*	*Scale*	*Technical*
bos	0.4	0.4		100.0	100.0	100.0
sfr				100.0	100.0	100.0
phi		-4.8	4.8	94.3	94.3	100.0
lan	21.9	21.1	1.0	100.0	100.0	100.0
sdi	6.5	6.5		100.0	100.0	100.0
slo				100.0	100.0	100.0
por	-10.9	-17.4	6.5	82.6	82.6	100.0
dal	-26.4	-33.5	7.4	62.9	62.9	100.0
sac	4.2	-19.0	23.2	79.4	80.2	99.0
pit	7.8	-17.8	26.5	78.7	78.7	100.0
buf	-6.2	-8.9	2.9	84.7	84.7	100.0
bal	8.1	-2.3	10.7	94.3	94.3	100.0
sjo	-27.6	-31.2	3.8	62.5	62.5	100.0
cle	-23.2	-43.8	20.6	56.2	56.2	100.0
den	-22.4	-22.4		68.5	68.5	100.0
new	9.4	8.5	1.0	97.1	97.1	100.0
Average	*-3.7*	*-10.3*	*6.8*	*85.1*	*85.1*	*99.9*

Heavy Rail

Table 42 shows that DEA-ND underestimates overall efficiency of almost all heavy rail agencies. The new "inputs" were stop spacing and density of service. DEA-ND underestimated overall efficiency by 10 percent that is mostly contributed by scale efficiency.

Table 42 2F-DEA versus DEA-ND (Non-Discretionary Factors) (%) - Heavy Rail

Agency	*Difference DEA-ND minus 2F-DEA*			*DEA-ND (non-discretionary factors)*		
	Overall	*Scale*	*Technical*	*Overall*	*Scale*	*Technical*
nyo				100	100	100
was	-3		-3	85	97	88
chi	20	18	4	96	99	97
bos	-1	-11	10	88	88	100
atl				100	100	100
phi	-13	-21	7	79	79	100
sfr				100	100	100
path				100	100	100
mia	-5	-6		93	94	98
bal	-18	-18		72	72	100
lan	-4	-4		85	85	100
patco	-14	-14		78	78	100
cle	-54	-54		40	40	100
sta	-40	-40		44	44	100
Average	*-10*	*-11*	*1*	*83*	*84*	*99*

5.3.5 Comparison of DEA-2S (Two-Step) to 2F-DEA

Light Rail

The method DEA-2S (Two-Step) assumes that some operating conditions are sources of inefficiency and as such they are correlated with the efficiency scores that result from the conventional DEA (DEA-C). Consequently, a low correlation between efficiency and operating conditions indicates an empirical success of 2F-DEA. Table 43 shows that operating conditions correlation with efficiency are noticeably higher for DEA-C than for 2F-DEA. All correlation coefficients of 2F-DEA are lower than 0.5 suggesting that 2F-DEA successfully extracted the effect of heterogeneous operating conditions from efficiency.

Table 43 2F-DEA versus DEA-2S (Two-Step) - Light Rail

	Efficiency scores				*Inefficiency scores*					
	Overall		*Technical*		*Overall*		*Scale*		*Technical*	
	2F-DEA	*DEA-2S*	*2F-DEA*	*DEA-2S*	*2F-DEA*	*DEA-2S*	*2F-DEA*	*DEA-2S*	*2F-DEA*	*DEA-2S*
Auto factor										
Per capita	0.14	0.46	0.31	0.54	0.13	0.49	-0.45	-0.26	0.32	0.63
Per household	0.11	0.48	0.23	0.58	0.11	0.47	-0.31	-0.20	0.23	0.59
Income factor										
Per household	0.22	0.54	0.18	0.60	0.00	0.50	-0.42	-0.16	0.17	0.60
Supply quality										
Density of serv.	-0.29	-0.55	-0.32	0.47	-0.31	-0.57	0.04	-0.23	-0.34	-0.49

Heavy Rail

Table 44 shows that operating conditions have higher correlation with DEA-C scores than with 2F-DEA scores. Correlation with 2F-DEA scores have values lower than 0.5 suggesting that the effect of operating conditions on productivity has been successfully extracted by DEA(1). Neither DEA-2S nor 2F-DEA detects any correlation in the case of technical efficiency suggesting that the effect of heterogeneous conditions in heavy rail cause apparent "scale inefficiency."

Table 44 2F-DEA versus DEA-2S (Two-Step) - Heavy Rail

	Efficiency scores				*Inefficiency scores*			
	Overall		*Technical*		*Overall*		*Scale*	
	2F-DEA	*DEA-2S*	*2F-DEA*	*DEA-2S*	*2F-DEA*	*DEA-2S*	*2F-DEA*	*DEA-2S*
Demand factor								
Rush half-an-hour Concentration	-0.18	-0.68	-0.04	-0.44	-0.17	-.66	-0.21	-.60
Network factor								
Circuit availability	-0.31	-0.42	-0.13	-0.28	-0.33	-.51	-0.34	
Network complexity	-0.32	-0.58	-0.02	-0.23	-0.34	-.66	-0.44	-.68
Supply quality								
Density of service	-0.32	-0.65	-0.14	-0.40	-0.35	-.72	-0.35	-.64
Circuity index	-0.15	-0.51	0.01	0.25	-0.17	-.52	-0.43	-.66

5.4 Application of 2F-DEA to Productivity Analysis

Transit productivity analysis estimates the maximum possible production given the available resources determined by transit policy. Variables useful for policy include the returns to the consumption of one input, returns to scale, substitutability between inputs, and the production function itself. Policies may include increasing the use of those inputs that permit faster increases of the outputs, producing at the optimal scale of the transit firm, decreasing dependence on one production technique, and maximizing the effectiveness of additional funding to the transit industry.

5.4.1 Returns to the Consumption of One Input

Returns to the consumption of a single input are the changes of the marginal productivity of the input when its consumption increases. This variable estimates the law of diminishing returns which states that, when the quantity of one input increases, its marginal productivity decreases continually after a certain threshold. The curve of the output as a function of input usually consists of three sections representing increasing, constant, and decreasing returns to the scale. The more inputs that have values in the increasing returns to scale region the more favorable will be to expand operations. Usually this is a characteristic cited to explain the increase of production achieved by rail operations that use the track length more intensely. The returns to scale for a single input is the change of marginal productivity and therefore it is the trend of the marginal productivity when the quantity of the input increases. The method of calculating marginal productivity consists of taking the coefficients of the linear production function and calculating their trend with ordinary least squares using a small sample. Since the application presented here has two outputs, two analyses are possible.

Table 45 indicates that marginal production of trips will be decreasing by –0.013 trips for each additional hour of labor in operations. Vehicle revenue miles on the other hand, will increase by 0.319 for each additional hour of labor in operations. Light rail has increasing returns to scale with respect to energy and decreasing returns with respect to rail tracks. Vehicles generate decreasing returns in the production of trips and increasing returns in the production of vehicle revenue miles.

Table 45 Returns to Quantity of a Single Input (*) – Light Rail

Input	*Trend of marginal productivity*	
	TRIPS	*VRM*
loper	-0.013	+0.319
lmain	0	-0.063
ener	+0.000006	+0.00005
cars	-0.16	+3.53
rails	-3.78	-10.79

(*) Rate of change of the marginal productivity of the input when input increases.

Table 46 shows that heavy rail has increasing returns for both outputs not only with respect to energy but also with respect to rail tracks. On the other hand, expanding labor hours in operation will always produce decreasing returns. Notice that the expansion of stations generates increasing returns with respect to trips but decreasing returns with respect to vehicle revenue miles consistent with the fact that the number of stations affects operating speed when stop spacing is reduced below a threshold.

Table 46 Returns to Quantity of a Single Input (*) – Heavy Rail

Input	*Trend of marginal productivity*	
	TRIPS	*VRM*
loper	-0.017	-0.0003
lmain	+0.115	-0.0002
ener	+0.0000001	+0.00000005
cars	-0.237	+0.023
rails	+9.35	+6.28
stats	+16.93	-0.595

(*) Rate of change of the marginal productivity of the input when input increases

5.4.2 Returns to Scale

Returns to scale compares the expansion of outputs to the expansion of inputs. The expansion of outputs may be larger, equal, or smaller than the expansion of inputs corresponding to increasing, constant, or decreasing returns to scale, respectively. The optimal size corresponds to the point of scale efficiency, right at the point of constant returns to scale. The proposition that an agency should break down in systems of less than 150-buses each, to increase the efficiency of the system was based on returns to scale arguments (Naciones Unidas-CEPAL 1992). In another application, the 1947 Transport Act that nationalized the British Railways assumed that central planning of a large organization increased efficiency over several independent private railways (Gwilliam 1964). Policy makers sometimes break down giant organizations in smaller more efficient units as in the case of the Japanese Railways (Hughes 1994). The method of obtaining returns to scale consists of estimating scale efficiency with the ratio $\frac{z_0}{h_0}$ (Charnes, Cooper and Rhodes 1978 efficiency score to Banker, Charnes and Cooper 1984 efficiency score of formulas (12) and (13)). Another way to check optimal size is with the constant term w_0 calculated in the dual of the model (12). The optimum size occurs simultaneously with a change in sign of the constant w_0. Scale efficiency means that the company may be technically efficient, but if it operates in the non-optimal region, the loss of productivity is the percentage of scale inefficiency. Two optimal sizes are expected, one for trips and the other for vehicle revenue miles, both optimal sizes indicate the existence of two techniques of production, one technique intensely producing trips and the other technique intensely producing vehicle revenue miles. A technique of production is defined in this dissertation as a particular set of technical ratios like labor per vehicle, stop spacing, and others.

Figure 12 shows the optimal size for light rail. The two upper curves describe the envelope of scale efficiency, with respect to the right-hand scale, of two groups of agencies versus network length. Following the leaders of each group, San Francisco and St. Louis, the rest of the agencies have been assigned to two groups, traditional and newer systems. The lower curve represents the constant term of the linear production function. The optimal size occurs when this curve crosses the zero level. One optimal size corresponds to the first crossing at a network of approximately 35 miles. Systems of that size usually operate fleets of 30 to 50 vehicles. Another optimal size corresponds to the second crossing at a 50-mile network (135-vehicle fleet). The optimal sizes are associated with different system reliance on trips, with San Francisco experiencing more intense trip making than St. Louis. Also, the optimal sizes are associated with different technical ratios of vehicles per track mile (2.7 in San Francisco versus 1.1 in St. Louis).

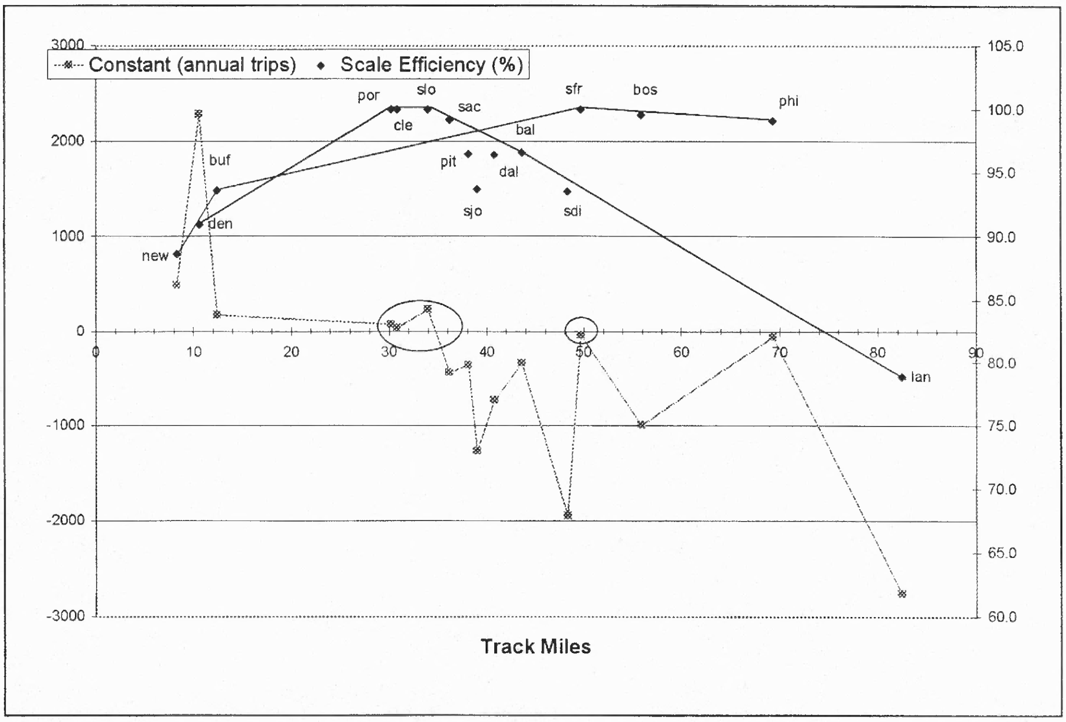

Figure 12 Graphic Determination of Optimal Size – Light Rail

Figure 13 presents the graphical estimation of the optimal size for heavy rail. The upper curves are the envelopes of scale efficiency of two groups of agencies, those that are more intensive in producing trips (traditional group) and those that are more intensive in producing vehicle revenue miles (newer group). The lower curve represents the value of the constant term in the linear production function for vehicle revenue miles. The optimal size occurs when this curve crosses the zero level. One optimal size is between a 300 and 600-vehicle fleet that usually operates on a 100 to 200-mile network represented by systems like Miami, Atlanta, and San Francisco, with a technical ratio of 1.1 vehicles per track mile. Another optimal size corresponds to the size of New York with a fleet larger than 5,000 vehicles and a network larger than 450 miles, with a technical ratio of 2.5 vehicles per track mile. Note that the graphical estimation of optimal size is more precise in the case of light rail than it is for heavy rail.

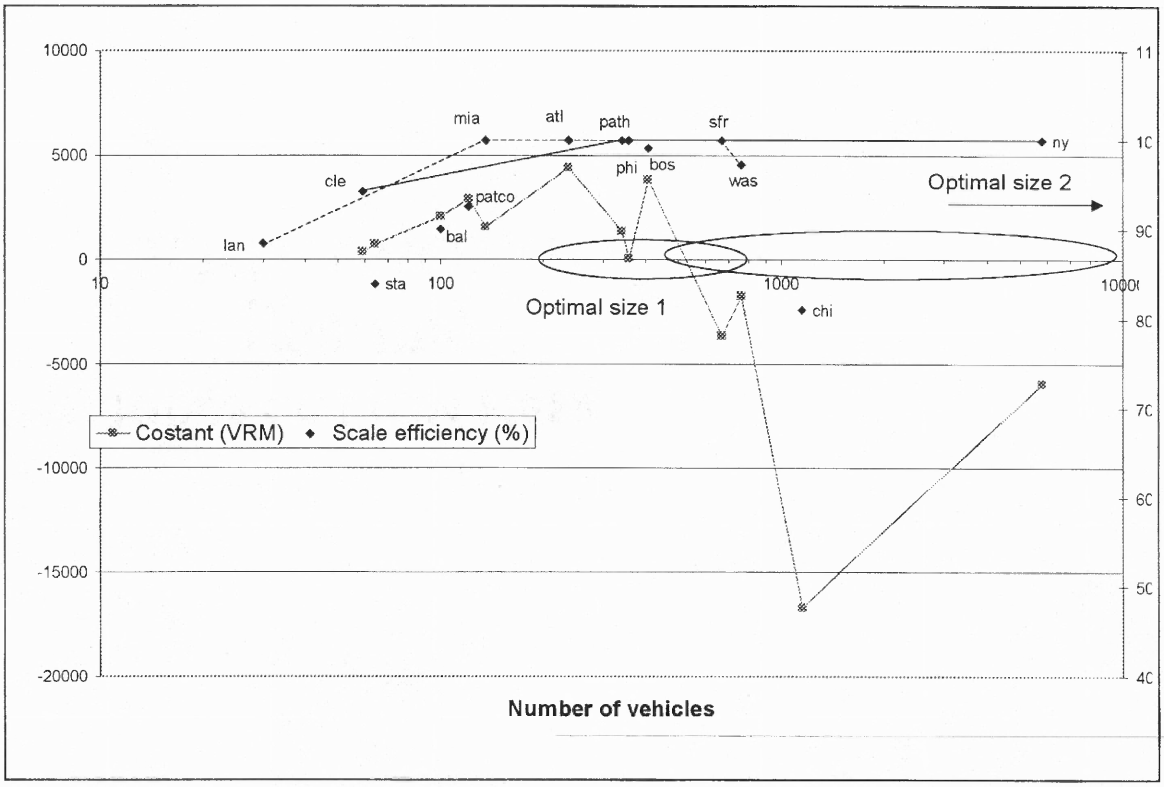

Figure 13 Graphic Determination of Optimal Size – Heavy Rail

5.4.3 Substitutability, Technical Ratios, and Scale of Production

Substitutability measures the degree to which one input can be used to replace another for the production of an output. An input is a substitute of other input if its consumption increases when the marginal production of the other input increases. DEA estimates piecewise linear production functions and therefore it assumes that all inputs are perfect complements to each other at a given scale. This dissertation assumes that an approximation to the elasticity of substitution refers to a variable scale by using the coefficients of the production function when the coefficient of output is 1.00.

This section also confirms the existence of two techniques of production by using the ratio between the values of technical ratios between both groups. Finally, the elasticity of substitution is the change of the logarithm of the technical ratio caused by changes of the logarithm of the ratios of marginal productivity.

Table 47 contains a list of the traditional light rail systems where production is more intensive in trips and where there is a high number of vehicles per track mile. It also shows the list of the newer light rail systems where production is more intensive in vehicle revenue miles and where there is a low number of vehicles per track mile.

Table 47 Technical Groups for Light Rail

Traditional	*Newer*
Boston	Los Angeles
San Francisco	San Diego
Philadelphia	St. Louis
Pittsburgh	Portland
Buffalo	Dallas
Newark	Sacramento
	Baltimore
	San Jose
	Cleveland
	Denver

Table 48 presents the proportional difference between the values of technical ratios of the groups. Each number is the ratio of the technical ratio of the traditional system over the technical ratio of the newer system. The technical ratio is the input numerator of the first row to the input denominator of the first column of Table 48. A value larger than one says that the traditional system uses a technical ratio more intense in the input of the denominator that is at the first column of the table. A value smaller than one says that the newer system uses a technical ratio more intense in the input of the denominator that is in the same first column of the table. Therefore, the table shows that the row of *rails* (track miles) indicates that traditional systems have a technique of production that uses tracks intensely while from the row of *cars* (number of vehicles) indicates that newer systems use vehicles intensely.

Table 48 Proportional Difference of Technical Ratios between Traditional and Newer Light Rails

	loper	*lmain*	*ener*	*cars*
lmain	0.74			
ener	1.24	1.52		
cars	0.76	0.94	0.61	
rails	1.60	1.96	1.31	2.03

Table 49 presents selected results of the trend of the technical ratio with respect to size. The positive results of the trends indicate that the intensity of use of the network might also be linked with size while there are no trends on the intensity of use of vehicles. Therefore, since traditional systems are also the larger and since there are no trends on the intensity of use of vehicles, this trend is indeed a coincidence because of the production technique chosen by the traditional systems.

Table 49 Trends of Technical Ratios versus Scale – Light Rail

Technical ratio	*Trend (size in Trips)*	R^2
loper/rail	0.0002	0.55
lmain/rail	0.0001	0.33
ener/rail	0.009	0.66
car/rail	0.00003	0.35

Table 50 presents the elasticity of substitution for light rail systems. Six out of ten indicators are negative and therefore indicate mostly complementary inputs. The most complementary of all are the labor hours in maintenance (*lmain*) and vehicles (*cars*). Four pairs of inputs have positive elasticity and therefore they are substitute, all related to labor hours in operations and to labor hours in maintenance, which has the highest value between these two inputs.

Table 50 Elasticity of Substitution (Allowing for Varying Size) (*) – Light Rail

	loper	*lmain*	*cars*	*ener*
lmain	-0.11			
cars	+0.005	-0.173		
ener	+0.09	+7.957	-0.053	
Rail	-0.046	+0.231	-0.067	-0.123

(*) $\dfrac{d\ln\left(\frac{loper}{lmain}\right)}{d\ln\left(\frac{marginal\_product\_lmain}{marginal\_product\_loper}\right)}$ Elasticity of substitution of loper to lmain. Substitute if > 0, complement if < 0.

Table 51 presents the members of two groups of heavy rails, the traditional, with more intense production in trips and higher ratio vehicles per track mile, and the newer, with more intense production in vehicle revenue miles and lower ratio vehicles per track mile.

Table 51 Technical Groups for Heavy Rail

Traditional	*Newer*
New York	Washington
Chicago	Atlanta
Boston	San Francisco
Philadelphia	Miami
PATH	Baltimore
Cleveland	Los Angeles
Staten Island	PATCO

Table 52 presents the proportional difference between the values of technical ratios of the groups. Each number is the ratio of the technical ratio of the traditional system over the technical ratio of the newer system. The technical ratio is the input numerator of the first row to the input denominator of the first column of Table 52. A value larger than one says that the traditional system uses a technical ratio more intense in the input of the denominator that is at the first column of the table. A value smaller than one says that the newer system uses a technical ratio more intense in the input of the denominator that is in the same first column of the table. Therefore, Table 52 indicates that the traditional and newer groups confirm their different techniques of production. Traditional systems use tracks more intensely than newer while newer systems use vehicles and stations more intensely.

Table 52 Proportional Difference of Technical Ratios between Traditional and Newer Heavy Rails

	loper	*Lmain*	*ener*	*cars*	*rails*
lmain	1.17				
ener	1.15	0.97			
cars	0.88	0.76	0.66		
rail	1.51	1.41	1.15	1.82	
stats	0.93	0.88	0.80	1.08	0.60

Table 53 shows positive trends for technical ratios when network length increases revealing that larger agencies also tend to be more intense in the use of track length, as it was the case of light rail. There is no tendency for the intensity of use of vehicles and stations indicating that the tendency is a coincidence with size. Since New York is the largest system and also an efficient representative of the traditional systems, the trend is expressing the difference in production techniques of the groups rather than the effect of size.

Table 53 Trends of Technical Ratio versus Scale – Heavy Rail

Technical ratio	*Trend (size in Trips)*	R^2
car/rail	0.000005	0.43
lmain/rail	0.00002	0.45
loper/rail	0.00002	0.48

Table 54 shows that all of the substitution elasticity indicators of heavy rail have positive values. They show that most of the inputs are substitutable, contrary to the case of light rail. The only complementary relation exists between stations (*stats)* and labor hour in operations (*loper*)—including personnel in stations and security. Heavy rail shows more signs of flexibility in the use of resources than light rail.

Table 54 Elasticity of Substitution (Allowing for Varying Size) (*) – Heavy Rail

	loper	*lmain*	*cars*	*ener*
lmain	0.181			
cars	0.07	0.101		
ener	0.095	0.169	0.028	
rails	0.136	0.138	0.121	0.178
stats	-0.007	0.314	0.011	0.695

(*) $\dfrac{d\ln\left(\frac{loper}{lmain}\right)}{d\ln\left(\frac{marginal\_product\_lmain}{marginal\_product\_loper}\right)}$ Elasticity of substitution of loper to lmain. Substitute if > 0, complement if < 0.

5.4.4 Piecewise Linear Production Function

The model 2F-DEA estimates piecewise linear production functions that are valid at the vicinity of individual observations. The production function calculates the increase of output achieved after marginal increases in inputs, indicating that it is possible to calculate the optimal direction of expansion. Answers can be provided to questions on whether additional miles of rail tracks should be built or more vehicles should be bought. The coefficients of the linear production function answer those questions because they are the marginal products when the coefficient of the output is 1.00. Since the marginal products are the shadow prices of the firm, they indicate the optimal direction of expansion, and, if the cost of the inputs is added, the most cost effective way of expansion. This analysis assumes that it is feasible to add inputs such as an additional mile of track or to buy one additional vehicle.

Table 55 presents the marginal production of labor hours in operation (*lloper*), in maintenance (*llmain*), in energy (*lener*), in vehicles (*lcars*), and in track miles (*lrails*). The smaller systems of Denver and Newark show the highest increase in trips caused by an additional mile of track. Also, Portland and Baltimore show the highest increase in trips with additional vehicles. Finally, Denver and St. Louis yield the highest increase in trips by expanding the labor hours in operations.

Table 55 Marginal Production of Trips per Unit Increase of Input – Light Rail

Agency	*TRIPS ('000)*	*VRM ('000)*	*TRIPS/ VRM*	*/loper ('000)*	*/lmain ('000)*	*/ener ('000)*	*/cars*	*/rails*	*Total TRIPS*	*Total VRM*
bos	67000	5435	12	4			10	0	14	1
sfr	36738	3740	10	4	2		1		7	1
phi	25003	3049	8	5					5	1
lan	22659	4436	5				29		29	6
sdi	18287	5059	4			0		28	28	8
slo	14486	2585	6	22	2	0		4	29	5
por	10432	1579	7			0	81		81	12
dal	7972	1794	4			0	18		18	4
sac	7862	1852	4	5	5		17		28	7
pit	7421	1718	4			0			0	0
buf	6919	897	8	10		0	1		11	1
bal	6772	2296	3				68		68	23
sjo	6728	1888	4			0			0	0
cle	5337	1181	5			0			0	0
den	4428	648	7	24			13	219	255	37
new	4294	656	7	5	1	0	7	109	122	19

Cost effectiveness is the number of trips achieved per dollar spent on one additional unit of input. Table 56 shows that, excluding labor hours in maintenance (*lmain*) and energy (*ener*), the most cost-effective options for expansion are buying additional vehicles for Portland and Baltimore, and expanding the labor force in operations in Denver and St. Louis.

Table 56 Cost Effectiveness in Trips per Additional Dollar Spent in Inputs – Light Rail

Agency	*loper*	*lmain*	*ener*	*cars*	*rails*	*Total TRIPS*	*Total VRM*
bos	0.14			0.16		0.31	0.02
sfr	0.15	0.10		0.02		0.26	0.03
phi	0.20					0.20	0.02
lan				0.49		0.49	0.10
sdi			1.93		0.06	1.99	0.55
slo	0.88	0.09	1.00		0.01	1.98	0.35
por			1.53	1.35		2.88	0.44
dal			6.98	0.29		7.27	1.64
sac	0.22	0.21		0.29		0.71	0.17
pit			3.14			3.14	0.73
buf	0.39		2.56	0.01		2.96	0.38
bal				1.13		1.13	0.38
sjo			2.30			2.30	0.65
cle			1.94			1.94	0.43
den	0.94			0.21	0.44	1.59	0.23
new	0.18	0.05	0.69	0.12	0.22	1.26	0.19
Avrg	0.19	0.03	1.38	0.25	0.05	1.90	0.39

Expansion costs (*)

Input	*Unit cost ($)*	*Life (years)*	*Annual cost ($)*
loper	50,000	1	25,000
lmain	50,000	1	25,000
ener	63.7	1	63.70
cars	1.5 M	25	60,000
rails	20 M	40	500,000

(*) (APTA 2001; CUTA 1993; Vuchic 1981)

As a result a priority list can be made with the fifteen more cost-effective ways to expand light rail as shown in the Table 57. Priority also permits ordering options for expansion of individual agencies. For example, Newark would like to expand first with additional tracks (*rails*) and then with larger labor force in operations (*loper*). On the other hand, Sacramento would choose a combination of increasing fleet size (*cars*) and labor force in operations (*loper*). This analysis assumes that there are sufficient funds to finance the minimum lump sums for each input, say $ 50,000 to hire an additional driver or $ 20 million to finance the construction of an additional mile of track (*rails*).

Table 57 Priority of Investment for Expansion Using Cost Effectiveness – Light Rail

Priority	*Cost effectiveness (TRIPS per $)*	*Agency*	*Input*
1	1.35	Portland	cars
2	1.13	Baltimore	cars
3	0.94	Denver	loper
4	0.88	St. Louis	loper
5	0.49	Los Angeles	cars
6	0.44	Denver	rails
7	0.39	Buffalo	loper
8	0.29	Dallas	cars
9	0.29	Sacramento	cars
10	0.22	Newark	rails
11	0.22	Sacramento	loper
12	0.21	Denver	cars
13	0.20	Philadelphia	loper
14	0.18	Newark	loper
15	0.16	Boston	cars

Table 58 indicates that most of the heavy rail systems have high incremental production of trips with respect to stations. Also, high marginal production is generated by expanding the track mileage for Boston and Atlanta and by purchasing new vehicles for Los Angeles. In the case of heavy rail the larger systems seem to be capable of becoming more productive by expansion.

Table 58 Marginal Production of Trips per Unit Increase of Input – Heavy Rail

	TRIPS	*VRM*	*TRIPS/ VRM*	*/loper*	*/lmain*	*/ener*	*/cars*	*/rails*	*/stats*	*Total TRIPS*	*Total VRM*
ny	1579783	304094	5	10	2	1			296	308	59
was	198003	37984	5	16			46		1590	1653	317
chi	151010	50687	3		38	0				38	13
bos	113715	22934	5	20	27		12	538		596	120
atl	90991	27101	3	2	19	0		552		574	171
phi	86245	15640	6	13		0	16		853	882	160
sfr	80490	48523	2		2	0			1393	1395	841
path	67998	12834	5	47	8	0	3		500	558	105
mia	14020	5739	2	19	4			98	206	327	134
bal	12600	4231	3	3	6	0	14		399	421	141
lan	11628	1737	7				480			480	72
patco	10660	4017	3	20	11	0	6		268	304	115
cle	7695	2046	4	10	7	0	5			22	6
sta	4618	2104	2	11	7	0	9	3		29	13

Table 59 indicates that besides energy and labor hours directed to maintenance, the more cost-effective ways to expand heavy rail systems are increasing the number of stations (*stats*) and the labor hours for operations (*loper*). Noticeable is the high cost effectiveness of expanding stations in San Francisco and Washington.

Table 59 Cost Effectiveness in Trips per Additional Dollar Spent in Inputs – Heavy Rail

Agency	*loper*	*lmain*	*ener*	*cars*	*rails*	*stats*	*Total TRIPS*	*Total VRM*
nyo	0.40	0.06	10.91			2.36	13.74	2.64
was	0.63			0.77		12.72	14.13	2.71
chi		1.51	0.35				1.86	0.62
bos	0.78	1.07		0.20	0.54		2.59	0.52
atl	0.08	0.78	3.83		0.55		5.24	1.56
phi	0.51		0.12	0.27		6.83	7.72	1.40
sfr		0.09	1.03			11.14	12.26	7.39
path	1.89	0.31	0.78	0.05		4.00	7.02	1.33
mia	0.78	0.14			0.10	1.65	2.67	1.09
bal	0.10	0.22	5.42	0.24		3.19	9.17	3.08
lan				8.01			8.01	1.20
patco	0.79	0.43	1.16	0.09		2.15	4.62	1.74
cle	0.40	0.27	1.78	0.09			2.54	0.68
sta	0.42	0.26	0.79	0.15	0		1.63	0.74
Avrg	0.48	0.37	1.87	0.70	0.09	3.15		

Expansion costs (*)

Input	*Unit cost ($)*	*Life (years)*	*Annual cost ($)*
loper	50,000	1	25,000
lmain	50,000	1	25,000
ener	63.70	1	63.70
cars	1.5 M	25	60,000
rails	40 M	40	1 M
stat	5 M	40	125,000

(*) (APTA 2001; CUTA 1993; Vuchic 1981)

Table 60 shows that eight out of twenty prioritized options include stations, two include vehicles, ten expand labor hours in operations, and two expand track length. Additionally, nine of the systems are traditional and eleven are newer systems. Besides that, individual systems can order their own priorities in investment programs. For example, Washington may want to increase its number of stations and later expand in vehicles and labor force.

Table 60 Priority of Investment for Expansion Using Cost Effectiveness – Heavy Rail

Priority	*Cost effectiveness (TRIPS per $)*	*Agency*	*Input*
1	12.72	Washington	stats
2	11.14	San Francisco	stats
3	8.01	Los Angeles	cars
4	6.83	Philadelphia	stats
5	4.00	PATH	stats
6	3.19	Baltimore	stats
7	2.36	New York	stats
8	2.15	PATCO	stats
9	1.89	PATH	loper
10	1.65	Miami	stats
11	0.79	PATCO	loper
12	0.78	Boston	loper
13	0.78	Miami	loper
14	0.77	Washington	cars
15	0.63	Washington	loper
16	0.55	Atlanta	rails
17	0.54	Boston	rails
18	0.51	Philadelphia	loper
19	0.42	Staten Island	loper
20	0.40	New York	loper

5.5 Application of 2F-DEA to Transit Operations Planning (Scheduling)

Operations planning are a blend of industrial engineering concepts with general management, quantitative methods, and statistics applied to operational activities. Techniques of operations planning help to locate garages, to design service, to plan fleet size, network length, and labor force. They optimize the resources allocated to the production of the transit service although there can be ways to improve the checking of the consistency of planned technical ratios. Notwithstanding that 2F-DEA can be extended to the more specific route-by-route analysis, this is left to further research. The contribution of productivity analysis to operations planning consists of checking the planned figures for new projects.

Transit operations planning (scheduling) designs transit service in stages called demand forecasting, routing, blocking (fleet size), and runcutting (labor force). Demand forecasting estimates transit demand based on the operating conditions of an urban area. Routing calculates the length of the route and the number of stops (stations) needed for optimal service. Blocking calculates the number of vehicles needed to supply the demand at the maximum load point of the route. Runcutting calculates the optimal number of operators that are adequate for the number of vehicles. The basic assumption of this analysis is that planned figures of new systems—Hudson Bergen Light Rail and San Juan Heavy Rail—are consistent if they fall within the ranges of currently efficient systems. The evidence is presented graphically to illustrate easily the concept of ranges.

5.5.1 Ratios Related with the Planning of Transit Demand

Light Rail

Transit demand forecasting estimates the number of trips according to operating conditions. It uses two major approaches, a four-step model and a discrete choice model. Figure 14 presents the density of transit demand per track mile as a function of the density of service (vehicle revenue miles per track mile). The positive trend with density of service means that agencies are successfully adjusting their service to demand. The Hudson Bergen density of service (as by May 2000) does not seem to be enough to supply the density of demand of stages 2 and 3. The stages of Hudson-Bergen are described in the Appendix C. Range of traditional systems is the area within the observations of Boston, Newark, Pittsburgh, and Philadelphia. The range for newer systems is the area enveloped by the observations of St. Louis, Cleveland, Dallas, Denver, and Baltimore. Those planned figures outside the areas will need an explanation why the forecast is unique to the system or why it behaves like an outlier. In this case the evidence says that probably Hudson Bergen will increase its density of service in the future. Current operations of the Hudson Bergen system (stage minimum initial) is slightly out of the range of the expected density of transit demand.

Figure 15 presents the number of trips versus number of employees residing in the area served by the system (0.3 miles around the stops). In this case, stage 3 of Hudson-Bergen is in the range of the traditional systems and the result is consistent with existent efficient operations. Also the range of the newer systems is smaller than the range of the traditional systems.

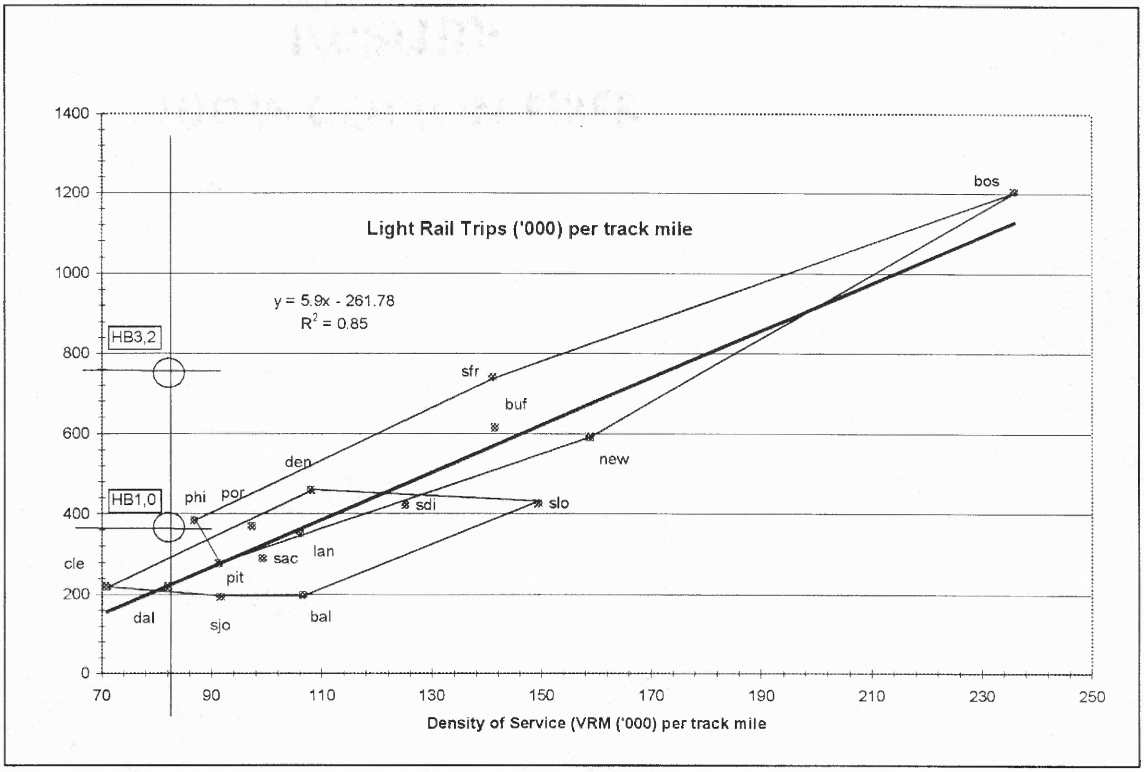

Figure 14 Density of Demand versus Density of Service – Light Rail

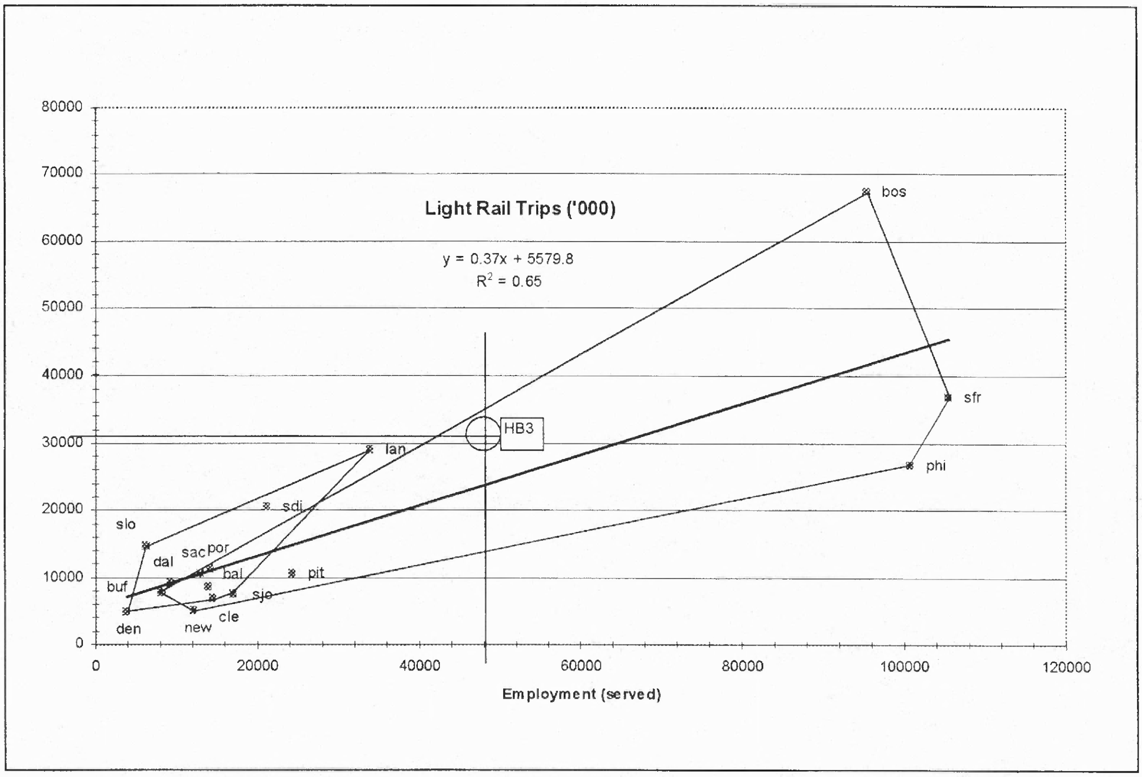

Figure 15 Transit Trips versus Employment Served around Stops – Light Rail

Figure 16 presents some evidence that groups of light rails correspond to the operating conditions of their respective urban areas. Traditional systems serve areas with lower demand per household and less autos per household. Notice how the range areas are almost separated. The Hudson Bergen system falls in the area of traditional systems.

Heavy Rail

Figure 17 presents the density of demand versus density of service for heavy rails. This time traditional and newer systems are all mixed and there is no evidence for a differentiated operating condition set for each heavy rail group. San Juan heavy rail assumes 4 minutes headway for peak hour with six-car trains and 8 minutes for off-peak hour but they are not consistent with existent efficient operations. Very probably the frequency during off-peak hours needed for San Juan is lower than the one assumed in this dissertation. Figure 18 shows that the planned figures of the transit demand of the San Juan system are consistent with the observed efficient operations of heavy rail.

5.5.2 Ratios Related with Route Design (Routing)

Light Rail

Routing is the stage of determining the route mileage and the number of stops (stations) of the transit service. Routing is determined by the location of residential areas, the location of trip generators (attracting centers) like downtown areas, job centers, retail centers, recreation centers, and other land uses that generate transit demand. Two ratios are useful to analyze routing, stops per track mile and density of demand versus size. Figure 19 shows that traditional systems increase their ratio stops per track mile with track length while newer systems decrease their ratio with track length. This is evidence that both groups serve different operating conditions to supply the demanded service. From Figure 19, Hudson Bergen has the supply of a newer system although, from Figures 15 and 16, its demand corresponds to the range of traditional systems. Figure 20 presents the density of demand versus track length. Traditional systems tend to be above newer systems with an overlapping zone. Hudson Bergen in stage 3 is far above the existing newer system behaving consistently like a traditional system. Figure 21 shows the density of transit demand versus the number of stops. This time the Hudson Bergen observations for stages 3 and 4 fall slightly above any efficient operation observed in reality.

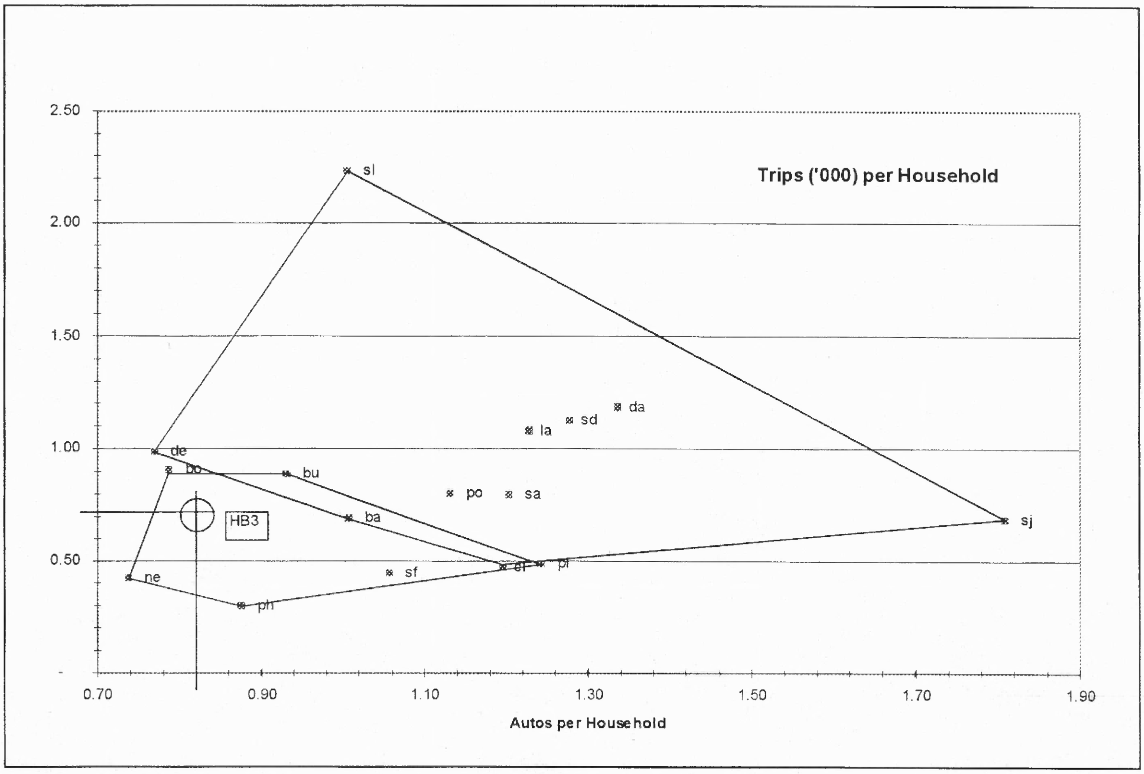

Figure 16 Trips per Household versus Autos per Household – Light Rail

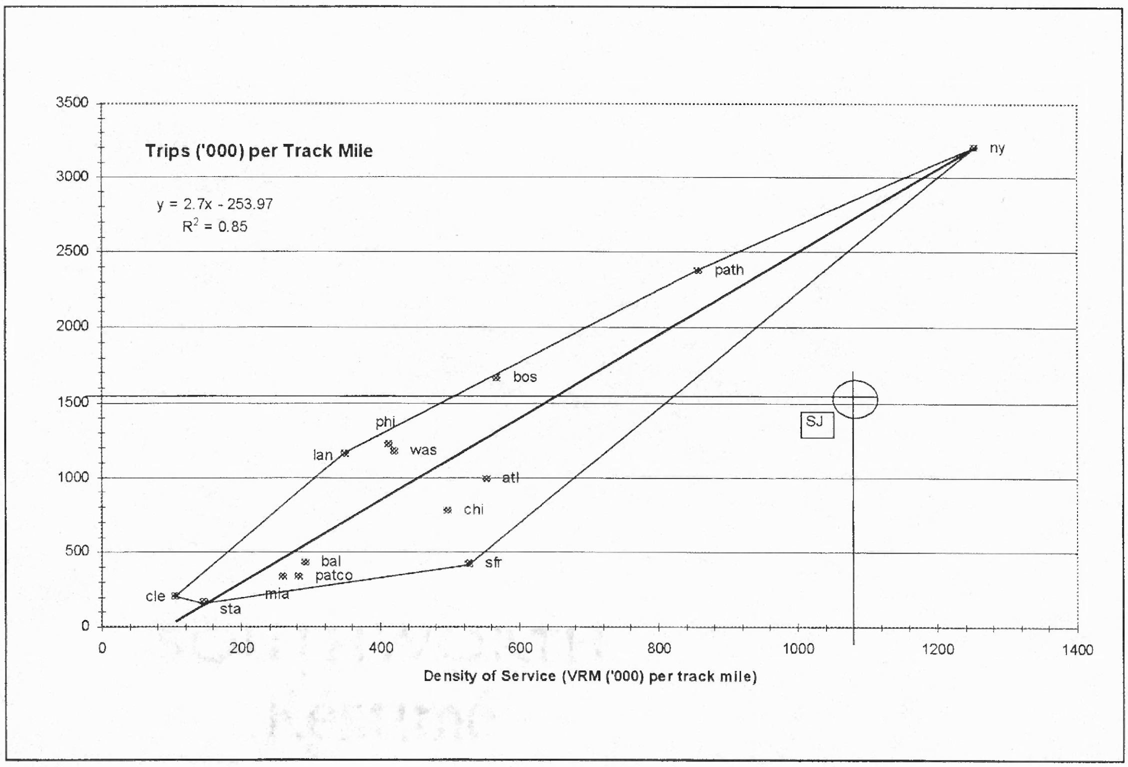

Figure 17 Density of Demand versus Density of Service - Heavy Rail

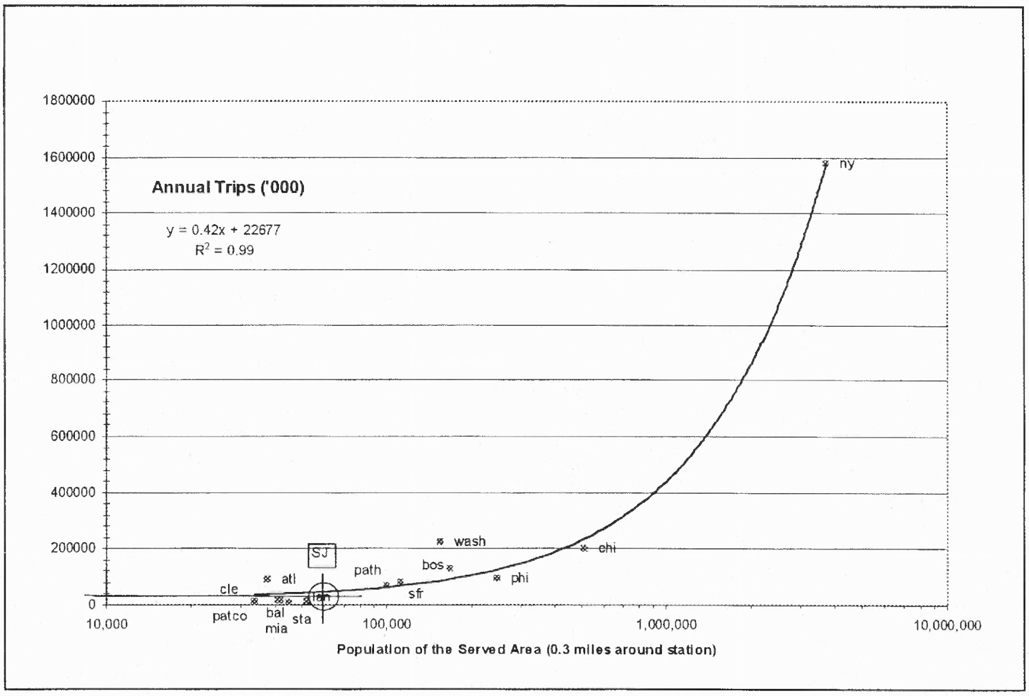

Figure 18 Demand versus Population of the Served Area (0.3 miles around stations) – Heavy Rail

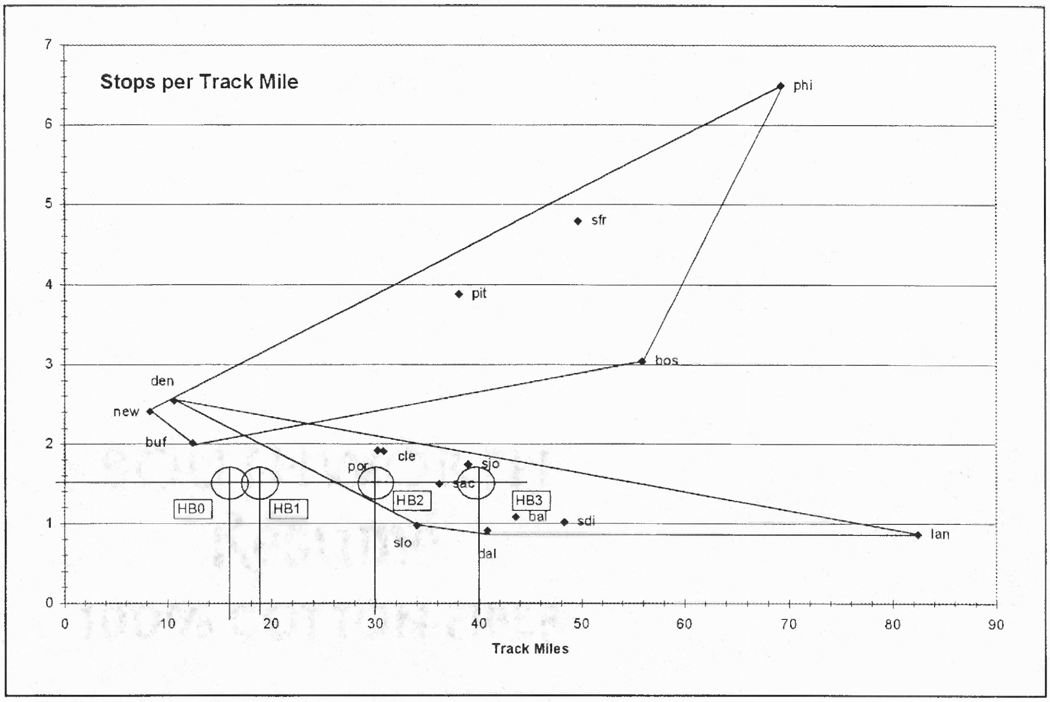

Figure 19 Ratio Stops per Track Mile versus Track Length – Light Rail

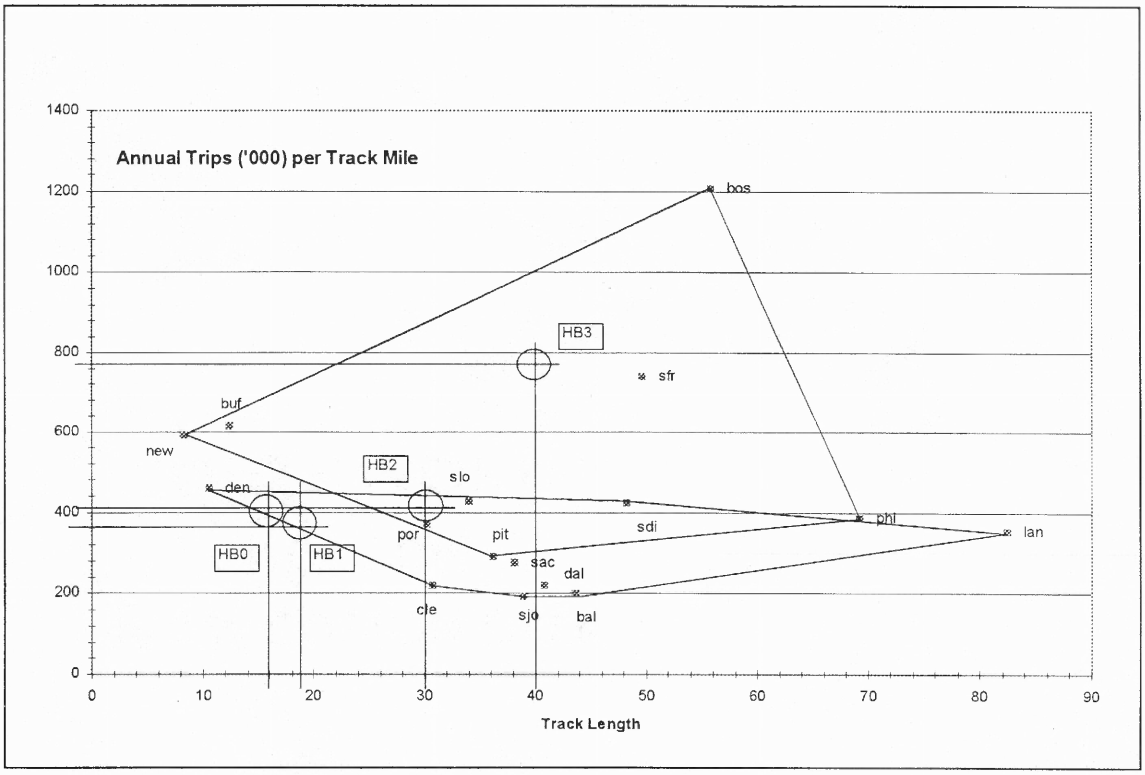

Figure 20 Density of Demand versus Track Length – Light Rail

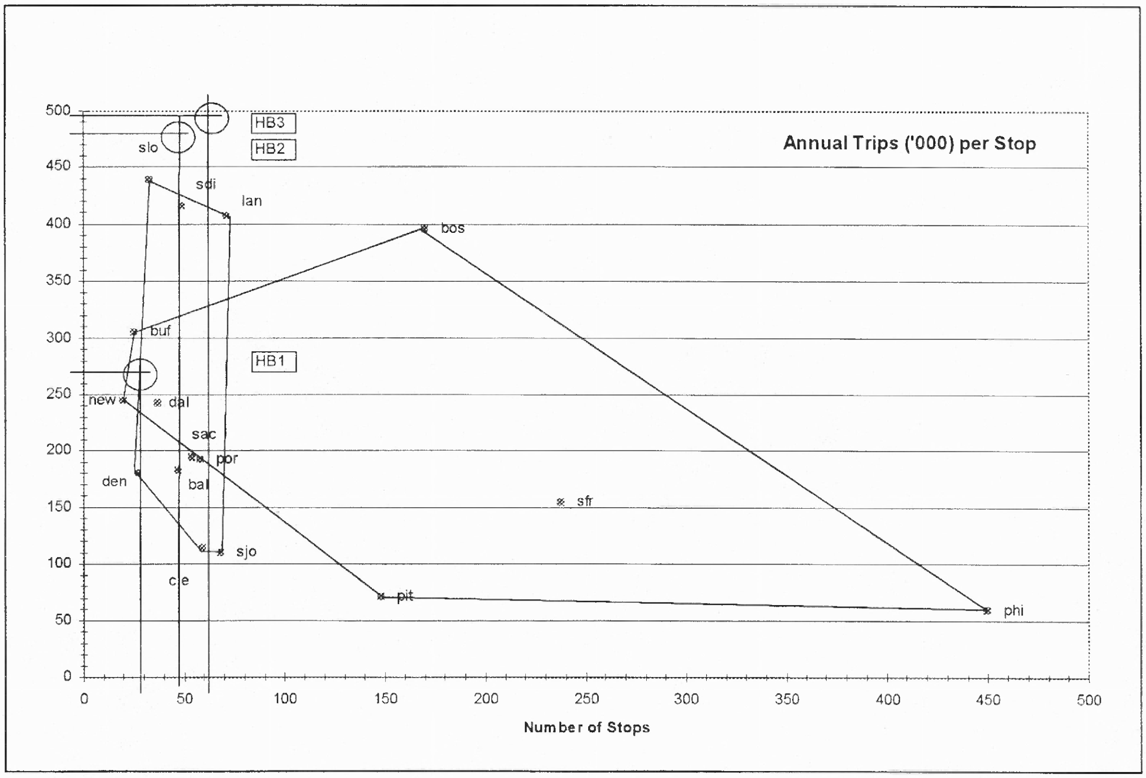

Figure 21 Density of Demand versus Number of Stops – Light Rail

Heavy Rail

Figure 22 shows that the ratio stations per track mile determines the difference between traditional and newer heavy rails. Traditional systems tend to increase their ratio stations per track mile with increases in track length. Newer systems tend to decrease their ratio stations per track mile with increases in track length, similar to the case of light rail. Notice that San Juan falls near the overlapping zone of both groups.

Figure 23 shows that traditional systems are almost completely separated from the newer systems with higher demand per station in a short range of the graph while traditional systems have lower demand per station for a broader range of size. PATH has exceptionally higher demand per station than any other system. The San Juan system appears small with 15 stations and near the area of newer systems, so high demand per station is expected.

5.5.3 Ratios Related with Fleet Size Planning (Blocking)

Light Rail

Blocking consists of developing vehicle assignments to specific routes. Consistency of blocking checks the density of demand per vehicle, the intensity of use of vehicles, the effectiveness ratio of trips per vehicle revenue mile, and the technical ratios of vehicles per track length and per stop. Figure 24 shows that newer systems can be less effective than traditional systems while effectiveness in traditional systems tends to increase with fleet size. Effectiveness planned for the Hudson Berger in stages 2 and 3 appear far higher than any observed efficient system in existence. Hudson Bergen may need more vehicles to cope with the demand of stages 2, 3. Figure 25 shows more signs of technical differences between traditional and newer groups. Newer systems use vehicles more intensely than traditional systems, while traditional systems tend to decrease the intensity of use of vehicles when fleet size increases. Also, Hudson-Bergen falls short in the intensity of use of vehicles and therefore it would need to adjust its density of service or to adjust its spare ratio assumed here as zero.

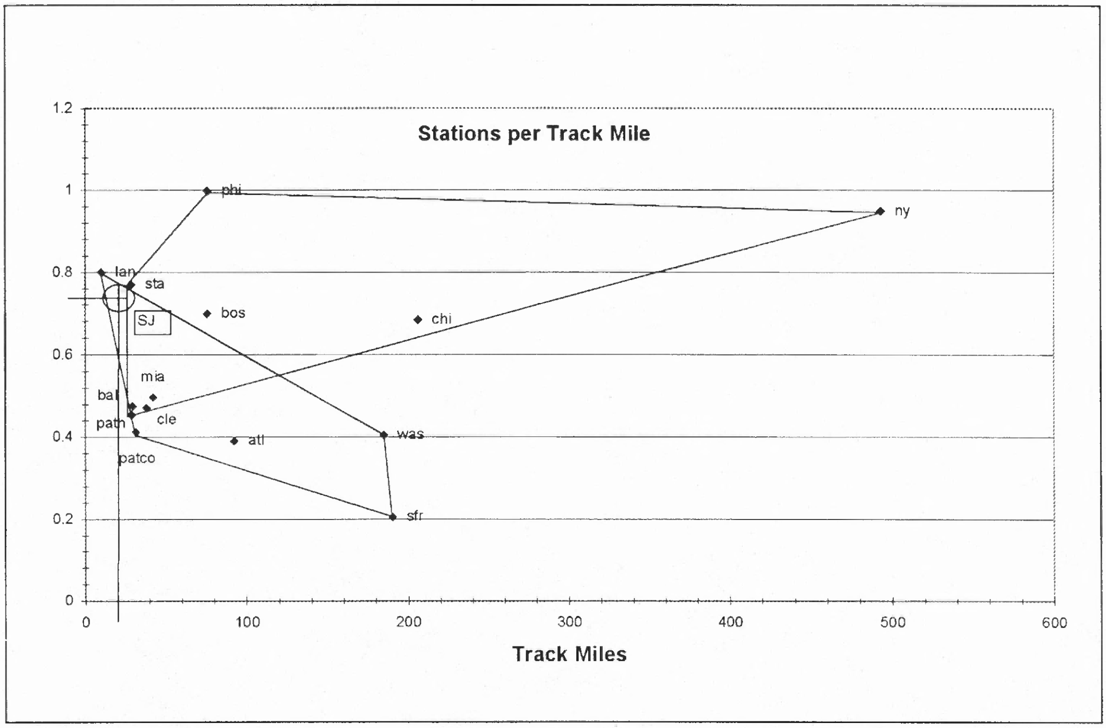

Figure 22 Ratio Stations per Track Mile versus Track Length – Heavy Rail

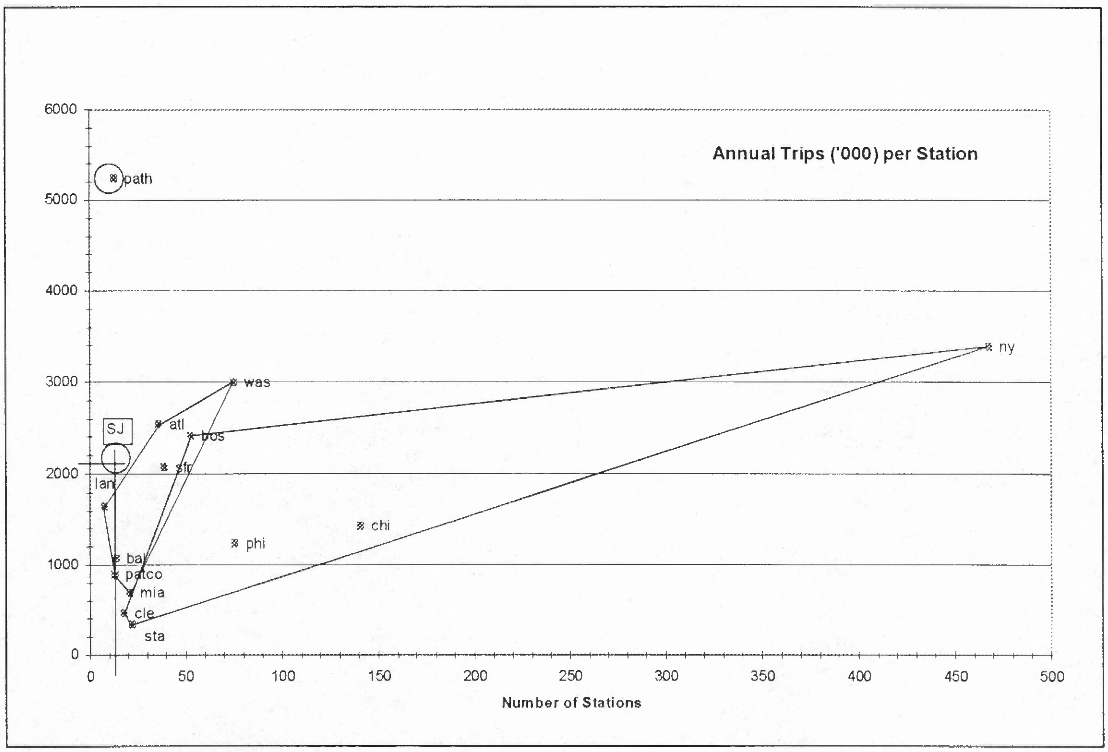

Figure 23 Density of Demand versus number of Stations – Heavy Rail

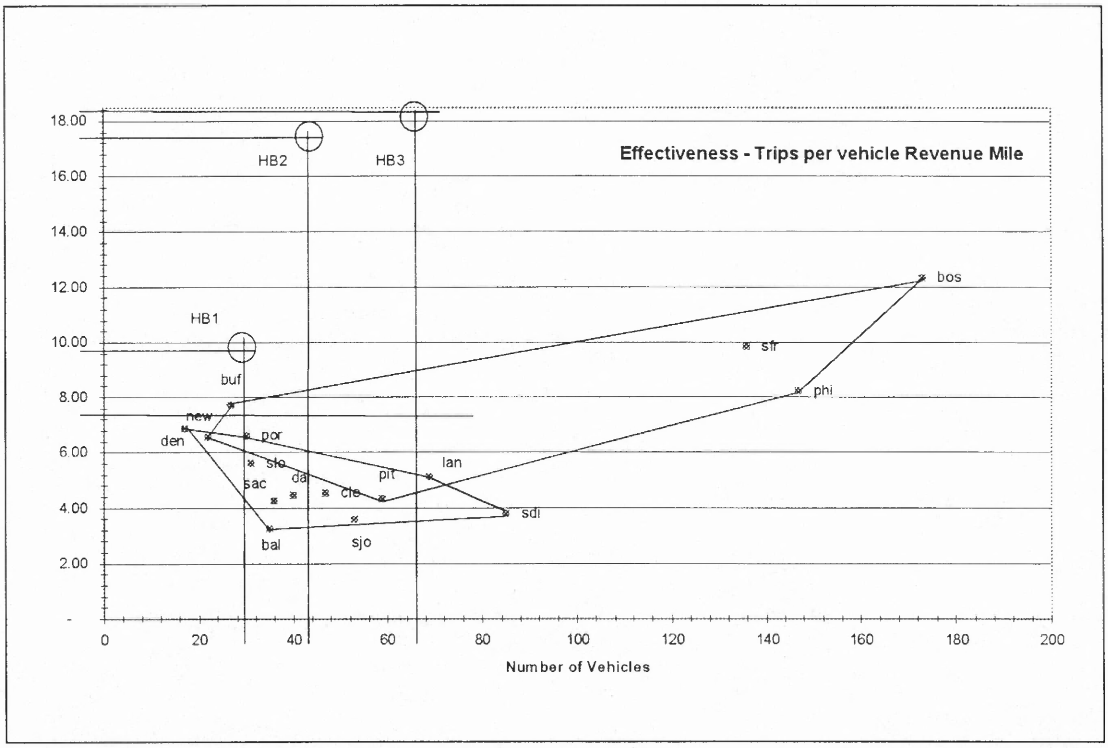

Figure 24 Effectiveness (TRIPS per VRM) versus Fleet Size – Light Rail

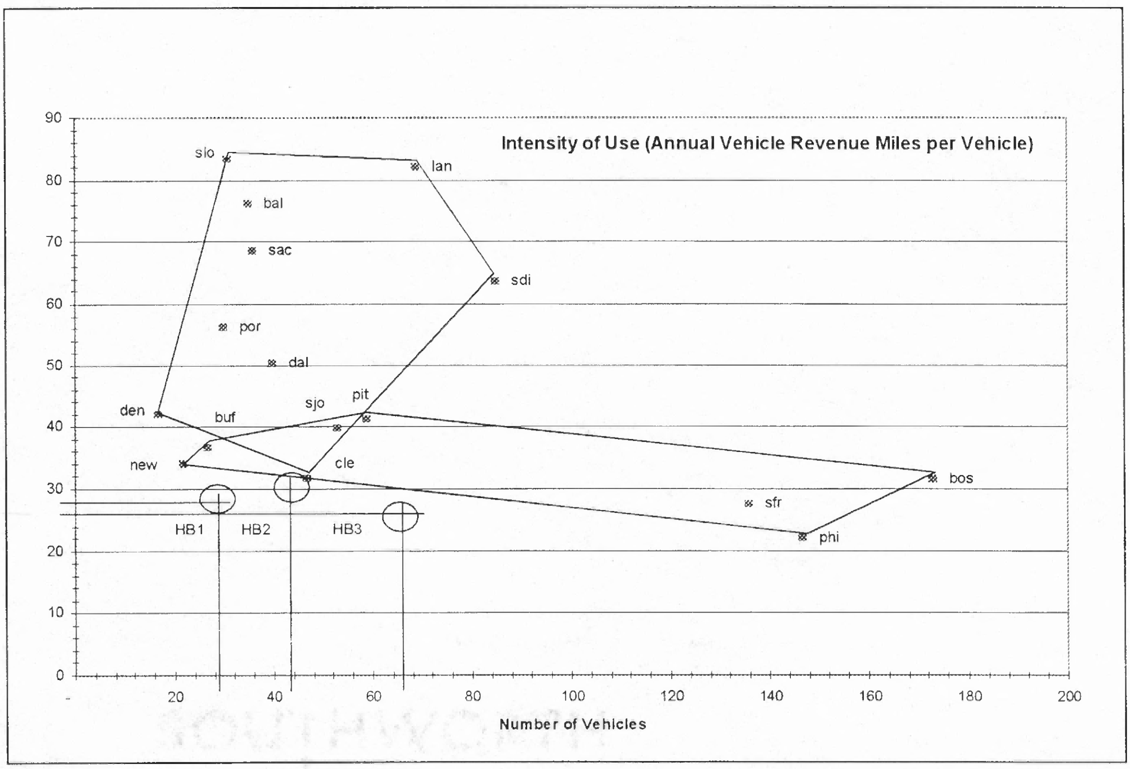

Figure 25 Intensity of Use of Vehicles versus Fleet Size - Light Rail

Figure 26 shows further evidence of the technical difference between traditional and newer systems. Traditional systems use more vehicles per track length than newer systems. Notice that Hudson-Bergen operates in the small overlapping zone between traditional and newer light rails. Currently, Hudson Bergen works with more vehicles per track mile than most of the newer systems. Figure 27 presents the intensity in the use of vehicles versus the ratio stops per track mile. Newer systems are clearly located at a lower number of stops per track mile but with more intense use of vehicles. Traditional systems work with higher number of stops per track mile but less intense use of vehicles. Consistently, Hudson Bergen shows that the current density of service will not be maintained if the system is to be as intense as others.

Heavy Rail

Figure 28 shows that the areas of newer and traditional heavy rails suggest a differentiated behavior between both groups. Newer systems tend to decrease their effectiveness when working at larger fleet size while traditional systems tend to increase effectiveness when working with larger fleet size. San Juan heavy rail is a small system that seems to be planned as effective as the most effective of the newer systems. Figure 29 shows that newer heavy rails tend to make more intense use of vehicles than traditional systems. The San Juan system seems to be designed more like a newer system than a traditional one. Figure 30 describes that newer heavy rails have less stations but higher number of vehicles per station. Traditional systems have more stations but work with a smaller ratio of vehicles per station although the ratio increases with fleet size. The PATH system behaves as an outlier due to its exceptionally higher number of vehicles per station. The San Juan system seems to be in between the newer and the traditional systems.

5.5.4 Ratios Related with Labor Force Design (Runcutting)

Light Rail

Figure 31 shows the assumed intensity of use of labor hours in operations per vehicle for Hudson Bergen. They are based on similarities with Newark, Dallas, or an average of both. Under any of the assumptions of the systems is near the range of current light rails. Figure 32 shows that Hudson-Bergen assumptions of labor with respect to vehicles are far from the range of existing efficient operations. Figure 33 shows that traditional light rails increase the ratio of labor in operations when fleet size increases, while newer systems decrease the ratio when fleet size increases. Los Angeles appears to be an outlier in this graph.

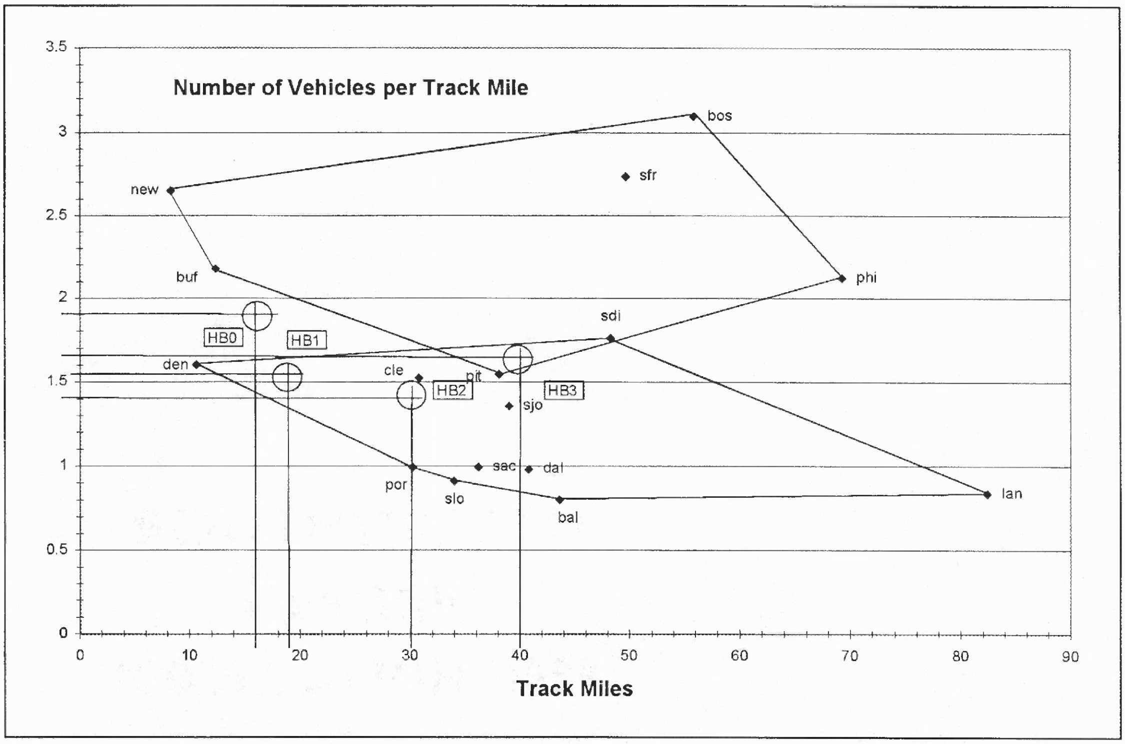

Figure 26 Ratio Vehicles per Track Mile versus Track Length – Light Rail

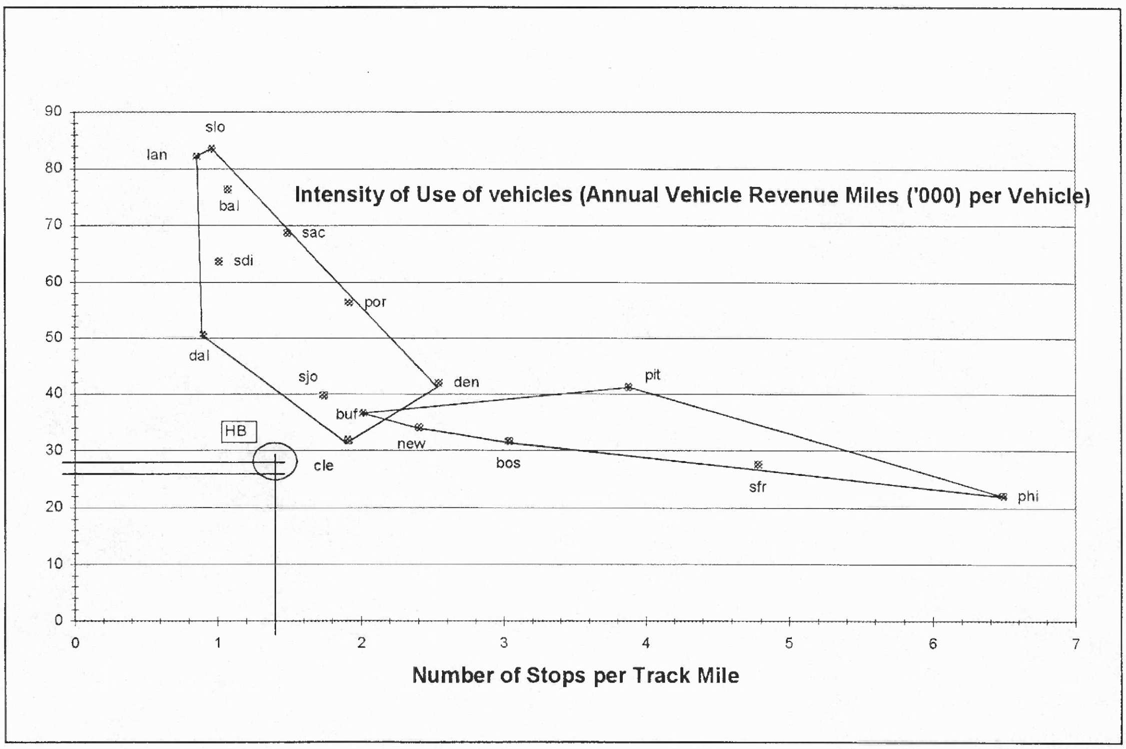

Figure 27 Intensity of Use of Vehicles versus the Ratio Stops per Track Mile – Light Rail

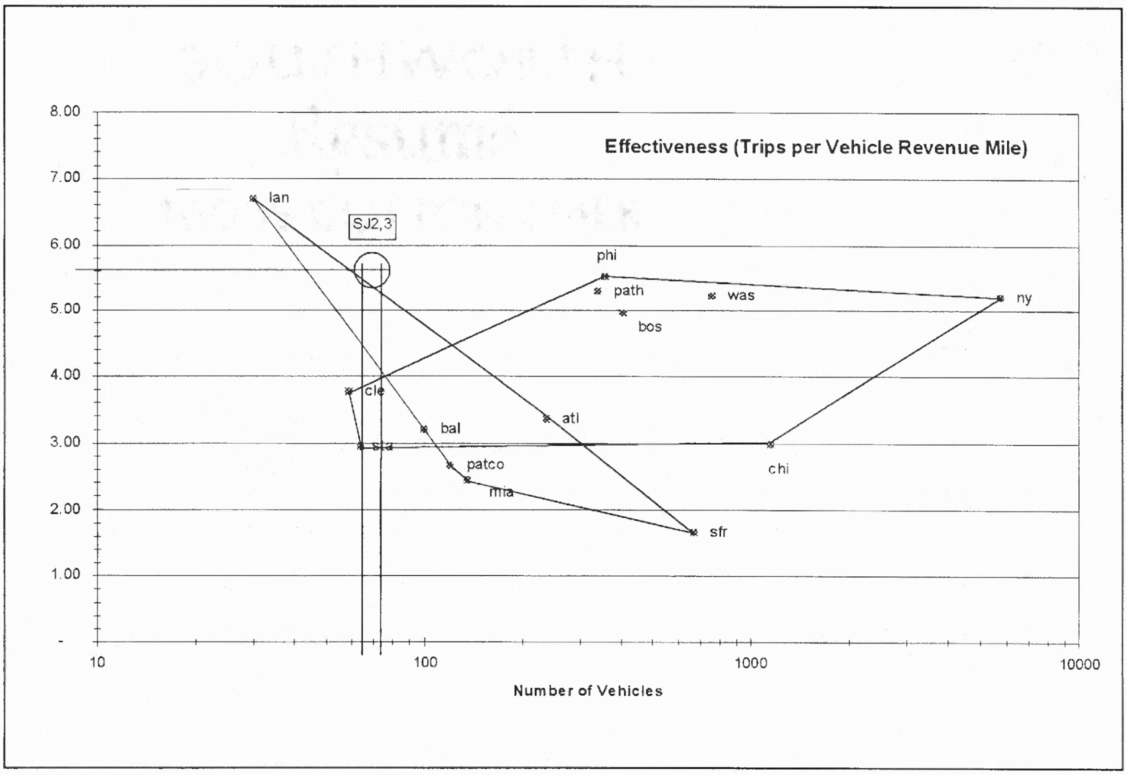

Figure 28 Effectiveness versus Fleet Size – Heavy Rail

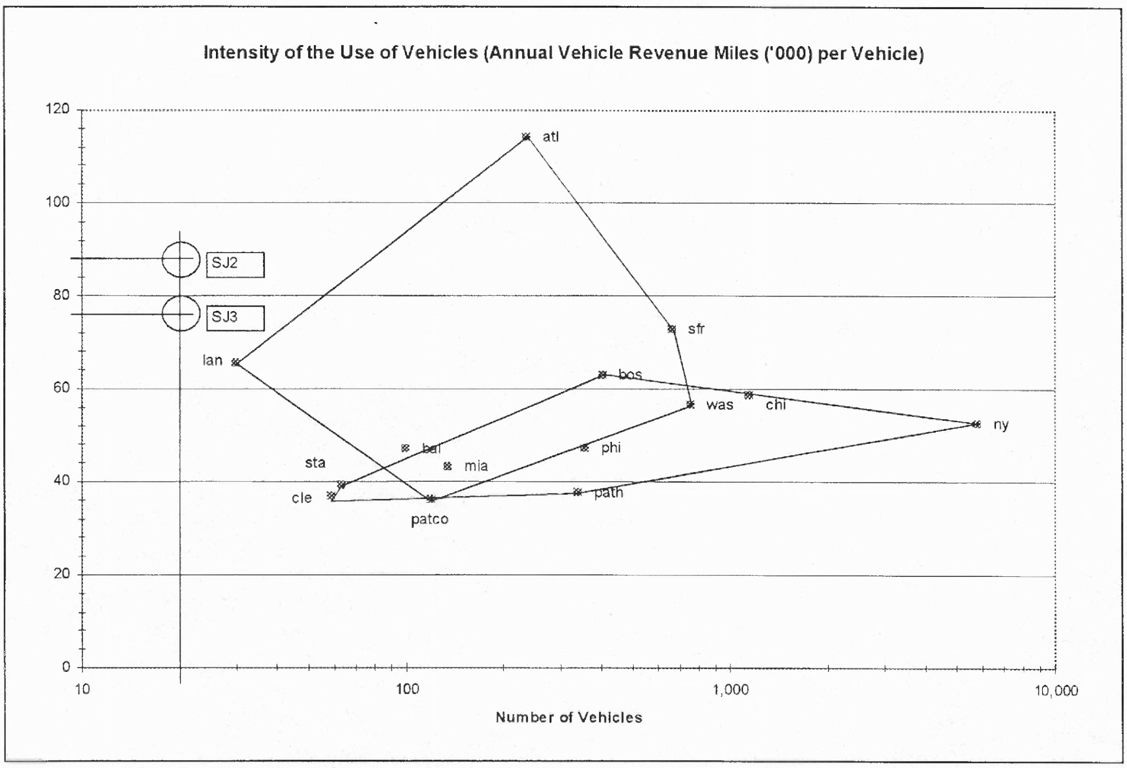

Figure 29 Intensity of Use of Vehicles versus Fleet Size – Heavy Rail

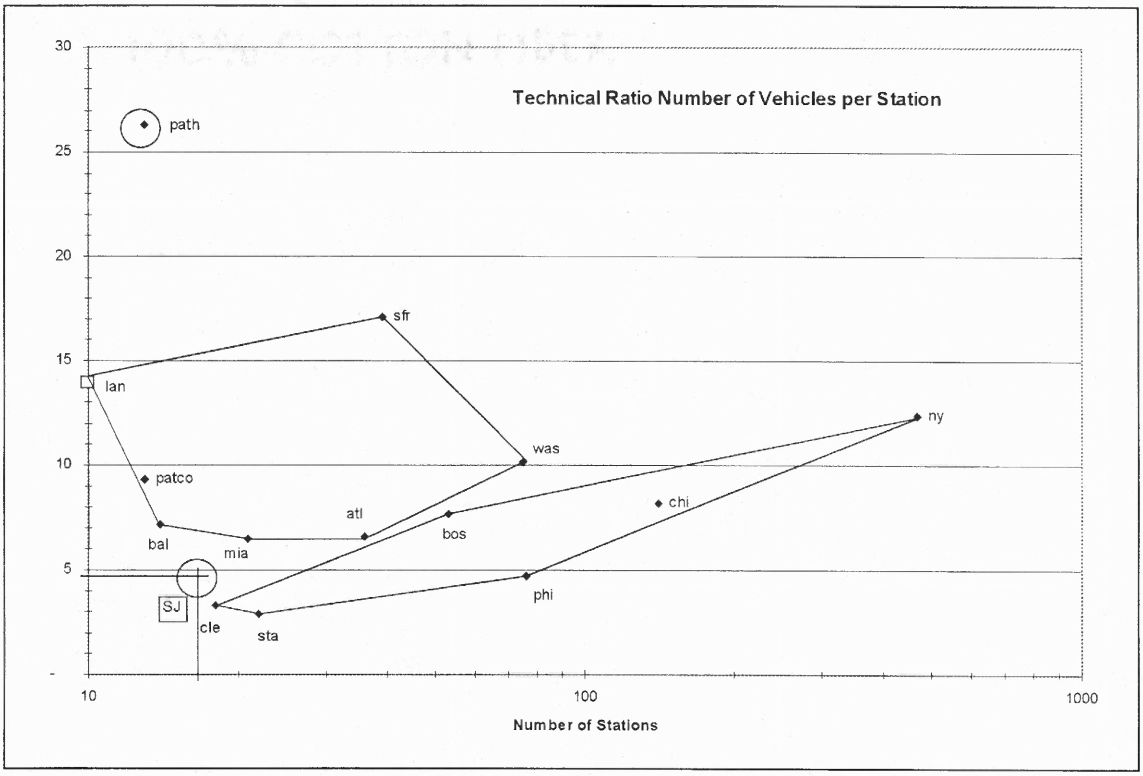

Figure 30 Ratio Vehicles per Station versus Number of Stations – Heavy Rail

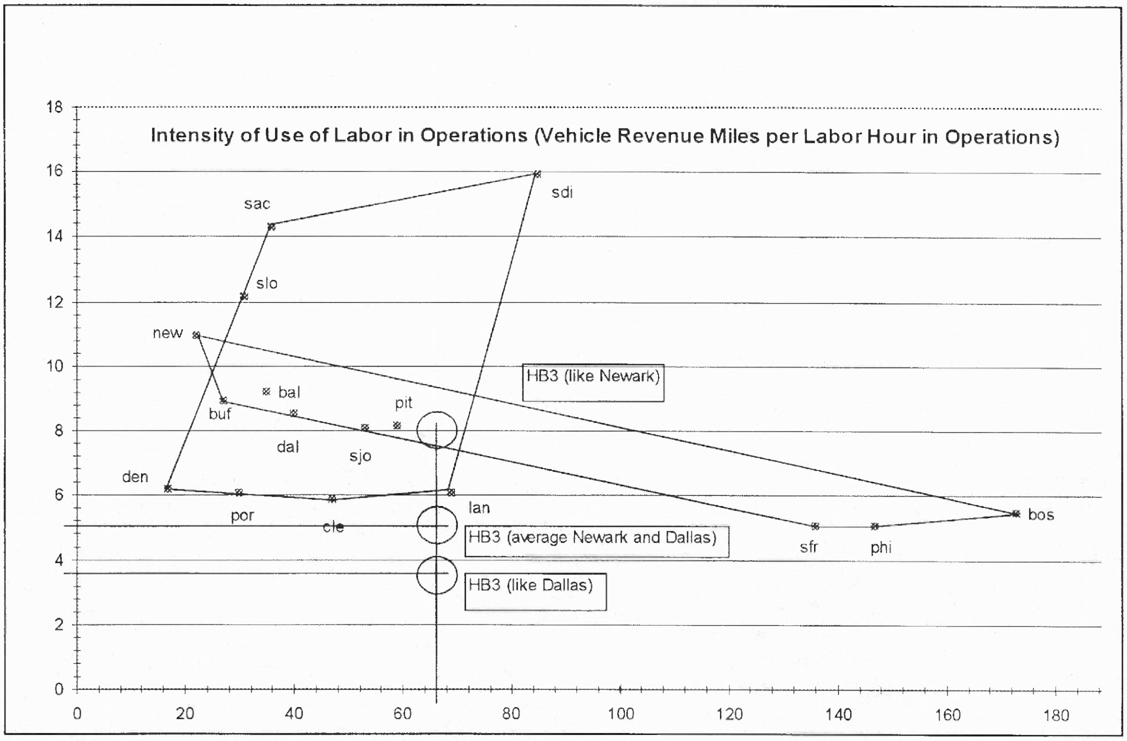

Figure 31 Intensity of Use of Labor in Operations versus Fleet Size – Light Rail

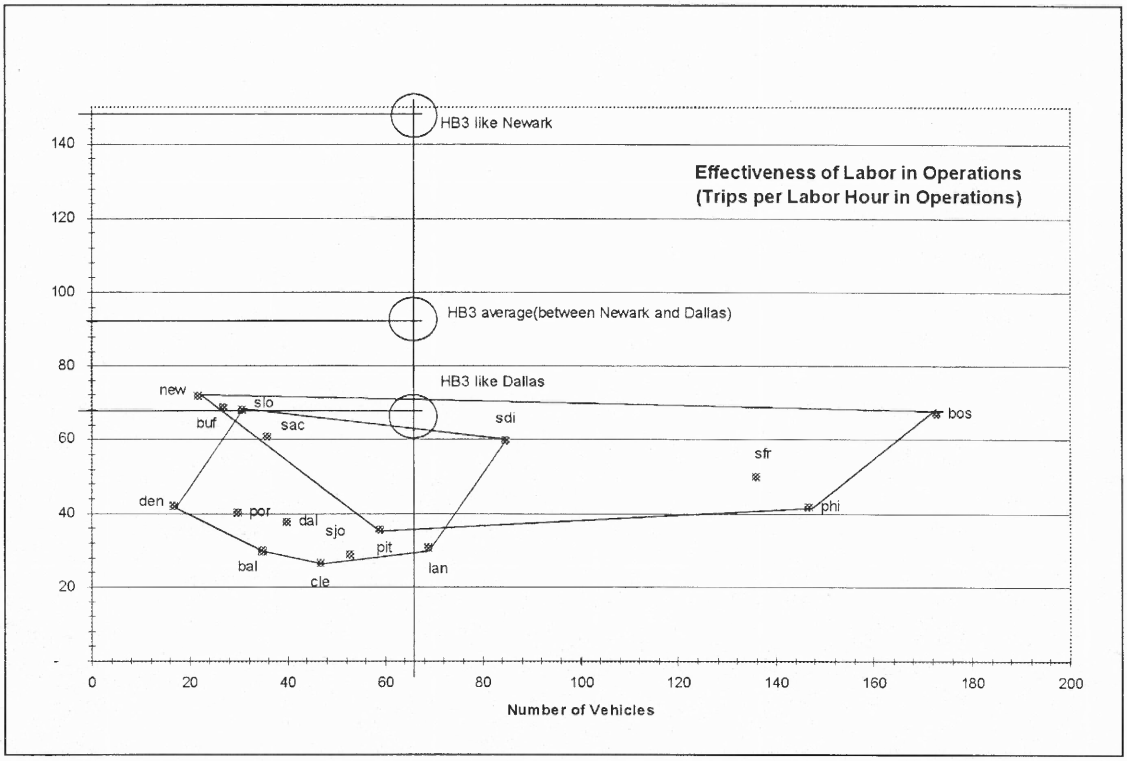

Figure 32 Trips per Labor Hour in Operations versus Fleet Size – Light Rail

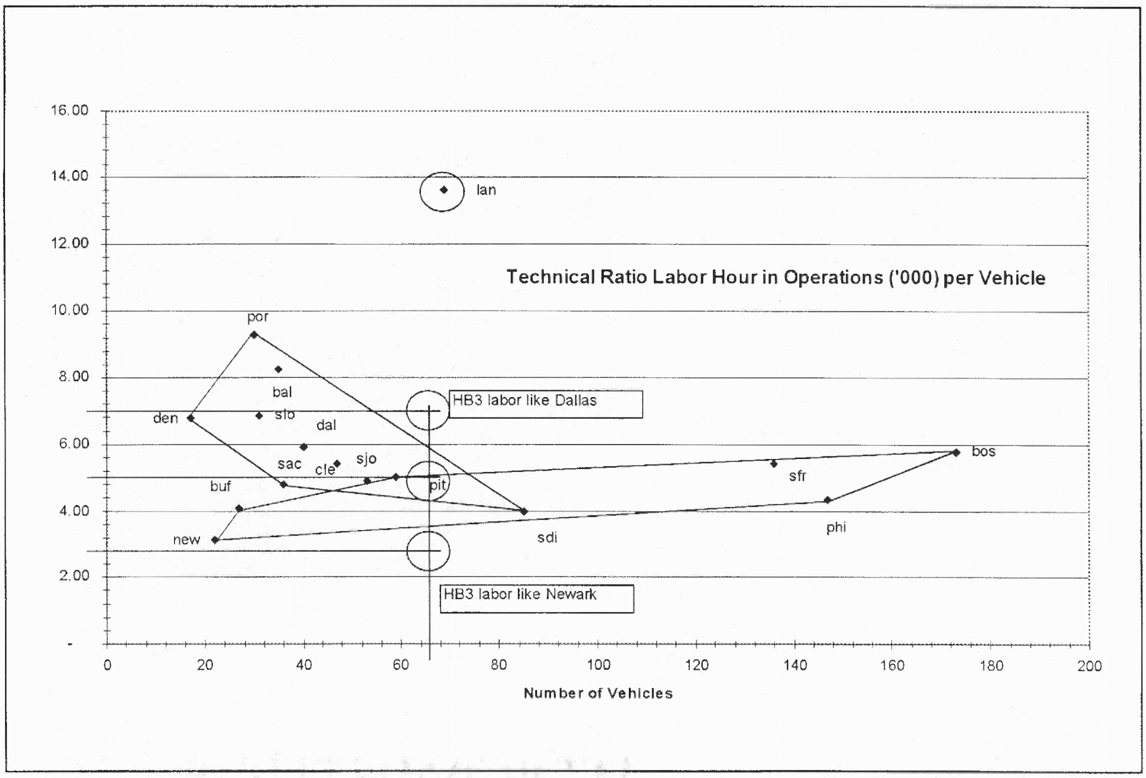

Figure 33 Ratio Labor in Operations per Vehicle versus Fleet Size – Light Rail

Heavy Rails

Figure 34 shows that San Juan works near the range of newer heavy rails in the intensity of use of labor hours versus fleet size. Figure 35 shows that the San Juan figures are above any agency. This dissertation assumes that San Juan uses a labor force ratio to fleet size similar to the average of the heavy rail industry in 1992. Notice the high productivity of *TRIPS* similar to PATH and New York. Finally, Figure 36 shows that there is no difference between traditional and newer heavy rails in the relation between labor force and fleet size.

5.6 Application of 2F-DEA to New Rail Projects

The new rail projects were designed to expand in stages. Four stages were considered for Hudson-Bergen light rail and one initial stage for San Juan heavy rail. For each stage there are planned a number of stations, a number of vehicles, and so on. Also, data on labor is assumed based on similarities to current operation or to the average of the industry. The following is the list of the cases considered.

5.6.1 Hudson-Bergen Light Rail

This application considers four segments, the initial operating segment as of May 2000 from Exchange Place in Jersey City to 34th Street in Bayonne (New Jersey). The first segment extends the northern tip to Hoboken as planned to operate in 2001, the second, and the third segments as published (US-DOT-FTA 1999). In this section, a case is feasible if it operates within the range of efficient current operations. Table 61 shows three cases, of the initial and first segments, that are feasible because they do not exceed observed productivity benchmarks. To achieve feasibility, Hudson-Bergen would need more or larger *cars* as well as labor resources as intensive as in the Dallas operations. Its efficient peers are Boston, St. Louis, Newark and San Diego. Feasible productivity benchmarks are; 8.4 *VRM/loper*, 6.6 *VRM/lmain*, 87 *TRIPS/loper*, and 39.5 thousands *TRIPS/cars*.

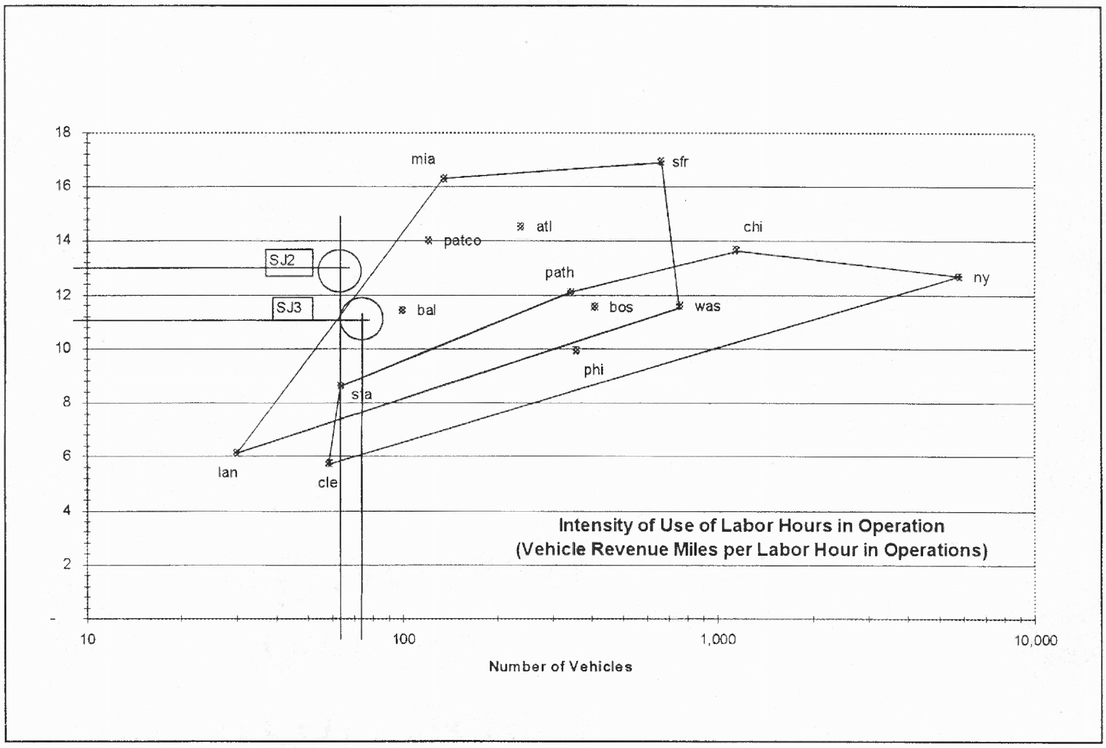

Figure 34 Intensity of Use of Labor in Operations versus Fleet Size – Heavy Rail

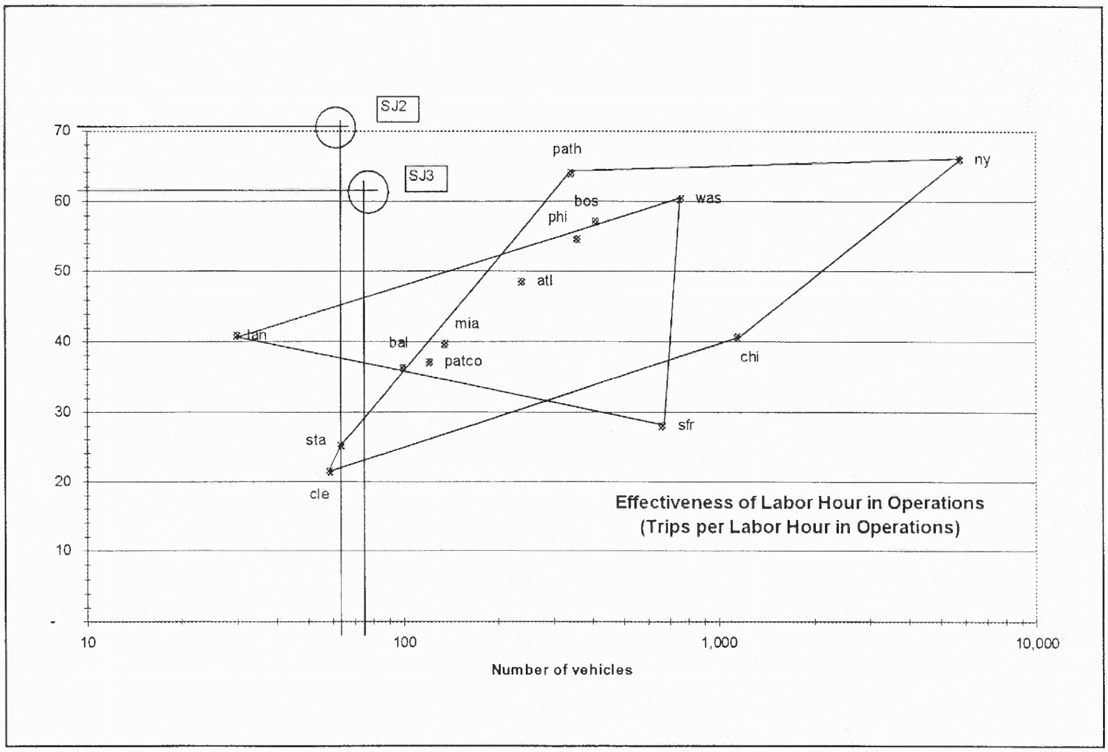

Figure 35 Trips per Labor Hour in Operations versus Fleet Size – Heavy Rail

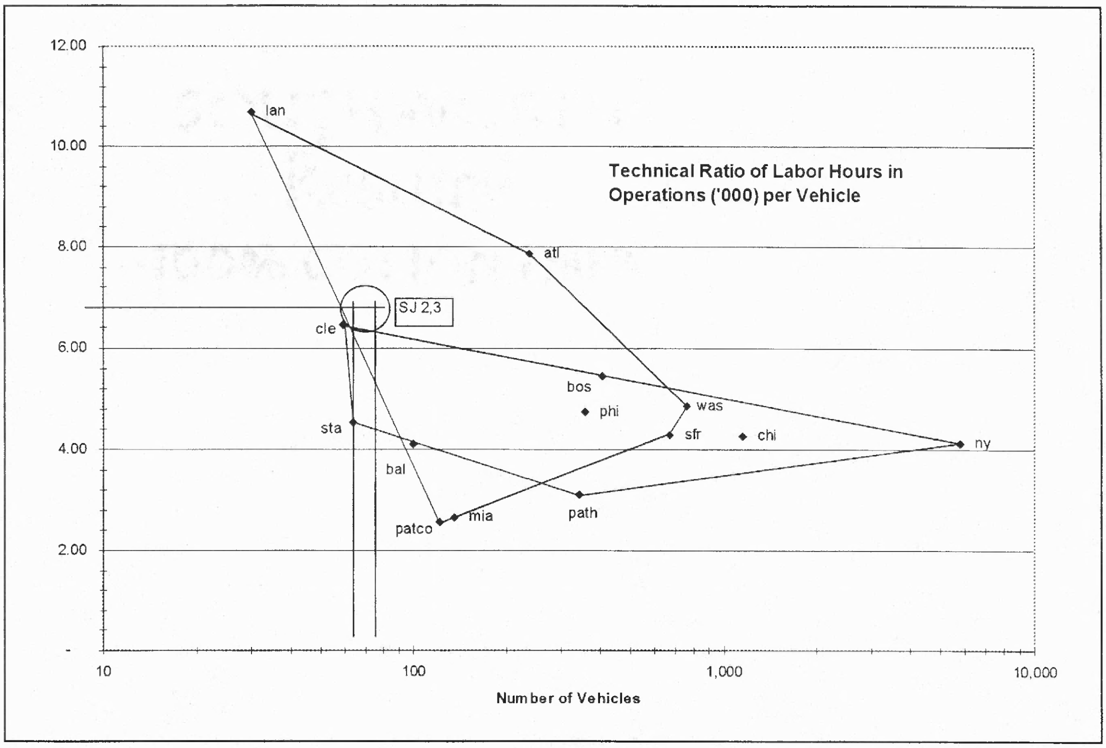

Figure 36 Ratio of Labor in Operations per Vehicle versus Fleet Size – Heavy Rail

Table 61 Hudson-Bergen Light Rail – Feasibility by using Results of DEA(1)

Case (*)	*VRM/loper*	*VRM/lmain*	*TRIPS/loper*	*TRIPS/cars*	*Feasible?*
3NJ	No	No	No	No	No
3DA				No	No
3AV			No	No	No
2NJ	No	No	No	No	No
2DA				No	No
2AV			No	No	No
1NJ	No	No			No
1DA					***YES***
1AV		No			No
0Njcon	No	No			No
0Dacon		No			No
0Avcon	No				No
0Njop	No	No			No
0Daop					***YES***
0Avop					***YES***
Efficient peers	*Boston St. Louis*	*Boston Newark*	*Boston San Diego*	*Boston St. Louis*	
Productivity benchmark	*8.4 per labor hour*	*6.6 per labor hour*	*87 per labor hour*	*39.5 000's per vehicle*	

(*) Appendix C contains the definition of these cases.

Table 62 displays the advantage factor of Hudson-Bergen light rail and shows that its operating conditions are not as advantageous as the rest of the transit agencies but it is at least similar to Boston, San Francisco and Philadelphia as registered in Table 22 of page 72 of this dissertation.

Table 62 Hudson-Bergen Light Rail – Advantage Factor of Operating Conditions

Case	*1DA*	*0Daop*	*0Avop*
Labor in operations		*0.78*	
Labor in maintenance		*0.73*	
Energy		1.22	
Vehicles		*0.85*	
Track length	1.30	*0.81*	*0.85*

Table 63 presents the efficiency of the three feasible cases of Hudson-Bergen. Planning figures assume technical efficiency while implying a certain degree of scale inefficiency.

Table 63 Hudson-Bergen Light Rail - Efficiency by using DEA(2) (%)

Case	*Technical efficiency*	*Overall efficiency*
1DA	100.0	86.2
0Daop	96.2	76.3
0Avop	100.0	86.2

5.6.2 San Juan Heavy Rail

San Juan heavy rail planning figures that correspond to a unique initial stage that has been publicized. Appendix C indicates the cases included in this analysis. Table 64 indicates that two out of six San Juan cases are feasible, they consider 15,000 daily trips and 64 or 74 *cars*. As a result there are three benchmarks of *VRM* and *TRIPS* productivity ratios that can be used to check future operations of the project. Notice that planned figures of San Juan are within the acceptable ranges for *stats*, *cars* or *rails*, but not of the average ratios assumed for *loper* and *lmain*. San Juan heavy rail will need more than average labor resources, *loper* and *lmain* per *VRM* and per *TRIPS* to be feasible.

Table 64 San Juan Heavy Rail – Feasibility by using Results of DEA(1)

Case (*)	*VRM/loper*	*TRIPS/loper*	*TRIPS/lmain*	*Conclusion, Feasible?*
14low	No	No		No
14high	No	No	No	No
64low				***YES***
64high	No	No		No
74low				***YES***
74high	No	No		No
Efficient peers	*Boston New York*	*Atlanta Washington*	*Chicago*	
Productivity benchmark	*13.40*	*47.0*	*107.0*	

(*) Appendix C contains the definition of these cases.

Table 65 shows the advantage factor of San Juan heavy rail and shows that it enjoys very advantageous operating conditions to develop high productivity in five inputs.

Table 65 San Juan Heavy Rail – Advantage Factor of Operating Conditions

Case	*64low & 74low*
Labor in operations	1.04
Labor in maintenance	1.14
Energy	1.19
Track Length	1.37
Stations	1.09

Table 66 indicates that the resources planned for San Juan assume technical efficiency and overall efficiency.

Table 66 San Juan Heavy Rail - Efficiency by using DEA(2) (%)

Case	*Technical efficiency*	*Overall efficiency*
64low	100	94
74low	100	85

5.7 Conclusions on the Results

The results of the application of 2F-DEA indicate that the new model extracted the effect of heterogeneous conditions achieving fairer and more accurate estimation of efficiency, with a minimum of additional effort. Additionally, 2F-DEA provided productivity benchmarks tailored to the operating conditions of individual agencies. The new model also provided the advantage factor in operating conditions of an agency with respect to the average of the industry.

Also, this chapter calculated the correlation of productivity with operating conditions including for the first time those related to network form. Those network descriptors that refer to the access of passengers explained productivity of track miles in the same dimension as socioeconomic variables of the served area. Besides, connectivity indices explained productivity of track miles and of stations in the case of heavy rail in a dimension associated with auto availability. Factor analysis organized operating conditions in few well-defined dimensions; conditions of the served area, conditions of the metropolitan area, auto availability, and income and rush hour concentration of demand.

Efficiency is high in light rail (89 percent) and in heavy rail (92 percent). The opportunity for improvement is $ 2 million for light rail and $ 79 million for heavy rail in unachieved revenues. The equivalent improvement in the use of resources reaches $ 14 million in possible annual savings in expenses for light rail and $ 54 million for heavy rail.

Cluster analysis left a level of between 5 and 36 percent of productivity differences and between 13 and 27 percent of efficiency differences attributable to heterogeneous conditions, indicating that the effect of operating conditions continued within the cluster at considerable levels. Conventional DEA underestimates efficiency by 17 percent in light rail and by 11 percent in heavy rail, justifying the development of 2F-DEA. Finally, 2F-DEA extracted the effect of the operating conditions before the estimation of efficiency up to the point that none of the correlation between efficiency and operating conditions reached 0.5 or higher.

The results of productivity analysis made evident the existence of two techniques of production, one adopted by traditional (older) transit agencies and the other by newer. Traditional agencies specialize in the production of trips with higher use of their track length, while newer systems specialize in the production of vehicle revenue miles with intense use of vehicles and stations. The inputs that are sources of increasing returns to scale are the use of the rail tracks and the use of energy. Results of 2F-DEA built a method for investment priority for expansion in which light rail would achieve high cost effectiveness in expanding number of vehicles, labor force in operations and administration, and, in the case of smaller systems, expanding rail tracks. Heavy rail achieves the highest cost effectiveness in expanding stations, labor force in operations, and, in the case of larger systems, expanding rail tracks.

Productivity analysis can check the consistency and feasibility of new rail projects. For example, Hudson Bergen light rail faces a demand typical of a traditional system while it plans a supply typical of a newer system. It would be advisable to study if more cars would be necessary for stages 2 and 3. Another example, San Juan heavy rail is planned like a newer system, although by some indicators a high production of trips per labor in operations is expected as in PATH or New York. Additional evidence on the production techniques of rail transit indicates that not only ratios of stops per track mile differ between traditional and newer systems, but also that the difference increases with size. Finally, feasibility analysis found that the first segment of Hudson Bergen could have productivity benchmarks near those of Boston and that their advantage factor indicates low advantage of operating conditions. The San Juan labor force would achieve productivity benchmarks of vehicle revenue miles like traditional systems and its advantage factor indicates high advantage in operating conditions.

CHAPTER 6

CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

This dissertation improves the accuracy and fairness in the estimation of transit productivity efficiency, a point that motivates major policy decisions on privatization, deregulation, contracting out, expansions, etc. Conventional methods underestimate efficiency under heterogeneous operating conditions because all observations refer to the performance of the most advantageous operating conditions while being unfair to all other agencies. The problem of transit productivity analysis arose because of the fact that transit operates under heterogeneous conditions with evident influence on productivity while current methods of productivity analysis do not calculate this influence in an adequate manner.

This dissertation discussed several methods of productivity analysis finding their limitations in the case of heterogeneous conditions. Cluster analysis reduced but did not eliminate the effect of heterogeneous conditions within the clusters. Empirical equations used an uncertain set of variables with the possible exclusion of relevant ones or the inclusion of irrelevant ones. Current Two-Step methods forget the estimation of internal inefficiency or assume the contradiction that efficiency is stochastic and deterministic at the same time. Other methods include operating conditions as if they were other inputs—that is not true—generating a source of redundancy with those inputs affected by the operating conditions. A theoretically correct method includes operating conditions in constraints for one-step estimation but becomes complicated for the case of many operating conditions, and methods to simplify it hold only for particular cases. Consequently, the dissertation found that a new method was necessary for productivity analysis for the case of heterogeneous conditions.

The approach of the new model is based on the Reversed Two-Step DEA approach, a method that estimates first the productivity differences caused by heterogeneous conditions and then it estimates the productivity efficiency. The formulation of 2F-DEA departs from (Ray 1988) who correctly assumed that operating conditions impose limits to the production process as if they were technological strata. The assumption of independence between the effect of operating conditions with scale and with efficiency complements the formulation of 2F-DEA. In a preliminary step, factor analysis gathers the relevant set of operating conditions for the analysis. A transforming multiplier is the connector between DEA(1) (applied to each productivity ratio versus operating conditions) and DEA(2) (applied to outputs versus adjusted inputs). The transforming multiplier is the ratio of productivity of the agencies at the frontier calculated by DEA(1). It is used to adjust those inputs included in DEA(2). The model 2F-DEA enriches transit productivity analysis with two new indicators, productivity benchmarks and advantage factors. Productivity benchmarks are standards tailored to the unique reality of each individual agency while the advantage factors calculate the degree of goodness of the operating conditions of one agency with respect to the industry.

The application of 2F-DEA found that those operating conditions of the network form do correlate with transit productivity, including access density, network density, comprehensive accessibility, connectivity index, circuit availability, stop spacing, and density of service. Factor analysis reduced those operating conditions that correlated with transit productivity to few main factors. They are the served area conditions computed within 0.3 miles of the rail station, the metropolitan area conditions computed for the whole metropolitan area, the car factor that refers to auto availability, income and rush hour concentration of the demand, and stop spacing in the case of heavy rail.

The first stage DEA(1) calculated the productivity benchmarks for individual agencies indicating that some agencies could reach standards of vehicle revenue miles and of passenger trips well below other agencies adding to the evidence of the increased fairness of comparison of 2F-DEA. The advantage factors of light rail showed that Pittsburgh and Cleveland operated on less advantageous conditions than the industry in all their inputs, while this was true for the heavy rail systems of Miami, Baltimore, Cleveland, and Staten Island.

The second stage DEA(2) estimated that light rail systems are 89 percent efficient on the average, and identified two efficient agencies, San Francisco and St. Louis. The room for improvement is still considerable. Light rail systems could increase their revenues by $ 2 million per year, at a 55-cent average fare, or save $ 14 millions from the annual expenses of the used resources. The new method estimated the overall efficiency of heavy rail systems at 92 percent. Four agencies, New York, Atlanta, San Francisco, and PATH, reached the efficiency frontier. In this case, the potential for improvement reaches $ 79 million per year in revenues at a 96-cent average fare, or an annual expense savings of $ 54 million.

The results of 2F-DEA were very useful in interpreting the estimated production function. Returns to the consumption of a single input indicated sources for increasing returns to scale in heavy rail because the most intense use of the tracks occurred at longer networks, while in light rail this source of increasing returns to scale does not exist. Since larger light rails operate extensively on the streets, these systems did not show increasing returns in the use of rail tracks.

The analysis of returns to scale of light rail indicated two optimal sizes associated with the intensity of production of two outputs, trips and vehicle revenue miles. The optimal trip intensive size corresponds to San Francisco (50-directional mile network) and the optimal vehicle-mile intensive size corresponds to St. Louis (35-directional mile network and 30 to 50-vehicle fleet). The analysis of returns to scale of heavy rail indicated that the optimal size is between a 300 to 600-vehicle fleet and a 100 to 200-directional mile network, with representative systems being Miami, Atlanta, and San Francisco. The other optimal size corresponds to New York, the largest system by far, consistent with the existence of increasing returns to scale in heavy rail.

Further evidence of the different techniques of production was demonstrated by grouping all agencies around two groups differentiated by the year of their opening. Traditional (older) systems use intensely their rail tracks while the newer systems use intensely their vehicles and their stations. Analysis of the substitutability of inputs found a slight difference between heavy rail and light rail. While in light rail most of the inputs are complementary, in heavy rail most of them are substitutable.

The linear production function provided a method for prioritizing the expansion of inputs, based on their marginal productivity and cost effectiveness. A list of the most cost effective ways to expand light rail includes the purchase of more vehicles in Portland and Baltimore, the hiring of more operators in Denver and St. Louis, and the expansion of the rail tracks in Denver and Newark, among others. The most cost effective ways to expand heavy rail includes the building of more stations in Washington and San Francisco, the purchasing of more vehicles in Los Angeles and Washington, the hiring of more operators in PATCO and Boston and the expansion of the rail tracks in Atlanta and Boston.

The indirect contribution of productivity analysis to transit operations planning provided more information on the techniques of production. There is evidence that the different production techniques of rail transit have their origin in the different characteristics of their demand. In the graphic of trips per household versus autos per household, traditional and newer light rail systems occupy two separate areas. Furthermore, the ratios of stops per track mile for traditional systems are not only higher, but they also increase with network length, while, for newer systems, these ratios are smaller and decrease with network length.

The analysis of the planned figures for systems under development, indicated that the Hudson-Bergen light rail may face operating conditions similar to traditional systems (high density of demand), and a supply similar to newer systems (low density of service). On the other hand, the San Juan heavy rail is planned like a newer system although some demand indicators are near those of traditional systems. Finally, 2F-DEA estimated achievable productivity benchmarks and advantage factors for the new rail projects. Hudson Bergen operates in less advantageous operating conditions for almost all inputs, while the San Juan heavy rail operates in more advantageous operating conditions.

Suggestions for Further Research

The application of 2F-DEA to a single output model using the output measure of passenger-miles would be the most desirable extension of this research. This is an immediate application possible for rail as well as for bus transit. Another research area is the application of Monte Carlo analyses to evaluate the empirical accuracy of 2F-DEA in comparison to other methods. An additional research area is the relaxation of the assumptions of 2F-DEA to allow for input-specific shifts in the production frontier and to allow for variable returns to scale in the relation between the productivity frontier and operating conditions. The new models will apply a generalized 2F-DEA.

A necessary research is the generation of a database of indicators of connectivity between the evaluated systems and the other transportation modes to ensure a higher level of comprehensiveness. Another area is the generation of a database of attributes of inputs (automation, right of way, train formation capabilities, etc.) and of characteristics of outputs (comfort, safety, security, reliability, on-time performance, etc.) Another research area is the managerial application of 2F-DEA to transit performance evaluation to satisfy the most immediate needs of transit practitioners for optimal allocation of internal resources among alternative routes, modes, capital projects, etc.

A final research area is the further extension of the managerial application of 2F-DEA to facilitate those decision-making processes that are complex. An example is the implementation and integration of intelligent transportation systems (ITS) in transit operations. Decisions in ITS for transit may involve simultaneous decisions on technology, customer satisfaction, operating conditions effect, labor-management relations, and alternative financing. DEA models can provide simple, exact and stratified criteria that enrich the decision possibility set with a minimum effort in linear programming. In summary, the application of DEA to transit becomes more practical because the effect of heterogeneous operating conditions is isolated permitting an accurate evaluation of performance.

APPENDIX A

MODIFICATIONS TO THE RAIL TRANSIT NETWORKS OF THE NATIONAL TRANSPORTATION ATLAS

The National Transportation Atlas provided the geographic location of the rail networks and stations of rail systems, at the year 1997 or, in some cases, the future planned whole network. Before applying 2F-DEA, the networks were adapted to represent the operations at each of the years between 1984 and 1997. A special research traced the successive expansions and changes of each network that rendered the following list of modifications.

Heavy rail

New York-NYCT: Three stations opened in the Archer Avenue segment in 1988, two stations opened in the Long Island City CBD, and one in the Midtown area in 1989. In 1985, two stations closed in the Jamaica segment and one in 1995 in the Franklin Avenue segment.

Washington-WMATA: Eight stations did not operate during the period. Four stations opened in 1985, four in 1986, six in 1991, three in 1992, and four in 1994.

Chicago-CTA: In 1985 opened the O'Hare Airport station. In 1994 opened Orange line to Midway Airport. Green line closed during 1994-1995 for repairs. In the Loop, the Library station opened in 1997, in 1993 opened Lake Av. station linked with State station (red and blue lines), in 1995 opened Washington station, in 1989 opened Clark station, Madison station closed in 1995, and Quincy station closed 1985-1987 for renovations. A group of stations closed in the green line during 1994 for renovations of the line.

Boston-MBTA: In 1987 Orange line opened new alignment and stations to the south. In 1985 opened three stations of the red line to Harvard station. Add Mattapan high speed line.

Atlanta-MARTA: In 1985 opened five stations, one in 1987, three in 1988, four in 1993, and three in 1996.

Philadelphia-SEPTA: In 1986 Norristown High Speed line shut down for two months, operated limited and bus service for two months, and finally restored full service. In the early 1990's, the reconstruction program of the Frankford Elevated occurred during weekends. This dissertation considers 1986 and early 1990's as normal years (Vigrass 1990; Palmer 1998).

San Francisco-BART: Two stations opened in 1996 and three in 1997.

Miami-DCTA: Five stations opened in 1985 and one in 1989.

Baltimore-MMTA: Three stations opened in 1987 and two in 1995.

Los Angeles-LACMTA: Metro-rail began operations in 1993. Three stations opened in 1996.

Light Rail

Boston-MBTA: Add stops at street level. Modify branch to Arborway 1986 and 1989.

San Francisco-MUNI: Add stops at street level. J line extended to Balboa Park Transportation Center in 1990. Add F line and stations in 1995 with walking links to Market Street Tunnel stations.

Philadelphia-SEPTA: Add stops at street level to Green, Median, and Sharon Hill lines.

Los Angeles-LACMTA: Green line opened in 1996.

St. Louis-BSDA: Modify location of two stations at the Airport.

Portland-TCMTDO: Correct the number of stations.

Sacramento-RTD: Modify line.

Buffalo-NFTS: Add two stations in 1987.

Baltimore-MMTA: Exchange stations opened in 1998.

Pittsburgh-PAT: Add stops at street level. Overbrook line closed 1994. Allentown line closed 1992-1994.

New Orleans-RTA: Add stops at street level. Add link to River Front line opened since 1988.

Cleveland-GRTA: Extend Waterfront line to South Harbor in 1996.

Denver-RTD: Exclude a station.

Hudson Bergen Light Rail: Add line and stations.

San Diego Trolley: Add a stop in downtown to reproduce early operations. Four stations opened in 1985, eight in 1987, four in 1989, three in 1990, one in 1994, three in 1995, and three in 1996.

APPENDIX B

ABBREVIATIONS FOR VARIABLES, AGENCIES, AND MODELS

Throughout the dissertation many abbreviations are used for variables, observations and models. Following is a list of those abbreviations.

Outputs

VRM = Annual vehicle revenue miles (000's)
TRIPS = Annual unlinked passenger trips (000's)

Inputs

loper = Annual labor hours in operation and in administration (000's)
lmain = Annual labor hours in maintenance (000's)
ener = Annual kilowatt hours of electricity (000's)
cars = Number of rail vehicles
rails = Number of directional track miles
stats = Number of stations (only for heavy rail)

Selected operating conditions

Stopsp = Stop spacing, average distance between stations
Rushalf = Highest concentration of demand of motorized trips to go to work in half an hour
PopCC = Population residing in center city
IncoPC = Income per capita of the served area, around 0.3 miles of the stations
Denserv = Density of service in vehicle revenue miles per track mile
AutoPH = Number of autos per household of the served area ,around 0.3 miles of the stations
EmpCCD = Density of employees residing in center city
EmpDen = Density of employees residing in the served area, around 0.3 miles of the stations
NetCom = Network complexity, ratio of number of links to number of stops

Agencies

Light Rail	*Short name*	*Heavy Rail*	*Short name*
Boston-MBTA	bos	New York-CTA	nyo
San Francisco-MUNI	sfr	Washington-WMTA	was
Philadelphia-SEPTA	phi	Chicago-CTA	chi
Los Angeles-LACMTA	lan	Boston-MBTA	bos
San Diego Trolley	sdi	Atlanta MARTA	atl
St. Louis-Bi-State	slo	Philadelphia-SEPTA	phi
Portland Tri-County MTD	por	San Francisco-BART	sfr
Dallas-DART	dal	New York-PATH	path
Sacramento-RTD	sac	Miami-Dade Cnty TA	mia
Pittsburgh-PAT	pit	Baltimore-MTA	bal
Buffalo-Niagara Frontier	buf	Los Angeles-LACMTA	lan
Baltimore-Maryland MTA	bal	Lindenwold-PATCO	patco
Santa Clara County TD	sjo	Cleveland-RTA	cle
New Orleans Public Svc	nor	Staten Island Rapid Trans	sta
Cleveland-RTA	cle	San Juan Heavy Rail	SJ
Denver-RTD	den		
Newark-NJT	new		
Hudson-Bergen Light Rail	HB		

Models of Data Envelopment Analysis

2F-DEA = Two Farrell Data Envelopment Analysis
DEA(1) = Data Envelopment Analysis Number One
DEA(2) = Data Envelopment Analysis Number Two
DEA-C = Data Envelopment Analysis Conventional
DEA-ND = Data Envelopment Analysis with Non Discretionary Factors
DEA-2S = Data Envelopment Analysis Two-Step
DEA-CL = Data Envelopment and Analysis Cluster Analysis

APPENDIX C

PLANNED PRODUCTIVITY OF NEW RAIL PROJECTS

Hudson-Bergen Light Rail

The assumptions are as follows.

1) Energy consumption is comparable to the Dallas system that uses similar vehicles, 464 thousands Kw-h per vehicle per year.
2) *VRM* derives from the scheduled vehicle revenue miles of the first initial segment valid in May 22, 2000 and extrapolated to the length of the line of the other segments. Hudson-Bergen Light Rail plans for 683 thousands of *VRM* per year for the initial operational segment.
3) Published planned *TRIPS* for the other segments are the following; 18,000 daily unlinked trips for the initial operating segment to Exchange Place, 25,000 for the first segment to Hoboken, 72,360 for the second segment and 100,000 for the third. The first segment to Exchange Place considered two approaches, the optimistic assumes 18,000 trips for 365 days while the conservative assumes 50 percent for Saturdays and Sundays (conservative).
4) Published track length figures are the following; 8.1 miles in the initial segment to Exchange Place, 9.5 in the first segment, 15.4 in the second, and 20.1 in the third segment.
5) This dissertation assumed three approaches for the relation Labor/Vehicles, one similar to Newark system, other similar to Dallas system, and a third as the average of both.
6) Published number of vehicles are the following; 29 for the first segment, 43 for the second and 66 for the third. As a result, Table A presents fifteen cases with all the alternatives.

Table A Hudson-Bergen Light Rail - Cases

Case	*Segment*	*Labor*	*Planned TRIPS on Weekends*
3NJ	Third	Newark-like	Conservative
3DA	Third	Dallas-like	Conservative
3AV	Third	Average	Conservative
2NJ	Second	Newark-like	Conservative
2DA	Second	Dallas-like	Conservative
2AV	Second	Average	Conservative
1NJ	First	Newark-like	Conservative
1DA	First	Dallas-like	Conservative
1AV	First	Average	Conservative
0Njcon	Initial	Newark-like	Conservative
0Dacon	Initial	Dallas-like	Conservative
0Avcon	Initial	Average	Conservative
0Njop	Initial	Newark-like	Optimistic
0Daop	Initial	Dallas-like	Optimistic
0Avop	Initial	Average	Optimistic

San Juan Heavy Rail

San Juan Heavy Rail is to operate in Puerto Rico. Planned operational data for the San Juan system was collected from published data of San Juan Department of Transportation, Federal Transit Administration, Siemens, and other providers of the project (US-DOT-FTA 2000).

1) *VRM* is calculated by using the track length of first segment and planned headway of 4 minutes in peak hour and 8 minutes during off-peak hours for a total of 20 daily hours and 50 percent during weekends.
2) Published planned *TRIPS* data from a low of 15,000 trips to a high of 100,000 trips on weekday.
3) Published average productivity of *loper*, *lmain* and *ener* (US-DOT-FTA 1992), Tables 2-5, 2.8.
4) Published number of *cars*, 14, 64 and 74.
5) Published track length 10.2 miles on each direction, a total of 20.4 miles on both.
6) Published number of stations, 15 for the first stage.

As a result Table B presents six cases.

Table B San Juan Heavy Rail - Cases

Case	*cars*	*TRIPS per weekday*
14low	14	15,000
14high	14	100,000
64low	64	15,000
64high	64	100,000
74low	74	15,000
74high	74	100,000

APPENDIX D

DATABASE OF RAIL TRANSIT PRODUCTIVITY ANALYSIS

Vehicle Revenue Miles

HEAVY RAIL — Annual actual vehicle revenue miles (000's)

agency	1984	1985	1986	1987	1988	1989	1990
New York-MTA-NYCT	278,089	275,303	290,493	293,921	306,431	312,195	308,342
Washington, D.C.-WMATA	17,336	24,202	26,859	31,938	32,120	32,859	33,212
Chicago-RTA-CTA	45,552	47,645	46,401	46,992	55,087	54,630	56,582
Boston-MBTA	16,828	17,511	17,543	18,440	20,078	21,858	23,186
Atlanta-MARTA	5,943	9,735	11,741	12,341	13,256	14,619	15,609
Philadelphia-SEPTA	15,282	15,627	15,572	15,862	16,192	16,276	15,930
San Francisco-BART	29,560	30,635	30,490	30,267	31,943	33,195	40,328
New York-PATHC	10,508	11,305	11,344	11,440	12,434	13,190	12,653
Miami-MDTA	478	3,628	4,442	4,708	5,071	4,657	5,444
Baltimore-MMTA	960	1,734	1,792	2,062	4,365	3,530	3,691
Los Angeles-LACMTA							
Philadelphia-NJ-PATC	3,938	3,767	3,829	3,883	4,007	4,096	4,036
Cleveland-GCRTA	2,136	2,113	2,065	2,069	1,986	1,952	1,828
New York-MTA-SIRTOA	2,360	2,289	2,311	2,078	2,081	2,089	2,091
TOTAL	428,970	445,492	464,880	475,999	505,051	515,145	522,932

agency	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	294,032	295,548	295,239	300,167	302,370	299,291	304,094
Washington, D.C.-WMATA	36,036	38,749	36,650	40,202	41,575	41,429	37,984
Chicago-RTA-CTA	57,598	51,122	45,575	45,745	45,283	49,734	50,687
Boston-MBTA	22,622	23,420	23,573	19,835	20,813	22,638	22,934
Atlanta-MARTA	15,633	15,795	16,938	20,854	21,879	22,622	27,101
Philadelphia-SEPTA	15,296	15,307	15,339	15,518	14,676	15,387	15,640
San Francisco-BART	39,193	40,874	41,893	43,054	43,850	44,877	48,523
New York-PATHC	12,798	12,485	12,838	12,798	12,818	12,957	12,834
Miami-MDTA	5,452	5,231	5,351	5,522	5,819	5,864	5,739
Baltimore-MMTA	3,377	3,192	3,557	3,656	3,984	4,239	4,231
Los Angeles-LACMTA			285	625	695	800	1,737
Philadelphia-NJ-PATC	4,207	4,115	4,264	4,271	4,193	4,063	4,017
Cleveland-GCRTA	2,010	2,134	1,908	1,910	1,989	2,015	2,046
New York-MTA-SIRTOA	2,061	1,761	1,819	1,887	1,843	1,928	2,104
TOTAL	510,314	509,731	505,229	516,044	521,784	527,844	539,670

LIGHT RAIL — Annual actual vehicle revenue miles (000's)

agency	1984	1985	1986	1987	1988	1989	1990
Boston-MBTA	1,652	1,691	1,078	1,074	1,100	1,184	1,295
San Francisco-MUNI	3,831	3,958	4,067	4,059	4,057	4,002	4,093
Philadelphia-SEPTA	5,927	5,117	5,532	5,050	4,873	4,832	4,756
Los Angeles-LACMTA							
San Diego Trolley Inc.	1,672	1,672	1,861	2,041	2,034	2,367	4,015
St. Louis-BSDA							
Portland-TCMTDO				1,094	1,406	1,400	1,333
Dallas-DARTA							
Sacramento-RTD				237	936	1,060	1,373
Pittsburgh-PAT	985	1,094	1,335	1,396	2,192	1,988	2,120
Buffalo-NFTS			505	700	914	919	1,016
Baltimore-MMTA							
San Jose-SCTD					225	534	553
New Orleans-RTA	707	697	668	652	661	545	677
Cleveland-GCRTA	1,062	1,082	1,082	1,087	1,028	1,035	1,037
Denver-RTD							
Newark-NJTC	442	545	575	590	596	622	634
TOTAL	16,278	15,855	16,702	17,981	20,021	20,486	22,899

agency	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	1,419	1,523	1,449	5,529	5,523	5,471	5,435
San Francisco-MUNI	4,130	3,888	3,875	3,622	3,498	3,692	3,740
Philadelphia-SEPTA	4,471	4,172	2,878	2,813	2,943	3,069	3,049
Los Angeles-LACMTA	2,395	2,919	2,864	2,944	2,783	4,150	4,436
San Diego Trolley Inc.	4,588	4,508	4,433	4,176	4,049	4,215	5,059
St. Louis-BSDA				1,770	2,527	2,513	2,585
Portland-TCMTDO	1,408	1,446	1,503	1,554	1,538	1,534	1,579
Dallas-DARTA						396	1,794
Sacramento-RTD	1,493	1,678	1,671	1,776	1,748	1,791	1,852
Pittsburgh-PAT	2,186	1,946	2,043	1,651	1,625	1,657	1,718
Buffalo-NFTS	911	916	905	901	892	893	897
Baltimore-MMTA		137	1,224	2,216	2,147	2,205	2,296
San Jose-SCTD	981	2,080	1,724	1,715	1,662	1,868	1,888
New Orleans-RTA	735	718	694	702	712	723	724
Cleveland-GCRTA	1,139	1,170	971	954	1,016	1,119	1,181
Denver-RTD				109	428	526	648
Newark-NJTC	647	645	644	664	654	654	656
TOTAL	26,502	27,745	26,876	33,094	33,743	36,477	39,534

Unlinked Passenger Trips

HEAVY RAIL — Annual unlinked passenger trips (000's)

name	1984	1985	1986	1987	1988	1989	1990
New York-MTA-NYCT	1,541,823	1,561,487	1,591,526	1,613,760	1,483,210	1,702,611	1,476,353
Washington, D.C.-WMATA	108,614	125,181	145,149	160,367	172,615	183,480	182,006
Chicago-RTA-CTA	153,421	155,479	145,348	148,213	174,436	168,659	165,733
Boston-MBTA	131,549	143,251	143,747	148,059	151,469	157,938	179,762
Atlanta-MARTA	49,427	57,688	65,548	66,098	65,908	65,603	68,947
Philadelphia-SEPTA	103,939	96,896	88,357	96,693	98,478	94,100	91,841
San Francisco-BART	62,471	66,036	63,959	60,304	61,160	64,065	74,762
New York-PATHC	59,769	53,619	53,795	70,451	60,905	60,495	60,678
Miami-MDTA	771	4,857	7,668	10,188	10,406	12,128	13,622
Baltimore-MMTA	3,383	9,565	11,567	11,883	13,424	13,984	13,612
Los Angeles-LACMTA							
Philadelphia-NJ-PATC	10,212	10,231	10,367	10,822	11,103	11,025	11,405
Cleveland-GCRTA	5,982	5,543	5,671	5,295	4,615	7,860	7,596
New York-MTA-SIRTOA	6,164	6,050	6,450	6,442	6,228	6,223	6,026
TOTAL	2,237,524	2,295,880	2,339,152	2,408,575	2,313,954	2,548,169	2,352,342

name	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	1,325,707	1,373,625	1,178,122	1,308,430	1,234,599	1,352,101	1,579,783
Washington, D.C.-WMATA	188,253	186,782	191,428	195,833	198,380	194,050	198,003
Chicago-RTA-CTA	147,608	137,373	135,370	143,579	135,462	142,041	151,010
Boston-MBTA	172,237	180,673	190,330	162,673	113,490	108,571	113,715
Atlanta-MARTA	67,117	64,078	65,005	69,855	70,351	72,434	90,991
Philadelphia-SEPTA	85,347	79,808	94,333	93,891	86,611	86,998	86,245
San Francisco-BART	76,099	77,247	78,302	77,530	76,332	76,807	80,490
New York-PATHC	60,108	60,143	61,815	64,606	64,734	66,222	67,998
Miami-MDTA	13,907	13,702	14,818	14,329	14,204	14,386	14,020
Baltimore-MMTA	12,820	11,997	11,114	10,470	10,557	11,605	12,600
Los Angeles-LACMTA			1,983	4,972	5,888	7,666	11,628
Philadelphia-NJ-PATC	11,373	11,151	11,232	11,134	10,881	10,658	10,660
Cleveland-GCRTA	6,414	5,557	6,563	6,908	6,949	8,459	7,695
New York-MTA-SIRTOA	5,355	5,089	5,141	5,150	5,069	4,897	4,618
TOTAL	2,172,342	2,207,222	2,045,554	2,169,359	2,033,506	2,156,894	2,429,455

LIGHT RAIL — Annual unlinked passenger trips (000's)

name	1984	1985	1986	1987	1988	1989	1990
Boston-MBTA	20,907	26,809	16,235		19,895	20,500	23,355
San Francisco-MUNI	60,749	38,915	38,935	38,731	39,485	38,909	40,214
Philadelphia-SEPTA	47,287	43,030	41,887	34,738	42,759	46,594	43,748
Los Angeles-LACMTA							
San Diego Trolley Inc.	5,382	5,382		8,947	9,281	11,217	15,934
St. Louis-BSDA							
Portland-TCMTDO				4,962	5,586	6,185	6,414
Dallas-DARTA							
Sacramento-RTD				611	3,582	4,011	5,703
Pittsburgh-PAT	4,131	2,527	6,041	5,398	8,185	9,044	9,890
Buffalo-NFTS			4,020	5,884	7,422	8,072	8,480
Baltimore-MMTA							
San Jose-SCTD					196	2,008	2,432
New Orleans-RTA	6,381	6,277	7,258	6,230	8,161	5,079	8,347
Cleveland-GCRTA	4,589	4,581	4,642	3,904	3,929	5,110	5,498
Denver-RTD							
Newark-NJTC	2,672	3,163	3,805	3,521	3,847	4,065	3,838
TOTAL	152,097	130,683	122,822	112,925	152,325	160,793	173,851

name	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	22,736	24,937	26,704	108,509	71,519	69,033	67,000
San Francisco-MUNI	40,044	39,034	39,332	37,616	37,243	36,728	36,738
Philadelphia-SEPTA	42,488	41,558	38,066	40,054	38,066	37,941	25,003
Los Angeles-LACMTA	7,487	11,307	11,809	11,849	12,027	19,064	22,659
San Diego Trolley Inc.	18,030	17,163	16,505	14,888	15,624	16,770	18,287
St. Louis-BSDA				8,005	12,488	12,870	14,486
Portland-TCMTDO	6,982	7,703	7,771	8,482	7,780	10,048	10,432
Dallas-DARTA						1,482	7,972
Sacramento-RTD	6,593	6,781	6,571	6,958	7,064	7,654	7,862
Pittsburgh-PAT	9,987	8,728	8,837	7,943	7,996	7,381	7,421
Buffalo-NFTS	8,108	8,570	8,209	8,248	7,898	7,136	6,919
Baltimore-MMTA		208	3,457	6,229	5,812	6,287	6,772
San Jose-SCTD	3,981	6,135	6,245	6,133	5,659	6,168	6,728
New Orleans-RTA	8,209	6,912	6,440	7,258	7,069	5,305	5,605
Cleveland-GCRTA	5,459	5,044	4,114	4,260	4,445	5,428	5,337
Denver-RTD				965	4,054	4,109	4,428
Newark-NJTC	3,283	3,057	2,987	3,813	3,933	4,091	4,294
TOTAL	183,386	187,135	187,047	281,210	248,676	257,494	257,942

Labor used in Maintenance Vehicles

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	9,645	11,137	11,641	11,786	10,725	10,263	9,793	9,092	9,084	8,652	8,896	8,291	7,960	7,336
Washington, D.C.-WMATA	1,295	1,231	1,320	1,457	1,475	1,508	1,532	1,631	1,688	1,512	1,563	1,596	1,572	1,513
Chicago-RTA-CTA	972	1,283	1,421	1,499	1,554	1,591	1,444	1,347	1,357	1,275	1,287	1,037	1,185	1,012
Boston-MBTA		1,077	1,046	1,065	1,107	1,148	1,005	1,021	993	1,017	725	746	657	617
Atlanta-MARTA	188	297	200	204	316	360	343	318	229	329	294	289	356	365
Philadelphia-SEPTA	668	835	1,109	919	1,068	1,106	1,061	1,473	704	657	588	623	686	656
San Francisco-BART	891	785	829	828	834	858	1,045	1,145	1,082	1,140	1,021	994	1,133	1,261
New York-PATHC	406	517	517	472	472	472	530	530		460	502	438	437	416
Miami-MDTA	91	222	240	307	309	319	245	232	156	183	170	171	156	165
Baltimore-MMTA	82	118	137	150	125	176	196	213	200	171	163	154	143	147
Los Angeles-LACMTA										72	82	89	102	102
Philadelphia-NJ-PATC	152	179	173	164	155	147	146	126	125	103	102	94	90	87
Cleveland-GCRTA	148	128	127	155	98	189	174	155	143	130	130	142	148	123
New York-MTA-SIRTOA	140	88	78	76	74	84	82	84	80	81	85	86	88	84
TOTAL	14,679	17,898	18,837	19,082	18,311	18,221	17,596	17,369	15,840	15,783	15,609	14,748	14,711	13,884

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		145	173	160	158	148	168	144	112	147	454	399	405	391
San Francisco-MUNI	591	603	568	524	593	607	607	406	392	372	500	395	367	386
Philadelphia-SEPTA	413	485	705	632	484	489	469	528	493	396	348	358	376	347
Los Angeles-LACMTA								88	118	127	117	120	235	334
San Diego Trolley Inc.	38	70	79	90	90	101	126	121	125	106	109	108	110	115
St. Louis-BSDA											32	40	46	46
Portland-TCMTDO				94	98	64	78	85	109	92	118	140	156	163
Dallas-DARTA													71	112
Sacramento-RTD				41	50	50	54	54	52	73	40	70	67	68
Pittsburgh-PAT	132	181	138	196	208	262	630	171	186	383	218	234	213	197
Buffalo-NFTS			55	58	60	58	57	51	54	56	57	60	60	49
Baltimore-MMTA									19	48	62	66	70	73
San Jose-SCTD					70	80	70	99	92	93	107	118	123	121
New Orleans-RTA	52	49	83	84	93	98	110	155	48	36	185	39	54	83
Cleveland-GCRTA	82	109	63	94	55	102	99	94	77	70	71	77	89	89
Denver-RTD											29	35	41	40
Newark-NJTC	30	52	48	58	59	58	56	56	60	53	65	49	67	69
TOTAL	1,337	1,695	1,912	2,031	2,016	2,117	2,525	2,050	1,936	2,052	2,512	2,308	2,551	2,683

Labor used on Non-Vehicle Maintenance

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	13,175	19,460	19,965	20,576	16,549	18,321	18,042	17,034	16,521	16,716	17,270	16,620	16,038	15,455
Washington, D.C.-WMATA	1,845	2,159	2,265	2,393	2,447	2,547	2,536	2,669	2,738	2,846	2,974	3,105	3,072	3,088
Chicago-RTA-CTA	1,875	1,860	1,781	1,644	1,884	1,752	1,797	1,772	1,731	1,635	1,668	1,450	1,306	1,831
Boston-MBTA		1,577	1,441	1,496	1,333	1,277	1,350	1,448	1,469	1,668	1,142	908	1,109	967
Atlanta-MARTA	90	549	668	774	362	412	599	595	416	525	368	440	454	492
Philadelphia-SEPTA	646	465	900	919	917	946	908	918	898	614	1,017	1,059	1,079	1,072
San Francisco-BART	766	999	1,005	982	989	977	1,090	1,117	1,060	1,057	1,014	986	1,057	1,215
New York-PATHC	708	799	799	745	745	728	851	851		895	778	774	740	719
Miami-MDTA	93	268	275	212	182	203	306	318	388	374	398	378	345	374
Baltimore-MMTA	126	254	251	280	344	334	350	342	349	329	303	296	302	301
Los Angeles-LACMTA										108	88	112	151	167
Philadelphia-NJ-PATC	196	191	187	190	199	196	200	172	170	170	171	159	164	167
Cleveland-GCRTA	173	152	168	187	238	173	187	167	175	169	168	185	188	65
New York-MTA-SIRTOA	82	156	196	196	218	224	230	224	112	132	149	120	139	126
TOTAL	19,774	28,889	29,902	30,593	26,407	28,089	28,446	27,626	26,027	27,238	27,509	26,593	26,144	26,039

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		212	214	196	168	204	150	112	139	171	521	452	414	459
San Francisco-MUNI	293	316	200	202	204	193	193	231	225	208	208	219	201	252
Philadelphia-SEPTA	335	261	982	959	749	774	743	784	352	247	282	272	273	269
Los Angeles-LACMTA								92	61	124	106	126	338	316
San Diego Trolley Inc.	19	6	12	23	31	40	110	102	95	124	137	143	178	209
St. Louis-BSDA											29	66	78	72
Portland-TCMTDO				4	4	52	53	40	29	44	56	120	158	183
Dallas-DARTA													53	109
Sacramento-RTD				19	29	26	31	33	44	52	51	51	49	56
Pittsburgh-PAT	256	183	207	333	354	196	60	292	294	296	319	215	236	224
Buffalo-NFTS			137	141	154	155	156	133	143	147	153	141	139	129
Baltimore-MMTA									21	73	95	109	117	125
San Jose-SCTD					75	64	80	104	87	64	81	88	89	105
New Orleans-RTA	70	82	75	76	65	64	65	67	14	10	8	2	20	17
Cleveland-GCRTA	125	137	83	107	140	99	108	104	94	90	92	100	113	46
Denver-RTD											23	30	30	33
Newark-NJTC	4	0	1	1	1	1	1	1	8	5	5	6	8	1
TOTAL	1,102	1,197	1,912	2,061	1,975	1,867	1,751	2,095	1,606	1,656	2,164	2,140	2,495	2,606

Labor used in General Administration

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	13,084	21,218	21,868	21,179	18,345	17,331	17,337	19,428	3,473	3,175	3,439	3,698	3,371	3,249
Washington, D.C.-WMATA	1,379	1,345	1,314	1,452	1,288	1,294	1,364	1,404	680	723	738	807	786	763
Chicago-RTA-CTA	724	516	569	610	710	651	2,394	2,297	428	588	428	427	479	513
Boston-MBTA		1,055	1,223	1,242	1,446	1,554	1,531	1,681	1,208	604	702	172	1,020	1,091
Atlanta-MARTA	200	268	501	283	266	304	1,005	1,044	402	573	491	346	481	487
Philadelphia-SEPTA	532	428	484	463	469	492	458	482	285	254	260	250	254	214
San Francisco-BART	895	991	968	996	998	971	1,132	1,158	784	756	718	679	729	769
New York-PATHC	286	550	550	391	391	374	391	408		220	94	27	22	54
Miami-MDTA	402	302	246	368	356	262	165	189	131	113	105	105	106	109
Baltimore-MMTA	162	230	182	243	215	238	232	213	55	66	60	67	47	50
Los Angeles-LACMTA										95	108	60	107	68
Philadelphia-NJ-PATC	147	175	173	172	180	184	180	165	62	64	76	79	76	76
Cleveland-GCRTA	147	67	33	145	139	144	152	174	57	51	49	47	123	81
New York-MTA-SIRTOA	84	92	94	96	98	98	96	94	45	47	53	60	63	62
TOTAL	18,042	27,237	28,206	27,639	24,900	23,896	26,437	28,737	7,612	7,328	7,320	6,824	7,662	7,588

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		142	96	89	127	100	108	81	66	68	386	53	208	136
San Francisco-MUNI	366	81	83	83	77	54	54	21	1	19	18	50	71	92
Philadelphia-SEPTA	350	235	365	367	372	389	373	379	70	97	89	99	99	87
Los Angeles-LACMTA								83	-	86	101	79	244	222
San Diego Trolley Inc.	29	28	29	42	30	35	56	64	33	68	47	56	62	97
St. Louis-BSDA											3	30	35	40
Portland-TCMTDO				37	58	53	51	48	3	69	84	82	109	104
Dallas-DARTA													163	46
Sacramento-RTD				12	12	17	17	17	-	59	60	54	54	54
Pittsburgh-PAT	63	26	25	46	52	85	-	79	6	48	47	40	43	30
Buffalo-NFTS			54	54	54	43	42	31	29	8	9	9	13	9
Baltimore-MMTA									12	33	39	38	26	29
San Jose-SCTD					44	46	64	38	0	39	70	75	82	85
New Orleans-RTA	38	28	17	1	22	5	24	25	-	25	134	49	17	14
Cleveland-GCRTA	117	33	16	54	53	82	86	105	14	28	27	26	48	58
Denver-RTD											19	26	28	29
Newark-NJTC	12	9	10	10	10	11	12	11	-	9	13	8	10	12
TOTAL	974	583	696	796	913	919	888	982	235	656	1,146	774	1,310	1,145

Labor used in Transportation also named Vehicle Operations

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	25,238	17,084	16,817	16,751	13,090	13,446	11,905	13,046	13,775	29,793	30,063	23,763	20,530	20,734
Washington, D.C.-WMATA	1,268	1,506	1,570	1,769	1,897	1,815	1,746	1,874	2,009	2,762	2,838	2,953	3,035	2,957
Chicago-RTA-CTA	4,377	4,356	4,563	4,559	4,828	4,758	3,297	3,187	3,313	4,547	4,138	3,921	4,374	4,411
Boston-MBTA		2,008	1,722	1,697	1,835	1,868	1,745	1,808	1,529	2,738	2,187	1,590	1,149	1,137
Atlanta-MARTA	438	347	580	826	953	1,086	622	574	413	-	1,145	1,144	1,221	1,386
Philadelphia-SEPTA	2,124	1,600	1,568	1,537	1,562	1,611	1,542	1,288	891	1,533	1,571	1,549	1,566	1,488
San Francisco-BART	1,298	1,004	1,026	1,038	1,034	1,008	1,096	1,129	1,116	1,790	1,588	1,677	1,903	2,104
New York-PATHC	882	866	866	928	928	880	957	940		1,248	983	1,019	1,052	1,009
Miami-MDTA	148	278	226	210	166	232	225	214	191	227	234	247	256	251
Baltimore-MMTA	182	186	182	190	225	234	230	223	143	339	312	343	384	361
Los Angeles-LACMTA										77	174	155	201	253
Philadelphia-NJ-PATC	184	163	157	158	158	160	158	140	141	253	236	235	235	235
Cleveland-GCRTA	270	224	282	165	218	217	240	220	246	243	325	334	346	300
New York-MTA-SIRTOA	252	238	244	234	224	250	252	240	200	252	238	215	215	230
TOTAL	36,661	29,861	29,806	30,061	27,117	27,564	24,017	24,882	23,967	45,802	46,031	39,144	36,469	36,856

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		274	191	193	162	179	270	191	165	237	1,065	911	813	865
San Francisco-MUNI	582	651	747	753	716	718	718	757	728	700	660	683	697	645
Philadelphia-SEPTA	981	1,038	1,005	1,004	1,096	916	879	904	889	570	615	624	614	551
Los Angeles-LACMTA								211	206	178	207	149	453	716
San Diego Trolley Inc.	71	84	100	127	115	132	176	204	237	245	245	228	228	242
St. Louis-BSDA											125	164	160	173
Portland-TCMTDO				79	94	101	85	92	104	112	105	126	162	175
Dallas-DARTA													168	191
Sacramento-RTD				69	76	100	102	96	108	115	120	126	124	118
Pittsburgh-PAT	213	181	159	230	322	349	279	311	287	302	267	256	260	267
Buffalo-NFTS			74	79	85	85	78	80	84	125	109	110	107	101
Baltimore-MMTA									29	159	239	240	233	260
San Jose-SCTD					64	119	126	163	161	156	156	160	185	175
New Orleans-RTA	92	109	100	92	95	116	124	129	100	106	199	72	117	123
Cleveland-GCRTA	178	146	142	117	142	129	132	127	162	87	178	182	222	196
Denver-RTD											46	80	84	86
Newark-NJTC	38	51	45	50	52	52	50	51	49	52	53	51	55	57
TOTAL	2,156	2,534	2,563	2,794	3,019	2,995	3,020	3,315	3,309	3,145	4,387	4,163	4,683	4,943

Labor used in Transportation and General Administration

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	38,322	38,303	38,686	37,930	31,435	30,777	29,243	32,474	34,248	32,968	33,502	27,462	23,901	23,984
Washington, D.C.-WMATA	2,647	2,850	2,884	3,221	3,184	3,109	3,110	3,278	3,412	3,485	3,576	3,760	3,820	3,720
Chicago-RTA-CTA	5,101	4,872	5,132	5,168	5,538	5,409	5,692	5,484	4,965	5,135	4,566	4,348	4,853	4,924
Boston-MBTA		3,063	2,945	2,939	3,280	3,422	3,276	3,488	3,618	3,342	2,888	1,761	2,169	2,228
Atlanta-MARTA	638	616	1,082	1,109	1,219	1,389	1,627	1,618	1,316	573	1,636	1,490	1,702	1,873
Philadelphia-SEPTA	2,656	2,029	2,052	2,000	2,031	2,102	2,000	1,770	1,894	1,788	1,830	1,799	1,821	1,702
San Francisco-BART	2,193	1,995	1,994	2,034	2,032	1,980	2,228	2,286	2,359	2,545	2,306	2,356	2,632	2,873
New York-PATHC	1,168	1,416	1,416	1,319	1,319	1,254	1,348	1,348		1,468	1,077	1,045	1,074	1,063
Miami-MDTA	550	580	473	577	521	493	390	403	343	340	339	352	362	361
Baltimore-MMTA	344	416	364	433	441	472	463	436	408	405	372	410	432	411
Los Angeles-LACMTA										172	282	215	308	321
Philadelphia-NJ-PATC	330	338	331	330	338	344	339	305	306	317	312	314	311	312
Cleveland-GCRTA	417	291	316	310	356	361	392	394	329	294	374	381	469	381
New York-MTA-SIRTOA	336	330	338	330	322	348	348	334	294	298	291	275	278	291
TOTAL	54,703	57,099	58,013	57,700	52,016	51,460	50,454	53,619	53,493	53,130	53,351	45,969	44,131	44,444

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		416	287	283	289	279	379	272	296	305	1,450	965	1,020	1,001
San Francisco-MUNI	948	732	830	836	792	772	772	778	731	719	678	733	768	737
Philadelphia-SEPTA	1,331	1,274	1,370	1,371	1,468	1,305	1,253	1,283	1,029	668	704	724	713	637
Los Angeles-LACMTA								294	206	264	308	228	697	938
San Diego Trolley Inc.	100	111	130	168	145	167	232	268	304	313	292	284	290	340
St. Louis-BSDA											128	194	195	213
Portland-TCMTDO				116	152	154	136	140	109	180	189	208	270	279
Dallas-DARTA													331	237
Sacramento-RTD				81	88	116	119	112	108	174	180	180	178	173
Pittsburgh-PAT	276	207	184	276	374	434	279	391	299	350	314	296	303	297
Buffalo-NFTS			129	134	140	128	120	111	142	133	118	119	120	111
Baltimore-MMTA									53	192	278	278	259	289
San Jose-SCTD					108	165	190	201	162	195	227	235	267	260
New Orleans-RTA	130	138	116	93	118	121	148	154	100	132	332	121	134	138
Cleveland-GCRTA	295	179	158	171	196	210	219	232	190	114	204	207	270	255
Denver-RTD											65	106	113	115
Newark-NJTC	50	60	55	61	62	63	62	62	49	61	66	60	65	68
TOTAL	3,130	3,117	3,259	3,590	3,932	3,915	3,908	4,296	3,778	3,800	5,533	4,937	5,992	6,088

Total Labor

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	61,142	68,901	70,292	70,292	58,709	59,361	57,077	58,601	59,853	58,336	59,668	52,373	47,899	46,775
Washington, D.C.-WMATA	5,787	6,240	6,469	7,072	7,107	7,164	7,178	7,578	7,838	7,843	8,113	8,461	8,464	8,321
Chicago-RTA-CTA	7,947	8,016	8,333	8,311	8,976	8,752	8,932	8,603	8,053	8,045	7,521	6,835	7,344	7,767
Boston-MBTA		5,718	5,433	5,500	5,720	5,847	5,631	5,957	6,080	6,027	4,756	3,415	3,935	3,812
Atlanta-MARTA	916	1,462	1,949	2,086	1,897	2,161	2,569	2,531	1,961	1,427	2,298	2,220	2,512	2,730
Philadelphia-SEPTA	3,971	3,329	4,061	3,839	4,017	4,154	3,969	4,161	3,496	3,059	3,436	3,481	3,585	3,431
San Francisco-BART	3,851	3,779	3,828	3,844	3,854	3,814	4,363	4,548	4,501	4,743	4,342	4,336	4,822	5,349
New York-PATHC	2,282	2,732	2,732	2,536	2,536	2,454	2,729	2,729		2,822	2,357	2,257	2,251	2,199
Miami-MDTA	734	1,070	988	1,096	1,013	1,015	941	953	887	897	907	901	862	899
Baltimore-MMTA	552	787	752	862	910	982	1,009	990	956	905	838	860	877	859
Los Angeles-LACMTA										352	452	415	560	590
Philadelphia-NJ-PATC	678	708	691	684	692	688	685	603	601	590	585	567	565	566
Cleveland-GCRTA	738	571	611	652	692	723	753	716	647	594	671	708	805	569
New York-MTA-SIRTOA	558	574	612	602	614	656	660	642	486	511	525	481	505	502
TOTAL	89,155	103,886	106,751	107,375	96,735	97,770	96,496	98,614	95,360	96,151	96,469	87,310	84,987	84,368

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		773	674	639	616	630	697	528	548	623	2,425	1,816	1,839	1,852
San Francisco-MUNI	1,832	1,652	1,597	1,562	1,589	1,572	1,572	1,414	1,348	1,299	1,386	1,347	1,337	1,375
Philadelphia-SEPTA	2,079	2,020	3,057	2,962	2,701	2,568	2,465	2,595	1,874	1,310	1,333	1,353	1,362	1,254
Los Angeles-LACMTA								473	385	515	531	473	1,270	1,589
San Diego Trolley Inc.	157	188	221	281	266	308	468	491	523	543	538	535	578	663
St. Louis-BSDA											189	300	319	331
Portland-TCMTDO				214	254	270	268	264	247	316	363	468	584	625
Dallas-DARTA													455	458
Sacramento-RTD				141	167	192	204	200	204	300	272	301	294	297
Pittsburgh-PAT	665	571	528	805	936	891	969	854	779	1,030	850	745	752	719
Buffalo-NFTS			321	333	353	341	333	295	339	336	327	320	319	288
Baltimore-MMTA									93	313	435	453	447	488
San Jose-SCTD					253	310	340	405	341	352	415	441	479	486
New Orleans-RTA	251	269	275	253	276	283	323	376	162	178	525	162	208	237
Cleveland-GCRTA	502	425	305	372	390	411	426	429	362	274	366	385	472	390
Denver-RTD											117	172	183	189
Newark-NJTC	84	113	104	120	122	123	119	118	116	118	136	115	140	138
TOTAL	5,569	6,010	7,082	7,682	7,923	7,899	8,184	8,442	7,321	7,508	10,209	9,385	11,038	11,376

Number of Vehicles

HEAVY RAIL	Total Active Fleet 1984 / Vehicles available for maximum service 1985-1997 - units													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	5,701	6,108	6,138	6,077	6,044	6,106	6,089	5,951	5,936	5,840	5,803	5,801	5,801	5,790
Washington, D.C.-WMATA	363	454	536	586	658	664	664	664	668	746	764	764	764	764
Chicago-RTA-CTA	1,202	1,211	1,201	1,263	1,208	1,217	1,214	1,205	1,204	1,236	1,230	1,134	1,152	1,150
Boston-MBTA	284	304	350	350	500	579	404	400	402	402	432	408	408	408
Atlanta-MARTA	120	150	170	210	234	236	238	240	240	240	238	238	240	238
Philadelphia-SEPTA	383	386	381	380	386	383	378	368	375	376	373	358	358	358
San Francisco-BART	438	438	418	438	465	530	567	589	589	589	589	611	668	668
New York-PATHC	288	289	316	322	376	376	342	342	342	342	342	342	342	342
Miami-MDTA	40	96	130	130	130	134	136	136	136	136	136	136	136	136
Baltimore-MMTA	58	72	72	100	100	100	100	100	100	100	100	100	100	100
Los Angeles-LACMTA										30	30	30	30	30
Philadelphia-NJ-PATC	119	119	121	121	121	121	121	121	121	121	121	121	121	121
Cleveland-GCRTA	87	133	83	45	57	60	60	60	59	60	60	59	59	59
New York-MTA-SIRTOA	52	52	52	52	52	52	72	72	64	64	64	64	64	64
TOTAL	9,135	9,812	9,968	10,074	10,331	10,558	10,385	10,248	10,236	10,282	10,282	10,166	10,243	10,228

LIGHT RAIL	Total Active Fleet 1984 / Vehicles available for maximum service 1985-1997 - units													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	146	229	225	211	57	12	237	229	229	229	209	201	173	173
San Francisco-MUNI	133	130	146	142	143	143	128	128	128	128	128	127	138	136
Philadelphia-SEPTA	230	238	238	250	249	236	224	226	230	147	147	147	147	147
Los Angeles-LACMTA								40	54	54	54	54	69	69
San Diego Trolley Inc.	18	24	30	30	30	30	49	71	71	71	71	71	119	85
St. Louis-BSDA											31	31	31	31
Portland-TCMTDO				26	26	26	26	26	26	26	26	26	26	30
Dallas-DARTA													36	40
Sacramento-RTD				15	26	26	26	35	35	35	36	36	36	36
Pittsburgh-PAT	60	55	56	97	97	70	71	71	71	71	71	71	60	59
Buffalo-NFTS			27	27	27	27	27	27	27	27	27	27	27	27
Baltimore-MMTA									18	34	35	35	35	35
San Jose-SCTD					32	50	53	55	53	54	54	55	54	53
New Orleans-RTA	35	35	35	35	39	35	21	43	44	44	44	51	42	36
Cleveland-GCRTA	67	65	65	45	45	48	48	48	47	46	60	47	47	47
Denver-RTD											11	11	17	17
Newark-NJTC	24	22	22	22	22	24	22	22	22	22	22	22	22	22
TOTAL	713	798	844	900	793	727	932	1,021	1,055	988	1,026	1,012	1,079	1,043

Track Length

HEAVY RAIL	Directional Miles													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	483	481	481	481	488	493	493	493	493	493	493	493	493	493
Washington, D.C.-WMATA	93	121	139	139	139	139	139	156	162	162	178	178	178	185
Chicago-RTA-CTA	191	191	191	191	191	191	191	191	191	220	208	208	206	206
Boston-MBTA	76	76	77	76	77	77	77	77	77	76	76	76	76	76
Atlanta-MARTA	34	52	52	55	67	67	67	67	67	81	81	81	92	92
Philadelphia-SEPTA	76	80	80	80	77	76	76	76	76	76	76	76	76	76
San Francisco-BART	142	142	142	142	142	142	142	142	142	142	142	142	152	190
New York-PATHC	28	28	28	28	28	28	28	29	29	29	29	29	29	29
Miami-MDTA	21	40	40	40	42	42	42	42	42	42	42	42	42	42
Baltimore-MMTA	15	14	14	14	27	27	27	27	27	27	27	29	29	29
Los Angeles-LACMTA										6	6	6	6	10
Philadelphia-NJ-PATC	32	31	31	31	31	32	32	32	32	32	32	32	32	32
Cleveland-GCRTA	38	38	38	38	38	38	38	38	38	38	38	38	38	38
New York-MTA-SIRTOA	29	29	29	29	29	29	29	29	29	29	29	29	29	29
TOTAL	1,256	1,322	1,341	1,344	1,375	1,379	1,379	1,397	1,403	1,452	1,456	1,458	1,478	1,527

LIGHT RAIL	Directional Miles													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	56	56	56	56	56	56	52	52	52	56	56	56	56	56
San Francisco-MUNI	41	41	47	47	50	50	50	50	50	50	50	50	50	50
Philadelphia-SEPTA	179	179	166	166	148	127	127	127	127	69	69	69	69	69
Los Angeles-LACMTA								43	43	43	43	43	82	82
San Diego Trolley Inc.	16	32	41	41	41	41	41	41	42	42	42	42	45	48
St. Louis-BSDA											28	34	34	34
Portland-TCMTDO				30	30	30	30	30	30	30	30	30	30	30
Dallas-DARTA													23	41
Sacramento-RTD				21	37	37	37	36	36	36	36	36	36	36
Pittsburgh-PAT	33	29	30	41	41	45	60	65	45	48	38	38	38	38
Buffalo-NFTS			10	12	12	12	12	12	12	12	12	12	12	12
Baltimore-MMTA									26	47	44	44	44	44
San Jose-SCTD					17	17	17	39	39	39	39	39	39	39
New Orleans-RTA	13	13	13	13	16	16	17	17	17	16	16	16	16	16
Cleveland-GCRTA	26	26	26	26	26	26	27	27	27	27	27	27	31	31
Denver-RTD											11	11	11	11
Newark-NJTC	8	8	8	8	8	8	8	8	8	8	8	8	8	8
TOTAL	372	384	397	461	483	465	478	547	554	524	549	555	625	646

Number of Stations

HEAVY RAIL														
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	463	463	463	463	466	469	469	469	469	469	469	468	468	468
Washington, D.C.-WMATA	51	51	64	64	64	64	64	67	70	70	74	74	74	75
Chicago-RTA-CTA	143	143	143	143	143	143	143	143	137	145	145	145	140	141
Boston-MBTA	49	50	50	53	53	53	53	53	53	53	53	53	53	53
Atlanta-MARTA	20	25	25	26	29	29	29	29	29	33	33	33	36	36
Philadelphia-SEPTA	74	74	74	74	74	76	76	76	76	76	76	76	76	76
San Francisco-BART	34	34	34	34	34	34	34	34	34	34	34	34	36	39
New York-PATHC	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Miami-MDTA	10	20	20	20	20	21	21	21	21	21	21	21	21	21
Baltimore-MMTA	9	9	9	9	12	12	12	12	12	12	12	14	14	14
Los Angeles-LACMTA										5	5	5	5	8
Philadelphia-NJ-PATC	12	12	12	12	12	13	13	13	13	13	13	13	13	13
Cleveland-GCRTA	18	18	18	18	18	18	18	18	18	18	18	18	18	18
New York-MTA-SIRTOA	22	22	22	22	22	22	22	22	22	22	22	22	22	22
TOTAL	918	934	947	951	960	967	967	970	967	984	988	989	989	997

LIGHT RAIL														
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	33	95	85	85	85	85	77	77	77	77	95	95	95	95
San Francisco-MUNI	-	-	9	9	9	9	9	9	9	9	9	11	11	11
Philadelphia-SEPTA	15	9	9	9	9	60	64	64	64	64	64	64	64	64
Los Angeles-LACMTA								22	22	22	22	22	36	36
San Diego Trolley Inc.	18	18	22	22	22	22	22	22	24	35	35	35	38	41
St. Louis-BSDA											17	18	18	18
Portland-TCMTDO				24	24	24	25	27	27	27	27	27	27	27
Dallas-DARTA													14	20
Sacramento-RTD				15	15	15	15	28	28	28	28	28	28	28
Pittsburgh-PAT	-	-	6	12	13	13	14	14	14	14	13	13	13	13
Buffalo-NFTS			12	14	14	14	14	14	14	14	14	14	14	14
Baltimore-MMTA									15	24	24	24	24	24
San Jose-SCTD					20	20	20	33	33	33	33	33	33	34
New Orleans-RTA	-	-	-	-	-	-	-	-		-	2	2	2	9
Cleveland-GCRTA	29	29	29	29	29	29	29	29	29	29	29	29	33	33
Denver-RTD											15	15	15	15
Newark-NJTC	11	11	11	11	11	11	11	11	11	11	11	11	11	11
TOTAL	106	162	183	230	251	302	300	350	367	387	438	441	476	493

Density of service

HEAVY RAIL	Annual Vehicle Revenue Miles per Directional Mile of Route													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	1,171	1,159	1,227	1,242	1,275	1,288	1,272	1,213	1,219	1,218	1,238	1,247	1,237	1,254
Washington, D.C.-WMATA	335	412	394	469	472	482	488	471	492	465	463	479	477	422
Chicago-RTA-CTA	495	511	498	504	591	586	607	618	549	488	538	536	488	498
Boston-MBTA	455	440	441	458	499	543	576	562	582	586	493	517	563	570
Atlanta-MARTA	318	364	439	434	381	421	449	450	455	410	504	529	547	553
Philadelphia-SEPTA	414	414	414	414	414	414	414	414	414	414	414	414	414	414
San Francisco-BART	424	439	437	434	458	476	578	562	586	601	617	629	609	529
New York-PATHC	704	758	760	767	833	884	848	858	837	860	858	859	868	860
Miami-MDTA	45	165	202	214	231	212	248	248	238	244	251	265	267	261
Baltimore-MMTA	137	247	255	159	336	272	284	260	246	274	282	277	295	294
Los Angeles-LACMTA										97	213	236	161	350
Philadelphia-NJ-PATC	280	268	272	276	285	291	287	299	292	303	303	298	289	285
Cleveland-GCRTA	112	111	109	109	104	103	96	106	112	100	100	105	106	108
New York-MTA-SIRTOA	165	160	161	145	145	146	146	144	123	127	132	129	135	147
AVERAGE	389	419	432	433	463	471	484	477	473	442	458	466	461	468

LIGHT RAIL	Annual Vehicle Revenue Miles per Directional Mile of Route													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	66	68	48	48	49	53	56	62	66	63	240	240	237	236
San Francisco-MUNI	186	192	198	197	197	194	199	182	171	170	159	132	139	141
Philadelphia-SEPTA	87	87	87	87	87	87	87	87	87	87	87	87	87	87
Los Angeles-LACMTA								107	131	129	132	125	99	106
San Diego Trolley Inc.	103	103	90	98	98	77	122	139	136	134	114	110	104	125
St. Louis-BSDA											102	146	145	149
Portland-TCMTDO				67	87	86	82	87	89	93	96	95	94	97
Dallas-DARTA													31	82
Sacramento-RTD				13	50	57	74	80	90	90	95	94	96	99
Pittsburgh-PAT	42	47	57	60	93	85	90	93	92	96	88	86	88	91
Buffalo-NFTS			102	110	144	145	160	144	144	143	142	141	141	141
Baltimore-MMTA									11	57	103	100	102	107
San Jose-SCTD					18	42	43	48	101	84	83	81	91	92
New Orleans-RTA	96	94	90	88	89	58	72	78	76	74	74	75	77	77
Cleveland-GCRTA	73	74	74	74	70	71	71	78	80	66	65	70	77	71
Denver-RTD											18	71	88	108
Newark-NJTC	107	132	139	143	144	151	154	157	156	156	161	158	158	159
Hudson-Bergen LRT														
AVERAGE	96	101	100	90	95	93	102	104	103	104	112	115	110	116

Available Circuits

HEAVY RAIL	Number of observed paths / Maximum possible number of paths													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Washington, D.C.-WMATA	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Chicago-RTA-CTA	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.04	0.03
Boston-MBTA	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Atlanta-MARTA	-	-	-	-	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Philadelphia-SEPTA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
San Francisco-BART	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04
New York-PATHC	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Miami-MDTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baltimore-MMTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Los Angeles-LACMTA										-	-	-	-	-
Philadelphia-NJ-PATC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleveland-GCRTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
New York-MTA-SIRTOA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AVERAGE	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

LIGHT RAIL	Number of observed paths / Maximum possible number of paths													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
San Francisco-MUNI	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.05	0.05	0.05
Philadelphia-SEPTA	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Los Angeles-LACMTA								0.05	0.05	0.05	0.05	0.05	0.03	0.03
San Diego Trolley Inc.	-	-	-	-	-	-	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
St. Louis-BSDA											-	-	-	-
Portland-TCMTDO				0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	-
Dallas-DARTA													0.04	0.03
Sacramento-RTD				0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pittsburgh-PAT	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-	-	0.01	0.01	0.01	0.01
Buffalo-NFTS			-	-	-	-	-	-	-	-	-	-	-	-
Baltimore-MMTA									-	-	-	-	-	-
San Jose-SCTD					0.09	0.09	0.09	0.07	0.07	0.07	0.07	0.07	0.07	0.05
New Orleans-RTA	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Cleveland-GCRTA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Denver-RTD											0.04	0.04	0.04	0.04
Newark-NJTC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hudson-Bergen LRT														-
AVERAGE	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Circuitry Index

HEAVY RAIL	Average of ratio (Node-node Distance on the network / Node-node Airline Distance)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	1.37	1.37	1.37	1.37	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36
Washington, D.C.-WMATA	1.36	1.33	1.33	1.33	1.33	1.33	1.33	1.36	1.36	1.36	1.39	1.39	1.39	1.40
Chicago-RTA-CTA	1.41	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.39	1.43	1.43	1.43
Boston-MBTA	1.30	1.32	1.32	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34	1.34
Atlanta-MARTA	1.19	1.24	1.24	1.24	1.22	1.22	1.22	1.22	1.22	1.24	1.24	1.24	1.24	1.25
Philadelphia-SEPTA	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
San Francisco-BART	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.25	1.27
New York-PATHC	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Miami-MDTA	1.05	1.39	1.39	1.39	1.39	1.39	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Baltimore-MMTA	1.09	1.09	1.09	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.11	1.11	1.11
Los Angeles-LACMTA										1.22	1.22	1.22	1.13	1.13
Philadelphia-NJ-PATC	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Cleveland-GCRTA	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
New York-MTA-SIRTOA	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
AVERAGE	1.37	1.37	1.37	1.37	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36

LIGHT RAIL	Average of ratio (Node-node Distance on the network / Node-node Airline Distance)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	1.81	1.81	1.67	1.67	1.67	1.67	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75
San Francisco-MUNI	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.69	1.69	1.69	1.69	1.48	1.48	1.48
Philadelphia-SEPTA	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
Los Angeles-LACMTA								1.05	1.05	1.05	1.05	1.05	1.24	1.24
San Diego Trolley Inc.	1.07	1.07	1.20	1.20	1.20	1.38	1.51	1.51	1.51	1.51	1.53	1.52	1.74	1.49
St. Louis-BSDA											1.19	1.19	1.19	1.19
Portland-TCMTDO				1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.23
Dallas-DARTA													1.41	1.28
Sacramento-RTD				1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
Pittsburgh-PAT	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.20	1.20	1.21	1.21	1.21	1.21
Buffalo-NFTS			1.01	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Baltimore-MMTA									1.10	1.10	1.10	1.10	1.10	1.10
San Jose-SCTD					1.15	1.15	1.15	1.12	1.12	1.12	1.12	1.12	1.12	1.12
New Orleans-RTA	1.26	1.26	1.26	1.26	1.26	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Cleveland-GCRTA	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.28
Denver-RTD											1.22	1.22	1.22	1.22
Newark-NJTC	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Hudson-Bergen LRT														1.45
AVERAGE	1.49	1.49	1.45	1.43	1.43	1.43	1.46	1.41	1.42	1.41	1.43	1.39	1.39	1.49

Network Complexity

HEAVY RAIL	Ratio: (Number of Links / Number of access points)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Washington, D.C.-WMATA	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Chicago-RTA-CTA	1.01	1.02	1.02	1.02	1.01	1.00	1.00	1.00	1.01	1.01	1.00	1.02	1.06	1.06
Boston-MBTA	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Atlanta-MARTA	0.95	0.96	0.96	0.97	1.00	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.03	1.03
Philadelphia-SEPTA	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
San Francisco-BART	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.05
New York-PATHC	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Miami-MDTA	0.90	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Baltimore-MMTA	0.89	0.89	0.89	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.93
Los Angeles-LACMTA										0.80	0.80	0.80	0.88	0.88
Philadelphia-NJ-PATC	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Cleveland-GCRTA	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
New York-MTA-SIRTOA	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
AVERAGE	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	1.00	1.00

LIGHT RAIL	Ratio: (Number of Links / Number of access points)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
San Francisco-MUNI	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.02	1.02	1.02	1.09	1.09	1.09
Philadelphia-SEPTA	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Los Angeles-LACMTA								1.05	1.05	1.05	1.05	1.05	1.03	1.03
San Diego Trolley Inc.	0.94	0.95	0.95	0.95	0.95	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
St. Louis-BSDA											0.94	0.94	0.94	0.94
Portland-TCMTDO				1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	0.97
Dallas-DARTA													1.00	1.00
Sacramento-RTD				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pittsburgh-PAT	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	0.99	0.99	1.01	1.01	1.01	1.01
Buffalo-NFTS			0.92	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Baltimore-MMTA									0.93	0.96	0.96	0.96	0.96	0.96
San Jose-SCTD					1.10	1.10	1.10	1.09	1.09	1.09	1.09	1.09	1.09	1.06
New Orleans-RTA	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Cleveland-GCRTA	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Denver-RTD											1.00	1.00	1.00	1.00
Newark-NJTC	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
Hudson-Bergen LRT														0.97
AVERAGE	0.98	0.98	0.97	0.98	0.99	0.99	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.99

Connectivity Index

HEAVY RAIL	Ratio: (Actual number of links / Maximum possible number of links)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Washington, D.C.-WMATA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Chicago-RTA-CTA	0.34	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.36	0.36
Boston-MBTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Atlanta-MARTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36
Philadelphia-SEPTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
San Francisco-BART	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.37	0.37
New York-PATHC	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Miami-MDTA	0.38	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Baltimore-MMTA	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.36	0.36	0.36
Los Angeles-LACMTA										0.44	0.44	0.44	0.39	0.39
Philadelphia-NJ-PATC	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Cleveland-GCRTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
New York-MTA-SIRTOA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
AVERAGE	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37	0.37

LIGHT RAIL	Ratio: (Actual number of links / Maximum possible number of links)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
San Francisco-MUNI	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35	0.37	0.37	0.37
Philadelphia-SEPTA	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Los Angeles-LACMTA								0.38	0.38	0.38	0.38	0.38	0.36	0.36
San Diego Trolley Inc.	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
St. Louis-BSDA											0.35	0.35	0.35	0.35
Portland-TCMTDO				0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.34
Dallas-DARTA													0.39	0.37
Sacramento-RTD				0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Pittsburgh-PAT	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35
Buffalo-NFTS			0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Baltimore-MMTA									0.36	0.35	0.35	0.35	0.35	0.35
San Jose-SCTD					0.41	0.41	0.41	0.39	0.39	0.39	0.39	0.39	0.39	0.38
New Orleans-RTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Cleveland-GCRTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.34
Denver-RTD											0.38	0.38	0.38	0.38
Newark-NJTC	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
Hudson-Bergen LRT														0.34
AVERAGE	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36

Stop Spacing

HEAVY RAIL	Miles per link													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Washington, D.C.-WMATA	0.96	1.01	1.10	1.10	1.10	1.10	1.10	1.13	1.11	1.11	1.16	1.16	1.16	1.18
Chicago-RTA-CTA	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.65	0.65	0.70	0.69	0.68	0.68
Boston-MBTA	0.71	0.72	0.72	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Atlanta-MARTA	0.89	1.03	1.03	1.02	1.05	1.05	1.05	1.05	1.05	1.09	1.09	1.09	1.09	1.19
Philadelphia-SEPTA	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
San Francisco-BART	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	2.24
New York-PATHC	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Miami-MDTA	1.19	1.16	1.16	1.16	1.16	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Baltimore-MMTA	0.88	0.88	0.88	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.11	1.11	1.11
Los Angeles-LACMTA										0.74	0.74	0.74	0.71	0.71
Philadelphia-NJ-PATC	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
Cleveland-GCRTA	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12
New York-MTA-SIRTOA	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
AVERAGE	0.66	0.68	0.69	0.69	0.69	0.69	0.69	0.70	0.70	0.70	0.71	0.71	0.71	0.72

LIGHT RAIL	Miles per link													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.33	0.33	0.34	0.34	0.34	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
San Francisco-MUNI	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.21	0.21	0.21
Philadelphia-SEPTA	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Los Angeles-LACMTA								0.97	0.97	0.97	0.97	0.97	1.16	1.16
San Diego Trolley Inc.	0.95	0.90	0.99	0.99	0.99	1.06	0.97	0.97	0.97	0.97	0.99	0.97	0.99	0.99
St. Louis-BSDA											1.02	1.02	1.02	1.02
Portland-TCMTDO				0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Dallas-DARTA													0.92	1.09
Sacramento-RTD				0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Pittsburgh-PAT	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.25	0.26	0.26	0.26	0.26
Buffalo-NFTS			0.45	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Baltimore-MMTA									0.90	0.94	0.94	0.94	0.94	0.94
San Jose-SCTD					0.58	0.58	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.57
New Orleans-RTA	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Cleveland-GCRTA	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Denver-RTD											0.40	0.40	0.40	0.40
Newark-NJTC	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Hudson-Bergen LRT														0.65
AVERAGE	0.31	0.30	0.32	0.36	0.37	0.38	0.38	0.41	0.42	0.43	0.46	0.44	0.48	0.41

Density of Network

HEAVY RAIL	Miles of track length per square miles of metropolitan area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	1.17	1.17	1.17	1.17	1.18	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Washington, D.C.-WMATA	0.33	0.27	0.31	0.31	0.31	0.31	0.31	0.34	0.35	0.35	0.39	0.39	0.39	0.34
Chicago-RTA-CTA	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.63	0.59	0.54	0.63	0.63
Boston-MBTA	0.45	0.44	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Atlanta-MARTA	0.26	0.32	0.32	0.33	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.25	0.25
Philadelphia-SEPTA	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
San Francisco-BART	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.20
New York-PATHC	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Miami-MDTA	0.36	0.33	0.33	0.33	0.36	0.36	0.36	0.36	0.36	0.36	0.35	0.36	0.36	0.36
Baltimore-MMTA	0.37	0.37	0.37	0.11	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.19	0.19	0.19
Los Angeles-LACMTA										0.88	0.88	0.88	0.35	0.58
Philadelphia-NJ-PATC	0.27	0.26	0.26	0.26	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Cleveland-GCRTA	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
New York-MTA-SIRTOA	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
AVERAGE	0.41	0.41	0.41	0.39	0.39	0.40	0.40	0.40	0.40	0.45	0.44	0.44	0.41	0.41

LIGHT RAIL	Miles of track length per square miles of metropolitan area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.62	0.62	0.62	0.62	0.62	0.62	0.58	0.58	0.58	0.62	0.62	0.62	0.62	0.62
San Francisco-MUNI	1.03	1.03	1.19	1.19	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Philadelphia-SEPTA	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Los Angeles-LACMTA								0.13	0.13	0.13	0.13	0.13	0.25	0.25
San Diego Trolley Inc.	0.11	0.21	0.27	0.27	0.27	0.17	0.17	0.17	0.17	0.17	0.13	0.13	0.13	0.14
St. Louis-BSDA											0.17	0.21	0.21	0.21
Portland-TCMTDO				0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.17
Dallas-DARTA													0.55	0.26
Sacramento-RTD				0.29	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Pittsburgh-PAT	0.29	0.26	0.27	0.36	0.37	0.40	0.54	0.58	0.41	0.43	0.34	0.34	0.34	0.34
Buffalo-NFTS			0.46	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Baltimore-MMTA									0.29	0.16	0.15	0.15	0.15	0.15
San Jose-SCTD					0.25	0.25	0.25	0.19	0.19	0.19	0.19	0.19	0.19	0.19
New Orleans-RTA	0.81	0.81	0.81	0.81	1.00	0.73	0.75	0.75	0.75	0.71	0.71	0.71	0.71	0.71
Cleveland-GCRTA	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.41	0.41
Denver-RTD											0.57	0.57	0.57	0.57
Newark-NJTC	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Hudson-Bergen LRT														0.33
AVERAGE	0.56	0.57	0.58	0.51	0.53	0.50	0.51	0.48	0.45	0.44	0.42	0.43	0.45	0.43

Density of Access

HEAVY RAIL	Square miles of served area per access point													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	0.88	0.88	0.88	0.88	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.87	0.87
Washington, D.C.-WMATA	5.35	7.97	7.45	7.45	7.45	7.45	7.45	6.78	6.55	6.55	6.20	6.20	6.20	7.29
Chicago-RTA-CTA	2.45	2.52	2.52	2.52	2.50	2.46	2.46	2.46	2.46	2.46	2.88	3.20	2.32	2.31
Boston-MBTA	3.34	3.18	3.18	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03
Atlanta-MARTA	6.10	5.88	5.88	5.83	9.28	9.28	9.28	9.28	9.28	9.78	9.78	9.78	9.78	9.38
Philadelphia-SEPTA	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43
San Francisco-BART	21.58	21.58	21.58	21.58	21.58	21.58	21.58	21.58	21.58	21.58	21.58	21.58	22.03	24.25
New York-PATHC	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87	4.87
Miami-MDTA	5.83	5.95	5.95	5.95	5.95	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.65
Baltimore-MMTA	4.32	4.32	4.32	10.57	10.57	10.57	10.57	10.57	10.57	10.57	10.57	10.96	10.96	10.96
Los Angeles-LACMTA										1.36	1.36	1.36	2.14	2.14
Philadelphia-NJ-PATC	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88	8.88
Cleveland-GCRTA	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63	7.63
New York-MTA-SIRTOA	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36	4.36
AVERAGE	6.30	6.50	6.46	6.96	7.25	7.22	7.22	7.16	7.14	6.74	6.74	6.80	6.82	6.79

LIGHT RAIL	Square miles of served area per access point													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.62	0.62	0.62	0.62	0.62	0.62	0.58	0.58	0.58	0.62	0.62	0.62	0.62	0.62
San Francisco-MUNI	1.03	1.03	1.19	1.19	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
Philadelphia-SEPTA	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Los Angeles-LACMTA								0.13	0.13	0.13	0.13	0.13	0.25	0.25
San Diego Trolley Inc.	0.11	0.21	0.27	0.27	0.27	0.17	0.17	0.17	0.17	0.17	0.13	0.13	0.13	0.14
St. Louis-BSDA											0.17	0.21	0.21	0.21
Portland-TCMTDO				0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.17
Dallas-DARTA													0.55	0.26
Sacramento-RTD				0.29	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Pittsburgh-PAT	0.29	0.26	0.27	0.36	0.37	0.40	0.54	0.58	0.41	0.43	0.34	0.34	0.34	0.34
Buffalo-NFTS			0.46	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Baltimore-MMTA									0.29	0.16	0.15	0.15	0.15	0.15
San Jose-SCTD					0.25	0.25	0.25	0.19	0.19	0.19	0.19	0.19	0.19	0.19
New Orleans-RTA	0.81	0.81	0.81	0.81	1.00	0.73	0.75	0.75	0.75	0.71	0.71	0.71	0.71	0.71
Cleveland-GCRTA	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.41	0.41
Denver-RTD											0.57	0.57	0.57	0.57
Newark-NJTC	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Hudson-Bergen LRT														0.33
AVERAGE	0.56	0.57	0.58	0.51	0.53	0.50	0.51	0.48	0.45	0.44	0.42	0.43	0.45	0.43

Comprehensive Accessibility

HEAVY RAIL	Square mile of served area per square mile of Metropolitan area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Washington, D.C.-WMATA	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Chicago-RTA-CTA	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.07	0.10	0.10
Boston-MBTA	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Atlanta-MARTA	0.04	0.04	0.04	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Philadelphia-SEPTA	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
San Francisco-BART	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
New York-PATHC	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Miami-MDTA	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Baltimore-MMTA	0.06	0.06	0.06	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Los Angeles-LACMTA										0.19	0.19	0.19	0.12	0.12
Philadelphia-NJ-PATC	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Cleveland-GCRTA	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
New York-MTA-SIRTOA	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
AVERAGE	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

LIGHT RAIL	Square mile of served area per square mile of Metropolitan area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
San Francisco-MUNI	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Philadelphia-SEPTA	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Los Angeles-LACMTA								0.02	0.02	0.02	0.02	0.02	0.03	0.03
San Diego Trolley Inc.	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
St. Louis-BSDA											0.03	0.03	0.03	0.03
Portland-TCMTDO				0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Dallas-DARTA													0.08	0.03
Sacramento-RTD				0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Pittsburgh-PAT	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.09	0.09	0.09	0.09
Buffalo-NFTS			0.10	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Baltimore-MMTA									0.04	0.02	0.02	0.02	0.02	0.02
San Jose-SCTD					0.06	0.06	0.06	0.04	0.04	0.04	0.04	0.04	0.04	0.04
New Orleans-RTA	0.25	0.25	0.25	0.25	0.25	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Cleveland-GCRTA	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
Denver-RTD											0.12	0.12	0.12	0.12
Newark-NJTC	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Hudson-Bergen LRT														0.06
AVERAGE	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05

Employment Density

HEAVY RAIL	Number of employees residing per square mile of served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	21,080	21,080	21,125	21,125	21,064	20,990	20,990	20,990	20,990	20,990	20,990	21,009	20,982	20,982
Washington, D.C.-WMATA	5,000	4,779	4,582	4,582	4,582	4,582	4,582	4,688	4,676	4,676	4,630	4,630	4,630	4,577
Chicago-RTA-CTA	7,699	7,629	7,629	7,629	7,629	7,629	7,629	7,629	7,629	7,629	8,083	8,115	7,527	7,527
Boston-MBTA	6,046	6,344	6,344	6,854	6,854	6,854	6,854	6,854	6,854	6,854	6,854	6,854	6,854	6,854
Atlanta-MARTA	1,751	1,864	1,864	1,830	1,737	1,737	1,737	1,737	1,737	1,720	1,720	1,720	1,720	1,663
Philadelphia-SEPTA	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906	5,906
San Francisco-BART	5,446	5,446	5,446	5,446	5,446	5,446	5,446	5,446	5,446	5,446	5,446	5,446	5,338	5,076
New York-PATHC	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455	19,455
Miami-MDTA	3,279	2,937	2,892	2,892	2,892	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872	2,872
Baltimore-MMTA	4,929	4,929	4,929	4,081	4,081	4,081	4,081	4,081	4,081	4,081	4,081	4,142	4,142	4,142
Los Angeles-LACMTA										6,562	6,562	6,562	11,750	11,750
Philadelphia-NJ-PATC	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778	5,778
Cleveland-GCRTA	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362	2,362
New York-MTA-SIRTOA	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619	3,619
AVERAGE	7,204	7,185	7,169	7,138	7,125	7,117	7,117	7,126	7,125	7,080	7,112	7,120	7,464	7,326

LIGHT RAIL	Number of employees residing per square mile of served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	9,437	9,437	9,677	9,677	9,677	9,677	9,654	9,654	9,654	9,654	9,654	9,654	9,654	9,654
San Francisco-MUNI	9,699	9,699	9,699	9,699	9,699	9,699	9,699	9,661	9,661	9,661	9,661	9,675	9,675	9,675
Philadelphia-SEPTA	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987	5,987
Los Angeles-LACMTA								4,125	4,125	4,125	4,125	4,125	3,650	3,650
San Diego Trolley Inc.	1,798	1,772	2,188	2,188	2,188	2,259	2,212	2,212	2,212	2,212	2,128	2,113	2,081	2,081
St. Louis-BSDA											1,361	1,361	1,361	1,361
Portland-TCMTDO				2,604	2,604	2,604	2,604	2,604	2,604	2,604	2,604	2,604	2,604	2,620
Dallas-DARTA													1,251	1,903
Sacramento-RTD				2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117	2,117
Pittsburgh-PAT	2,437	2,437	2,437	2,437	2,437	2,437	2,437	2,437	2,339	2,339	2,442	2,442	2,442	2,442
Buffalo-NFTS			2,614	2,836	2,836	2,836	2,836	2,836	2,836	2,836	2,836	2,836	2,836	2,836
Baltimore-MMTA									3,131	2,459	2,459	2,459	2,459	2,459
San Jose-SCTD					3,409	3,409	3,409	2,229	2,229	2,229	2,229	2,229	2,229	2,175
New Orleans-RTA	3,862	3,862	3,862	3,862	3,862	3,603	3,603	3,603	3,603	3,603	3,603	3,603	3,603	3,603
Cleveland-GCRTA	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,444	2,177
Denver-RTD											1,686	1,686	1,686	1,686
Newark-NJTC	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148	5,148
Hudson-Bergen LRT														6,049
AVERAGE	4,975	4,971	4,759	4,301	4,220	4,203	4,197	4,089	4,008	3,956	3,633	3,633	3,452	3,757

Total Number of Employment

HEAVY RAIL	Number of employees residing in the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	1,642,774	1,642,774	1,639,312	1,639,312	1,646,562	1,649,810	1,649,810	1,649,810	1,649,810	1,649,810	1,649,810	1,651,292	1,648,975	1,648,975
Washington, D.C.-WMATA	67,896	70,300	72,532	72,532	72,532	72,532	72,532	81,852	85,521	85,521	89,917	89,917	89,917	90,166
Chicago-RTA-CTA	235,132	235,137	235,137	235,137	235,137	235,137	235,137	235,137	235,137	235,137	215,101	213,679	237,491	237,491
Boston-MBTA	70,075	78,862	78,862	89,447	89,447	89,447	89,447	89,447	89,447	89,447	89,447	89,447	89,447	89,447
Atlanta-MARTA	9,980	13,235	13,235	14,016	15,115	15,115	15,115	15,115	15,115	16,903	16,903	16,903	16,903	17,742
Philadelphia-SEPTA	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225	99,225
San Francisco-BART	50,704	50,704	50,704	50,704	50,704	50,704	50,704	50,704	50,704	50,704	50,704	50,704	52,690	54,413
New York-PATHC	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784	64,784
Miami-MDTA	8,952	16,269	16,019	16,019	16,019	16,714	16,714	16,714	16,714	16,714	16,714	16,714	16,714	16,714
Baltimore-MMTA	12,075	12,075	12,075	13,466	13,466	13,466	13,466	13,466	13,466	13,466	13,466	15,947	15,947	15,947
Los Angeles-LACMTA	-	-	-	-	-	-	-	-	-	8,465	8,465	8,465	24,441	24,441
Philadelphia-NJ-PATC	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200
Cleveland-GCRTA	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953	11,953
New York-MTA-SIRTOA	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386	21,386
TOTAL	2,213,911	2,235,679	2,234,199	2,246,956	2,255,305	2,259,248	2,259,248	2,268,568	2,272,237	2,282,490	2,266,850	2,269,391	2,308,848	2,410,884

LIGHT RAIL	Number of employees residing in the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	102,674	102,674	93,871	93,871	93,871	93,871	95,479	95,479	95,479	95,479	95,479	95,479	95,479	95,479
San Francisco-MUNI	95,535	95,535	95,535	95,535	95,535	95,535	95,535	102,505	102,505	102,505	102,505	105,555	105,555	105,555
Philadelphia-SEPTA	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766	100,766
Los Angeles-LACMTA								23,305	23,305	23,305	23,305	23,305	33,948	33,948
San Diego Trolley Inc.	7,732	8,115	12,407	12,407	12,407	17,757	18,385	18,385	18,385	18,385	19,473	19,670	21,125	21,125
St. Louis-BSDA											6,205	6,205	6,205	6,205
Portland-TCMTDO				14,038	14,038	14,038	14,038	14,038	14,038	14,038	14,038	14,038	14,038	14,173
Dallas-DARTA													4,229	9,400
Sacramento-RTD				13,080	13,080	13,080	13,080	13,080	13,080	13,080	13,080	13,080	13,080	13,080
Pittsburgh-PAT	29,929	29,929	29,929	29,929	29,929	29,929	29,929	29,929	27,084	27,084	24,347	24,347	24,347	24,347
Buffalo-NFTS			6,091	8,195	8,195	8,195	8,195	8,195	8,195	8,195	8,195	8,195	8,195	8,195
Baltimore-MMTA									10,019	13,940	13,940	13,940	13,940	13,940
San Jose-SCTD					14,214	14,214	14,214	16,940	16,940	16,940	16,940	16,940	16,940	17,029
New Orleans-RTA	15,988	15,988	15,988	15,988	15,988	18,953	18,953	18,953	18,953	18,953	18,953	18,953	18,953	18,953
Cleveland-GCRTA	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,371	14,497
Denver-RTD											3,843	3,843	3,843	3,843
Newark-NJTC	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097	12,097
Hudson-Bergen LRT														48,514
TOTAL	278,326	278,709	280,289	309,511	323,725	332,040	334,276	367,277	374,451	378,372	386,771	390,018	406,345	561,146

Transit Share on the Journey to Work (Motorized Trips)

HEAVY RAIL	Percentage of journey to work in those motorized trips served by transit													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Washington, D.C.-WMATA	0.44	0.44	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.42	0.42	0.42	0.42
Chicago-RTA-CTA	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.41	0.41	0.41
Boston-MBTA	0.38	0.38	0.38	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Atlanta-MARTA	0.29	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.23
Philadelphia-SEPTA	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
San Francisco-BART	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.35	0.34
New York-PATHC	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Miami-MDTA	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Baltimore-MMTA	0.36	0.36	0.36	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.35	0.35	0.35
Los Angeles-LACMTA										0.53	0.53	0.53	0.41	0.41
Philadelphia-NJ-PATC	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Cleveland-GCRTA	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
New York-MTA-SIRTOA	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
AVERAGE	0.40	0.40	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.39	0.39

LIGHT RAIL	Percentage of journey to work in those motorized trips served by transit													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
San Francisco-MUNI	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Philadelphia-SEPTA	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Los Angeles-LACMTA								0.20	0.20	0.20	0.20	0.20	0.15	0.15
San Diego Trolley Inc.	0.23	0.22	0.21	0.21	0.21	0.15	0.16	0.16	0.16	0.16	0.15	0.15	0.14	0.14
St. Louis-BSDA											0.12	0.12	0.12	0.12
Portland-TCMTDO				0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Dallas-DARTA													0.13	0.11
Sacramento-RTD				0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Pittsburgh-PAT	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.21	0.21	0.23	0.23	0.23	0.23
Buffalo-NFTS			0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Baltimore-MMTA									0.22	0.19	0.19	0.19	0.19	0.19
San Jose-SCTD					0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
New Orleans-RTA	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Cleveland-GCRTA	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Denver-RTD											0.23	0.23	0.23	0.23
Newark-NJTC	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Hudson-Bergen LRT														0.44
AVERAGE	0.29	0.29	0.28	0.25	0.23	0.23	0.23	0.22	0.22	0.21	0.21	0.21	0.20	0.22

Rush Hour Proportion (Proportion of initiating trips between 6 and 9 am)

HEAVY RAIL	Proportion of motorized trips initiated between 6 and 9 am over the 24-hour total													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Washington, D.C.-WMATA	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Chicago-RTA-CTA	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.68	0.68	0.67	0.67
Boston-MBTA	0.68	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Atlanta-MARTA	0.67	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Philadelphia-SEPTA	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
San Francisco-BART	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
New York-PATHC	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Miami-MDTA	0.64	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Baltimore-MMTA	0.65	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.65	0.65	0.65
Los Angeles-LACMTA										0.67	0.67	0.67	0.67	0.67
Philadelphia-NJ-PATC	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Cleveland-GCRTA	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
New York-MTA-SIRTOA	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
AVERAGE	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68

LIGHT RAIL	Proportion of motorized trips initiated between 6 and 9 am over the 24-hour total													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
San Francisco-MUNI	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.72	0.72	0.72	0.72	0.71	0.71	0.71
Philadelphia-SEPTA	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Los Angeles-LACMTA								0.73	0.73	0.73	0.73	0.73	0.73	0.73
San Diego Trolley Inc.	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
St. Louis-BSDA											0.71	0.71	0.71	0.71
Portland-TCMTDO				0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
Dallas-DARTA													0.72	0.73
Sacramento-RTD				0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Pittsburgh-PAT	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
Buffalo-NFTS			0.68	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Baltimore-MMTA									0.75	0.75	0.75	0.75	0.75	0.75
San Jose-SCTD					0.72	0.72	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
New Orleans-RTA	0.69	0.69	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Cleveland-GCRTA	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Denver-RTD											0.67	0.67	0.67	0.67
Newark-NJTC	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Hudson-Bergen LRT														0.78
AVERAGE	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.72

Autos per Capita

HEAVY RAIL	Number of autos per resident in the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Washington, D.C.-WMATA	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.46	0.46	0.46	0.46	0.46	0.46	0.46
Chicago-RTA-CTA	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.34	0.35	0.33	0.33
Boston-MBTA	0.34	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Atlanta-MARTA	0.37	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.45
Philadelphia-SEPTA	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
San Francisco-BART	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.41
New York-PATHC	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Miami-MDTA	0.44	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Baltimore-MMTA	0.24	0.24	0.24	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.25	0.25	0.25
Los Angeles-LACMTA										0.17	0.17	0.17	0.26	0.26
Philadelphia-NJ-PATC	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Cleveland-GCRTA	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
New York-MTA-SIRTOA	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
AVERAGE	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.33	0.33	0.33	0.34	0.34

LIGHT RAIL	Number of autos per resident in the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
San Francisco-MUNI	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.45	0.45	0.45
Philadelphia-SEPTA	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34
Los Angeles-LACMTA								0.31	0.31	0.31	0.31	0.31	0.36	0.36
San Diego Trolley Inc.	0.30	0.31	0.31	0.31	0.31	0.39	0.39	0.39	0.39	0.39	0.40	0.40	0.41	0.41
St. Louis-BSDA											0.47	0.47	0.47	0.47
Portland-TCMTDO				0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Dallas-DARTA													0.37	0.48
Sacramento-RTD				0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Pittsburgh-PAT	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.52	0.52	0.50	0.50	0.50	0.50
Buffalo-NFTS			0.37	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Baltimore-MMTA									0.42	0.43	0.43	0.43	0.43	0.43
San Jose-SCTD					0.61	0.61	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60
New Orleans-RTA	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Cleveland-GCRTA	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.52
Denver-RTD											0.37	0.37	0.37	0.37
Newark-NJTC	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Hudson-Bergen LRT														0.32
AVERAGE	0.41	0.41	0.40	0.44	0.45	0.46	0.46	0.45	0.45	0.45	0.44	0.44	0.44	0.43

Autos per Household

HEAVY RAIL	Number of autos per household in the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Washington, D.C.-WMATA	0.97	0.98	1.00	1.00	1.00	1.00	1.00	0.98	0.97	0.97	0.98	0.98	0.98	0.99
Chicago-RTA-CTA	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.83	0.84	0.81	0.81
Boston-MBTA	0.80	0.84	0.84	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Atlanta-MARTA	0.89	0.98	0.98	0.99	1.01	1.01	1.01	1.01	1.01	1.04	1.04	1.04	1.04	1.07
Philadelphia-SEPTA	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
San Francisco-BART	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.93	0.95
New York-PATHC	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Miami-MDTA	1.17	1.15	1.15	1.15	1.15	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16
Baltimore-MMTA	0.61	0.61	0.61	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.64	0.64	0.64
Los Angeles-LACMTA										0.47	0.47	0.47	0.69	0.69
Philadelphia-NJ-PATC	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
Cleveland-GCRTA	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
New York-MTA-SIRTOA	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
AVERAGE	0.82	0.83	0.83	0.84	0.84	0.84	0.84	0.84	0.84	0.81	0.82	0.81	0.83	0.82

LIGHT RAIL	Number of autos per household in the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.80	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
San Francisco-MUNI	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.08	1.08	1.08	1.08	1.06	1.06	1.06
Philadelphia-SEPTA	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
Los Angeles-LACMTA								1.07	1.07	1.07	1.07	1.07	1.23	1.23
San Diego Trolley Inc.	1.01	1.02	1.08	1.08	1.08	1.28	1.24	1.24	1.24	1.24	1.27	1.27	1.28	1.28
St. Louis-BSDA											1.01	1.01	1.01	1.01
Portland-TCMTDO				1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13
Dallas-DARTA													1.38	1.34
Sacramento-RTD				1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Pittsburgh-PAT	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.30	1.30	1.24	1.24	1.24	1.24
Buffalo-NFTS			0.81	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Baltimore-MMTA									0.80	1.01	1.01	1.01	1.01	1.01
San Jose-SCTD					1.83	1.83	1.83	1.81	1.81	1.81	1.81	1.81	1.81	1.81
New Orleans-RTA	1.02	1.02	1.02	1.02	1.02	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Cleveland-GCRTA	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.20
Denver-RTD											0.77	0.77	0.77	0.77
Newark-NJTC	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Hudson-Bergen LRT														0.82
AVERAGE	1.01	1.02	1.00	1.04	1.11	1.13	1.12	1.12	1.10	1.11	1.08	1.08	1.11	1.08

Proportion of Vacant Housing

HEAVY RAIL	Proportion of vacant housing in the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Washington, D.C.-WMATA	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Chicago-RTA-CTA	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.12	0.12
Boston-MBTA	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Atlanta-MARTA	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16
Philadelphia-SEPTA	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
San Francisco-BART	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
New York-PATHC	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Miami-MDTA	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Baltimore-MMTA	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14
Los Angeles-LACMTA										0.14	0.14	0.14	0.12	0.12
Philadelphia-NJ-PATC	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Cleveland-GCRTA	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
New York-MTA-SIRTOA	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
AVERAGE	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

LIGHT RAIL	Proportion of vacant housing in the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
San Francisco-MUNI	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Philadelphia-SEPTA	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Los Angeles-LACMTA								0.08	0.08	0.08	0.08	0.08	0.07	0.07
San Diego Trolley Inc.	0.08	0.08	0.07	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
St. Louis-BSDA											0.17	0.17	0.17	0.17
Portland-TCMTDO				0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Dallas-DARTA													0.16	0.15
Sacramento-RTD				0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Pittsburgh-PAT	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.07	0.07	0.07
Buffalo-NFTS			0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Baltimore-MMTA									0.13	0.11	0.11	0.11	0.11	0.11
San Jose-SCTD					0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
New Orleans-RTA	0.20	0.20	0.20	0.20	0.20	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Cleveland-GCRTA	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
Denver-RTD											0.19	0.19	0.19	0.19
Newark-NJTC	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Hudson-Bergen LRT														0.10
AVERAGE	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.11

Housing Density

HEAVY RAIL	Number of housing units per square mile of the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	20,407	20,407	20,465	20,465	20,377	20,329	20,329	20,329	20,329	20,329	20,329	20,329	20,312	20,312
Washington, D.C.-WMATA	4,614	4,388	4,166	4,166	4,166	4,166	4,166	4,302	4,341	4,341	4,248	4,248	4,248	4,194
Chicago-RTA-CTA	7,779	7,708	7,708	7,708	7,708	7,708	7,708	7,708	7,708	7,708	7,633	7,610	7,457	7,457
Boston-MBTA	5,433	5,586	5,586	6,008	6,008	6,008	6,008	6,008	6,008	6,008	6,008	6,008	6,008	6,008
Atlanta-MARTA	2,027	2,078	2,078	2,036	1,907	1,907	1,907	1,907	1,907	1,849	1,849	1,849	1,849	1,778
Philadelphia-SEPTA	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645	6,645
San Francisco-BART	5,297	5,297	5,297	5,297	5,297	5,297	5,297	5,297	5,297	5,297	5,297	5,297	5,129	4,853
New York-PATHC	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974	17,974
Miami-MDTA	2,653	2,762	2,762	2,762	2,762	2,711	2,711	2,711	2,711	2,711	2,711	2,711	2,711	2,711
Baltimore-MMTA	5,720	5,720	5,720	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,594	4,878	4,878	4,878
Los Angeles-LACMTA										6,888	6,888	6,888	10,682	10,682
Philadelphia-NJ-PATC	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282	6,282
Cleveland-GCRTA	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904	2,904
New York-MTA-SIRTOA	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897	2,897
AVERAGE	6,999	7,000	6,987	6,924	6,906	6,898	6,898	6,909	6,913	6,906	6,893	6,914	7,179	7,113

LIGHT RAIL	Number of housing units per square mile of the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	7,894	7,894	8,154	8,154	8,154	8,154	8,134	8,134	8,134	8,134	8,134	8,134	8,134	8,134
San Francisco-MUNI	8,151	8,151	8,151	8,151	8,151	8,151	8,151	8,038	8,038	8,038	8,038	8,108	8,108	8,108
Philadelphia-SEPTA	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940	5,940
Los Angeles-LACMTA								3,709	3,709	3,709	3,709	3,709	3,109	3,109
San Diego Trolley Inc.	1,767	1,759	2,063	2,063	2,063	2,062	2,062	2,062	2,062	2,062	1,967	1,950	1,909	1,909
St. Louis-BSDA											1,742	1,742	1,742	1,742
Portland-TCMTDO				2,710	2,710	2,710	2,710	2,710	2,710	2,710	2,710	2,710	2,710	2,731
Dallas-DARTA													1,164	1,810
Sacramento-RTD				2,288	2,288	2,288	2,288	2,288	2,288	2,288	2,288	2,288	2,288	2,288
Pittsburgh-PAT	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,292	2,130	2,130	2,327	2,327	2,327	2,327
Buffalo-NFTS			3,559	3,423	3,423	3,423	3,423	3,423	3,423	3,423	3,423	3,423	3,423	3,423
Baltimore-MMTA									3,674	2,654	2,654	2,654	2,654	2,654
San Jose-SCTD					2,263	2,263	2,263	1,489	1,489	1,489	1,489	1,489	1,489	1,453
New Orleans-RTA	4,738	4,738	4,738	4,738	4,738	4,608	4,608	4,608	4,608	4,608	4,608	4,608	4,608	4,608
Cleveland-GCRTA	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,570	2,352
Denver-RTD											2,661	2,661	2,661	2,661
Newark-NJTC	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448	5,448
Hudson-Bergen LRT														5,254
AVERAGE	4,694	4,693	4,622	4,184	4,009	3,997	3,995	3,898	3,868	3,789	3,585	3,588	3,397	3,664

Household Size

HEAVY RAIL	Average number of members of a household at the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Washington, D.C.-WMATA	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Chicago-RTA-CTA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.5	2.5
Boston-MBTA	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Atlanta-MARTA	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4
Philadelphia-SEPTA	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
San Francisco-BART	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4
New York-PATHC	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Miami-MDTA	2.6	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Baltimore-MMTA	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Los Angeles-LACMTA										2.8	2.8	2.8	2.7	2.7
Philadelphia-NJ-PATC	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Cleveland-GCRTA	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
New York-MTA-SIRTOA	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
AVERAGE	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4

LIGHT RAIL	Average number of members of a household at the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
San Francisco-MUNI	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Philadelphia-SEPTA	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Los Angeles-LACMTA								3.4	3.4	3.4	3.4	3.4	3.4	3.4
San Diego Trolley Inc.	3.4	3.3	3.5	3.5	3.5	3.3	3.2	3.2	3.2	3.2	3.2	3.2	3.1	3.1
St. Louis-BSDA											2.1	2.1	2.1	2.1
Portland-TCMTDO				2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Dallas-DARTA													3.8	2.8
Sacramento-RTD				2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Pittsburgh-PAT	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Buffalo-NFTS			2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Baltimore-MMTA									1.9	2.3	2.3	2.3	2.3	2.3
San Jose-SCTD					3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
New Orleans-RTA	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Cleveland-GCRTA	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Denver-RTD											2.1	2.1	2.1	2.1
Newark-NJTC	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Hudson-Bergen LRT														2.6
AVERAGE	2.6	2.5	2.5	2.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5

Population Density

HEAVY RAIL	Number of residents per square mile of served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	47,717	47,717	47,823	47,823	47,668	47,550	47,550	47,550	47,550	47,550	47,550	47,550	47,492	47,492
Washington, D.C.-WMATA	8,313	7,963	7,625	7,625	7,625	7,625	7,625	8,030	8,076	8,076	7,993	7,993	7,993	7,900
Chicago-RTA-CTA	16,859	16,706	16,706	16,706	16,706	16,706	16,706	16,706	16,706	16,706	16,470	16,438	16,236	16,236
Boston-MBTA	11,729	12,109	12,109	12,933	12,933	12,933	12,933	12,933	12,933	12,933	12,933	12,933	12,933	12,933
Atlanta-MARTA	4,029	4,016	4,016	3,955	3,732	3,732	3,732	3,732	3,732	3,682	3,682	3,682	3,682	3,532
Philadelphia-SEPTA	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756	14,756
San Francisco-BART	11,338	11,338	11,338	11,338	11,338	11,338	11,338	11,338	11,338	11,338	11,338	11,338	11,073	10,505
New York-PATHC	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027	30,027
Miami-MDTA	6,249	7,245	7,245	7,245	7,245	7,165	7,165	7,165	7,165	7,165	7,165	7,165	7,165	7,165
Baltimore-MMTA	12,387	12,387	12,387	9,982	9,982	9,982	9,982	9,982	9,982	9,982	9,982	10,686	10,686	10,686
Los Angeles-LACMTA										16,330	16,330	16,330	25,113	25,113
Philadelphia-NJ-PATC	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770
Cleveland-GCRTA	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679	6,679
New York-MTA-SIRTOA	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580	7,580
AVERAGE	14,473	14,545	14,525	14,389	14,357	14,341	14,341	14,374	14,378	14,525	14,500	14,552	15,187	15,098

LIGHT RAIL	Number of residents per square mile of served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	16,391	16,391	16,756	16,756	16,756	16,756	16,761	16,761	16,761	16,761	16,761	16,761	16,761	16,761
San Francisco-MUNI	17,542	17,542	17,542	17,542	17,542	17,542	17,542	17,515	17,515	17,515	17,515	17,576	17,576	17,576
Philadelphia-SEPTA	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963	13,963
Los Angeles-LACMTA								11,711	11,711	11,711	11,711	11,711	9,959	9,959
San Diego Trolley Inc.	5,480	5,361	6,690	6,690	6,690	6,270	6,101	6,101	6,101	6,101	5,797	5,736	5,517	5,517
St. Louis-BSDA											3,047	3,047	3,047	3,047
Portland-TCMTDO				5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,286	5,309
Dallas-DARTA													3,666	4,310
Sacramento-RTD				4,481	4,481	4,481	4,481	4,481	4,481	4,481	4,481	4,481	4,481	4,481
Pittsburgh-PAT	5,328	5,328	5,328	5,328	5,328	5,328	5,328	5,328	4,999	4,999	5,375	5,375	5,375	5,375
Buffalo-NFTS			6,691	6,933	6,933	6,933	6,933	6,933	6,933	6,933	6,933	6,933	6,933	6,933
Baltimore-MMTA									6,181	5,106	5,106	5,106	5,106	5,106
San Jose-SCTD					6,496	6,496	6,496	4,343	4,343	4,343	4,343	4,343	4,343	4,235
New Orleans-RTA	8,725	8,725	8,725	8,725	8,725	7,790	7,790	7,790	7,790	7,790	7,790	7,790	7,790	7,790
Cleveland-GCRTA	5,453	5,453	5,453	5,453	5,453	5,453	5,453	5,453	5,453	5,453	5,453	5,453	5,453	4,980
Denver-RTD											4,518	4,518	4,518	4,518
Newark-NJTC	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008	14,008
Hudson-Bergen LRT														12,002
AVERAGE	10,418	10,401	10,149	9,120	8,882	8,758	8,744	8,809	8,582	8,499	7,875	7,875	7,489	8,104

Proportion of Minorities in the Population

HEAVY RAIL	Proportion of African Americans and Hispanic American residing in the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Washington, D.C.-WMATA	0.44	0.43	0.42	0.42	0.42	0.42	0.42	0.47	0.48	0.48	0.48	0.48	0.48	0.48
Chicago-RTA-CTA	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.49	0.48	0.54	0.54
Boston-MBTA	0.33	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Atlanta-MARTA	0.66	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.58
Philadelphia-SEPTA	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
San Francisco-BART	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.37
New York-PATHC	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miami-MDTA	0.69	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Baltimore-MMTA	0.88	0.88	0.88	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.84
Los Angeles-LACMTA										0.72	0.72	0.72	0.65	0.65
Philadelphia-NJ-PATC	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Cleveland-GCRTA	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
New York-MTA-SIRTOA	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
AVERAGE	0.46	0.47	0.47	0.46	0.46	0.46	0.46	0.47	0.47	0.49	0.48	0.48	0.48	0.48

LIGHT RAIL	Proportion of African Americans and Hispanic American residing in the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.18	0.18	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
San Francisco-MUNI	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.30	0.30	0.30	0.30	0.23	0.23	0.23
Philadelphia-SEPTA	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Los Angeles-LACMTA								0.82	0.82	0.82	0.82	0.82	0.81	0.81
San Diego Trolley Inc.	0.60	0.60	0.70	0.70	0.70	0.60	0.59	0.59	0.59	0.59	0.58	0.58	0.56	0.56
St. Louis-BSDA											0.55	0.55	0.55	0.55
Portland-TCMTDO				0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Dallas-DARTA													0.80	0.68
Sacramento-RTD				0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Pittsburgh-PAT	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.09	0.09	0.09	0.09
Buffalo-NFTS			0.55	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Baltimore-MMTA									0.37	0.38	0.38	0.38	0.38	0.38
San Jose-SCTD					0.34	0.34	0.34	0.36	0.36	0.36	0.36	0.36	0.36	0.35
New Orleans-RTA	0.45	0.45	0.45	0.45	0.45	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Cleveland-GCRTA	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.54
Denver-RTD											0.65	0.65	0.65	0.65
Newark-NJTC	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Hudson-Bergen LRT														0.56
AVERAGE	0.40	0.40	0.43	0.37	0.37	0.35	0.35	0.40	0.40	0.40	0.43	0.42	0.44	0.44

Proportion of the Population below Poverty

HEAVY RAIL	Proportion of population below line of poverty in the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Washington, D.C.-WMATA	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.13	0.13	0.13	0.13	0.13	0.13
Chicago-RTA-CTA	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.23	0.22	0.25	0.25
Boston-MBTA	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Atlanta-MARTA	0.31	0.28	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.25
Philadelphia-SEPTA	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
San Francisco-BART	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
New York-PATHC	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Miami-MDTA	0.24	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Baltimore-MMTA	0.33	0.33	0.33	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.34	0.34	0.34
Los Angeles-LACMTA										0.34	0.34	0.34	0.30	0.30
Philadelphia-NJ-PATC	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Cleveland-GCRTA	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
New York-MTA-SIRTOA	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
AVERAGE	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.22	0.22	0.22	0.22	0.22

LIGHT RAIL	Proportion of population below line of poverty in the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
San Francisco-MUNI	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.12	0.12	0.12
Philadelphia-SEPTA	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Los Angeles-LACMTA								0.33	0.33	0.33	0.33	0.33	0.30	0.30
San Diego Trolley Inc.	0.22	0.22	0.28	0.28	0.28	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23
St. Louis-BSDA											0.23	0.23	0.23	0.23
Portland-TCMTDO				0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Dallas-DARTA													0.24	0.22
Sacramento-RTD				0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Pittsburgh-PAT	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.11	0.11	0.11	0.11
Buffalo-NFTS			0.27	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Baltimore-MMTA									0.22	0.21	0.21	0.21	0.21	0.21
San Jose-SCTD					0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11
New Orleans-RTA	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Cleveland-GCRTA	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19
Denver-RTD											0.44	0.44	0.44	0.44
Newark-NJTC	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Hudson-Bergen LRT														0.16
AVERAGE	0.18	0.18	0.20	0.19	0.19	0.18	0.18	0.19	0.19	0.19	0.21	0.21	0.21	0.21

Average Per Capita Income

HEAVY RAIL	Annual dollars per resident of served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	16,518	16,518	16,528	16,528	16,507	16,500	16,500	16,500	16,500	16,500	16,500	16,500	16,512	16,512
Washington, D.C.-WMATA	24,407	24,218	24,292	24,292	24,292	24,292	24,292	22,864	22,749	22,749	22,367	22,367	22,367	22,365
Chicago-RTA-CTA	14,481	14,481	14,481	14,481	14,481	14,481	14,481	14,481	14,481	14,481	15,686	15,794	14,673	14,673
Boston-MBTA	16,770	16,976	16,976	17,615	17,615	17,615	17,615	17,615	17,615	17,615	17,615	17,615	17,615	17,615
Atlanta-MARTA	11,824	13,838	13,838	13,627	13,473	13,473	13,473	13,473	13,473	13,290	13,290	13,290	13,290	14,061
Philadelphia-SEPTA	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922	11,922
San Francisco-BART	13,590	13,590	13,590	13,590	13,590	13,590	13,590	13,590	13,590	13,590	13,590	13,590	13,627	13,706
New York-PATHC	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639	32,639
Miami-MDTA	12,694	9,309	9,309	9,309	9,309	9,279	9,279	9,279	9,279	9,279	9,279	9,279	9,279	9,279
Baltimore-MMTA	10,206	10,206	10,206	10,869	10,869	10,869	10,869	10,869	10,869	10,869	10,869	10,279	10,279	10,279
Los Angeles-LACMTA										9,636	9,636	9,636	9,304	9,304
Philadelphia-NJ-PATC	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077	22,077
Cleveland-GCRTA	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932	8,932
New York-MTA-SIRTOA	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515	17,515
AVERAGE	16,429	16,325	16,331	16,415	16,402	16,399	16,399	16,289	16,280	15,792	15,851	15,817	15,717	15,777

LIGHT RAIL	Annual dollars per resident of served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	20,366	20,366	20,742	20,742	20,742	20,742	20,617	20,617	20,617	20,617	20,617	20,617	20,617	20,617
San Francisco-MUNI	19,302	19,302	19,302	19,302	19,302	19,302	19,302	19,124	19,124	19,124	19,124	18,982	18,982	18,982
Philadelphia-SEPTA	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292	12,292
Los Angeles-LACMTA								7,581	7,581	7,581	7,581	7,581	8,301	8,301
San Diego Trolley Inc.	10,144	10,134	8,532	8,532	8,532	9,891	10,187	10,187	10,187	10,187	10,374	10,367	12,141	12,141
St. Louis-BSDA											14,679	14,679	14,679	14,679
Portland-TCMTDO				13,420	13,420	13,420	13,420	13,420	13,420	13,420	13,420	13,420	13,420	13,475
Dallas-DARTA													7,944	11,589
Sacramento-RTD				13,392	13,392	13,392	13,392	13,392	13,392	13,392	13,392	13,392	13,392	13,392
Pittsburgh-PAT	14,407	14,407	14,407	14,407	14,407	14,407	14,407	14,407	15,018	15,018	14,872	14,872	14,872	14,872
Buffalo-NFTS			12,463	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313
Baltimore-MMTA									18,195	16,289	16,289	16,289	16,289	16,289
San Jose-SCTD					15,399	15,399	15,399	15,724	15,724	15,724	15,724	15,724	15,724	15,736
New Orleans-RTA	18,682	18,682	18,682	18,682	18,682	18,807	18,807	18,807	18,807	18,807	18,807	18,807	18,807	18,807
Cleveland-GCRTA	23,371	23,371	23,371	23,371	23,371	23,371	23,371	23,371	23,371	23,371	23,371	23,371	23,371	22,898
Denver-RTD											9,700	9,700	9,700	9,700
Newark-NJTC	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549	9,549
Hudson-Bergen LRT														15,499
AVERAGE	16,546	16,544	15,881	15,371	15,374	15,508	15,524	14,874	15,177	15,030	14,654	14,644	14,381	14,507

Average Household Median Income

HEAVY RAIL	Annual dollars of income per household of served area													
name	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York CTA	29,163	29,163	29,158	29,158	29,158	29,144	29,144	29,144	29,144	29,144	29,144	29,144	29,153	29,153
Washington, D.C.-WMATA	38,245	38,268	38,803	38,803	38,803	38,803	38,803	37,382	37,195	37,195	36,995	36,995	36,995	37,036
Chicago-CTA	26,089	26,089	26,089	26,089	26,089	26,089	26,089	26,089	26,089	26,089	27,885	28,069	26,538	26,538
Boston-MBTA	29,562	30,184	30,184	30,562	30,562	30,562	30,562	30,562	30,562	30,562	30,562	30,562	30,562	30,562
Atlanta-MARTA	18,780	21,845	21,845	21,737	21,822	21,822	21,822	21,822	21,822	22,162	22,162	22,162	22,162	23,396
Philadelphia-SEPTA	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635	22,635
San Francisco-BART	24,404	24,404	24,404	24,404	24,404	24,404	24,404	24,404	24,404	24,404	24,404	24,404	24,756	25,072
New York-PATH	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828	40,828
Miami-Dade Cnty TA	23,196	18,654	18,654	18,654	18,654	18,794	18,794	18,794	18,794	18,794	18,794	18,794	18,794	18,794
Baltimore-MTA	18,113	18,113	18,113	19,809	19,809	19,809	19,809	19,809	19,809	19,809	19,809	18,303	18,303	18,303
LA-LACMTA/SCRTD										13,369	13,369	13,369	16,892	16,892
Lindenwold-PATCO	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354	29,354
Cleveland RTA	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538	17,538
Staten Island Rapid Trans	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592	41,592
TOTAL	27,654	27,590	27,631	27,782	27,788	27,798	27,798	27,689	27,674	26,677	26,791	26,696	26,864	26,978

LIGHT RAIL	Annual dollars of income per household of served area													
name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	32,482	32,482	32,360	32,360	32,360	32,360	32,301	32,301	32,301	32,301	32,301	32,301	32,301	32,301
San Francisco-MUNI	35,243	35,243	35,243	35,243	35,243	35,243	35,243	35,586	35,586	35,586	35,586	35,107	35,107	35,107
Philadelphia-SEPTA														25,639
LA-SCRTD								19,894	19,894	19,894	19,894	19,894	22,831	22,831
San Diego Trolley	18,141	18,195	17,877	17,877	17,877	21,769	21,371	21,371	21,371	21,371	22,001	21,957	22,460	22,460
St. Louis-Bi-State											21,980	21,980	21,980	21,980
Portland Try-County MTD				20,878	20,878	20,878	20,878	20,878	20,878	20,878	20,878	20,878	20,878	20,856
Dallas-DART													20,158	23,979
Sacramento RTD				22,722	22,722	22,722	22,722	22,722	22,722	22,722	22,722	22,722	22,722	22,722
Pittsburgh-PAT	28,783	28,783	28,783	28,783	28,783	28,783	28,783	28,783	29,910	29,910	29,191	29,191	29,191	29,191
Buffalo-Niagara Frontier			17,737	19,338	19,338	19,338	19,338	19,338	19,338	19,338	19,338	19,338	19,338	19,338
Baltimore-Maryland DOT									23,794	25,490	25,490	25,490	25,490	25,490
Santa Clara County TD					40,553	40,553	40,553	40,175	40,175	40,175	40,175	40,175	40,175	40,217
New Orleans Public Svc	24,545	24,545	24,545	24,545	24,545	24,184	24,184	24,184	24,184	24,184	24,184	24,184	24,184	24,184
Cleveland RTA	38,112	38,112	38,112	38,112	38,112	38,112	38,112	38,112	38,112	38,112	38,112	38,112	38,112	37,350
Denver-RTD											12,765	12,765	12,765	12,765
Newark-NJT Corp.	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567	20,567
Hudson-Bergen LRT														31,057
TOTAL	28,268	28,275	26,903	26,043	27,362	27,683	27,641	26,993	26,833	26,964	25,679	25,644	25,516	26,002

Population

HEAVY RAIL	Population residing in the served area													
name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York CTA	3,718,553	3,718,553	3,711,029	3,711,029	3,726,225	3,737,456	3,737,456	3,737,456	3,737,456	3,737,456	3,737,456	3,737,456	3,732,428	3,732,428
Washington, D.C.-WMATA	112,889	117,133	120,701	120,701	120,701	120,701	120,701	140,208	147,719	147,719	155,226	155,226	155,226	155,623
Chicago-CTA	514,860	514,872	514,872	514,872	514,872	514,872	514,872	514,872	514,872	514,872	438,272	432,801	512,234	512,234
Boston-MBTA	135,942	150,513	150,513	168,775	168,775	168,775	168,775	168,775	168,775	168,775	168,775	168,775	168,775	168,775
Atlanta-MARTA	22,967	28,517	28,517	30,297	32,469	32,469	32,469	32,469	32,469	36,195	36,195	36,195	36,195	37,686
Philadelphia-SEPTA	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894	247,894
San Francisco-BART	105,557	105,557	105,557	105,557	105,557	105,557	105,557	105,557	105,557	105,557	105,557	105,557	109,293	112,617
New York-PATH	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990	99,990
Miami-Dade Cnty TA	17,060	40,137	40,137	40,137	40,137	41,699	41,699	41,699	41,699	41,699	41,699	41,699	41,699	41,699
Baltimore-MTA	30,347	30,347	30,347	32,941	32,941	32,941	32,941	32,941	32,941	32,941	32,941	41,142	41,142	41,142
LA-LACMTA/SCRTD										21,066	21,066	21,066	52,235	52,235
Lindenwold-PATCO	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927	33,927
Cleveland RTA	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797	33,797
Staten Island Rapid Trans	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799	44,799
TOTAL	4,870,688	4,918,142	4,914,186	4,936,822	4,954,190	4,966,983	4,966,983	4,986,490	4,994,001	5,018,793	4,949,700	4,952,430	5,061,740	5,314,846

LIGHT RAIL	Population residing in the served area													
name	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	178,330	178,330	162,535	162,535	162,535	162,535	165,771	165,771	165,771	165,771	165,771	165,771	165,771	165,771
San Francisco-MUNI	172,785	172,785	172,785	172,785	172,785	172,785	172,785	185,835	185,835	185,835	185,835	191,753	191,753	191,753
Philadelphia-SEPTA	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999	234,999
LA-SCRTD								66,167	66,167	66,167	66,167	66,167	92,621	92,621
San Diego Trolley	23,562	24,554	37,934	37,934	37,934	49,283	50,696	50,696	50,696	50,696	53,041	53,406	56,002	56,002
St. Louis-Bi-State											13,895	13,895	13,895	13,895
Portland Try-County MTD				28,491	28,491	28,491	28,491	28,491	28,491	28,491	28,491	28,491	28,491	28,722
Dallas-DART													12,391	21,293
Sacramento RTD				27,695	27,695	27,695	27,695	27,695	27,695	27,695	27,695	27,695	27,695	27,695
Pittsburgh-PAT	65,425	65,425	65,425	65,425	65,425	65,425	65,425	65,425	57,889	57,889	53,592	53,592	53,592	53,592
Buffalo-Niagara Frontier			15,590	20,037	20,037	20,037	20,037	20,037	20,037	20,037	20,037	20,037	20,037	20,037
Baltimore-Maryland DOT									19,779	28,949	28,949	28,949	28,949	28,949
Santa Clara County TD					27,088	27,088	27,088	33,006	33,006	33,006	33,006	33,006	33,006	33,160
New Orleans Public Svc	36,122	36,122	36,122	36,122	36,122	40,977	40,977	40,977	40,977	40,977	40,977	40,977	40,977	40,977
Cleveland RTA	32,066	32,066	32,066	32,066	32,066	32,066	32,066	32,066	32,066	32,066	32,066	32,066	32,066	33,168
Denver-RTD											10,300	10,300	10,300	10,300
Newark-NJT Corp.	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918	32,918
Hudson-Bergen LRT														96,258
TOTAL	541,208	542,200	555,375	616,008	643,096	659,300	663,949	749,084	761,327	770,497	792,740	799,023	840,464	1,182,110

Labor used on Maintenance

HEAVY RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York-MTA-NYCT	22,820	30,598	31,606	32,362	27,274	28,584	27,835	26,126	25,605	25,367	26,166	24,911	23,998	22,791
Washington, D.C.-WMATA	3,140	3,390	3,585	3,851	3,922	4,055	4,068	4,300	4,426	4,358	4,537	4,701	4,644	4,601
Chicago-RTA-CTA	2,846	3,144	3,202	3,143	3,438	3,342	3,240	3,119	3,088	2,910	2,955	2,488	2,491	2,843
Boston-MBTA		2,654	2,488	2,560	2,440	2,425	2,355	2,469	2,462	2,685	1,868	1,653	1,766	1,584
Atlanta-MARTA	278	847	867	978	678	772	942	913	646	854	661	729	810	857
Philadelphia-SEPTA	1,315	1,300	2,009	1,839	1,986	2,052	1,969	2,391	1,602	1,272	1,606	1,682	1,765	1,728
San Francisco-BART	1,658	1,784	1,834	1,810	1,822	1,834	2,135	2,262	2,142	2,197	2,035	1,980	2,190	2,476
New York-PATHC	1,114	1,316	1,316	1,217	1,217	1,200	1,381	1,381		1,355	1,280	1,212	1,177	1,136
Miami-MDTA	184	490	515	519	492	521	551	550	544	557	568	549	501	538
Baltimore-MMTA	208	371	388	429	469	510	546	555	548	500	465	450	445	448
Los Angeles-LACMTA										180	170	201	252	269
Philadelphia-NJ-PATC	348	370	360	354	354	344	346	298	295	273	273	253	254	254
Cleveland-GCRTA	320	280	295	342	336	362	361	322	318	299	298	326	336	188
New York-MTA-SIRTOA	222	244	274	272	292	308	312	308	192	213	234	206	227	210
TOTAL	19,774	28,889	29,902	30,593	26,407	28,089	28,446	27,626	26,027	27,238	27,509	26,593	26,144	26,039

LIGHT RAIL	Annual Labor Hours (000's)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		357	387	356	327	352	318	256	251	318	975	851	819	851
San Francisco-MUNI	884	919	768	726	797	801	801	636	617	580	708	614	569	638
Philadelphia-SEPTA	748	747	1,688	1,591	1,233	1,263	1,212	1,312	844	642	629	630	649	616
Los Angeles-LACMTA								179	179	251	223	246	574	650
San Diego Trolley Inc.	57	76	92	113	121	140	236	223	220	230	245	251	288	324
St. Louis-BSDA											61	105	124	118
Portland-TCMTDO				98	102	116	131	125	138	136	174	260	313	346
Dallas-DARTA													124	221
Sacramento-RTD				60	79	76	85	87	96	126	91	121	116	124
Pittsburgh-PAT	389	364	344	529	562	458	690	463	480	680	537	450	449	422
Buffalo-NFTS			192	199	213	213	213	184	197	203	209	200	199	177
Baltimore-MMTA									40	121	157	175	188	198
San Jose-SCTD					145	145	150	203	179	157	189	206	212	226
New Orleans-RTA	121	131	158	160	158	162	175	222	62	47	193	41	74	100
Cleveland-GCRTA	207	246	147	201	194	201	207	198	171	160	162	178	202	135
Denver-RTD											52	66	71	73
Newark-NJTC	34	53	49	59	60	59	57	57	68	57	70	55	75	69
TOTAL	1,102	1,197	1,912	2,061	1,975	1,867	1,751	2,095	1,606	1,656	2,164	2,140	2,495	2,606

Half Rush Hour Proportion (Proportion of initiating trips between 8 and 8:30 am)

HEAVY RAIL	Proportion of motorized trips between 8 and 8:30 am over the 24-hour total of the served area													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Washington, D.C.-WMATA	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Chicago-RTA-CTA	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Boston-MBTA	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Atlanta-MARTA	0.15	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Philadelphia-SEPTA	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
San Francisco-BART	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
New York-PATHC	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miami-MDTA	0.16	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Baltimore-MMTA	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13
Los Angeles-LACMTA										0.08	0.08	0.08	0.13	0.13
Philadelphia-NJ-PATC	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Cleveland-GCRTA	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
New York-MTA-SIRTOA	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
AVERAGE	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

LIGHT RAIL	Proportion of motorized trips between 8 and 8:30 am over the 24-hour total of the served area													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
San Francisco-MUNI	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16
Philadelphia-SEPTA														0.15
Los Angeles-LACMTA								0.09	0.09	0.09	0.09	0.09	0.09	0.09
San Diego Trolley Inc.	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09
St. Louis-BSDA											0.13	0.13	0.13	0.13
Portland-TCMTDO				0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Dallas-DARTA													0.09	0.12
Sacramento-RTD				0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Pittsburgh-PAT	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Buffalo-NFTS			0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Baltimore-MMTA									0.18	0.16	0.16	0.16	0.16	0.16
San Jose-SCTD					0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
New Orleans-RTA	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Cleveland-GCRTA	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Denver-RTD											0.10	0.10	0.10	0.10
Newark-NJTC	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Hudson-Bergen LRT														0.20
AVERAGE	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.14

Jobs Density of Metropolitan Area

HEAVY RAIL	Number of Jobs per Square Mile													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	4,013	4,105	4,178	4,184	4,235	4,262	4,210	4,068	4,023	4,023	4,058	4,065	4,067	4,027
Washington, D.C.-WMATA	372	394	415	436	452	467	472	462	460	468	476	482	503	506
Chicago-RTA-CTA	759	773	793	817	840	860	871	867	863	882	906	929	938	950
Boston-MBTA	555	574	590	594	611	609	592	565	570	581	595	608	597	593
Atlanta-MARTA	244	262	278	288	299	306	311	310	318	335	354	370	371	379
Philadelphia-SEPTA	623	641	656	676	691	701	701	685	681	686	696	700	714	714
San Francisco-BART	841	864	884	908	940	964	982	978	962	960	969	988	1,017	1,023
New York-PATHC	4,013	4,105	4,178	4,184	4,235	4,262	4,210	4,068	4,023	4,023	4,058	4,065	4,067	4,027
Miami-MDTA	498	509	517	516	536	549	553	546	543	562	572	580	585	591
Baltimore-MMTA	463	480	493	515	528	541	545	528	521	524	533	541	554	554
Los Angeles-LACMTA										1,216	1,224	1,240	1,282	1,273
Philadelphia-NJ-PATC	623	641	656	676	691	701	701	685	681	686	696	700	714	714
Cleveland-GCRTA	419	426	433	441	450	461	465	460	457	463	476	487	488	492
New York-MTA-SIRTOA	4,013	4,105	4,178	4,184	4,235	4,262	4,210	4,068	4,023	4,023	4,058	4,065	4,067	4,027

LIGHT RAIL	Number of Jobs per Square Mile													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		574	590		611		592	565	570	581	595	608	597	598
San Francisco-MUNI			1155	1173	1203	1227	1245	1234	1203	1199	1205	1223	1246	1254
Philadelphia-SEPTA	623	641	656	676	691	701	701	685	681	686	696	700	714	719
Los Angeles-LACMTA								1286	1240	1216	1224	1240	1282	1289
San Diego Trolley Inc.	264	279		307	324	337	344	346	340	337	341	345	367	374
St. Louis-BSDA											235	239	240	242
Portland-TCMTDO				161	169	178	184	187	189	196	205	214	217	222
Dallas-DARTA													327	333
Sacramento-RTD					168	178	188	189	187	184	189	194	206	211
Pittsburgh-PAT			245	251	257	263	269	268	270	273	276	279	285	288
Buffalo-NFTS			377	382	393	403	406	402	402	402	408	411	421	425
Baltimore-MMTA									521	524	533	541	554	559
San Jose-SCTD					787	801	812	803	786	786	801	827	833	842
New Orleans-RTA											219	225	222	225
Cleveland-GCRTA	419	426	433	441	450	461	465	460	457	463	476	487	488	493
Denver-RTD											325	335	328	333
Newark-NJTC	4013				4235	4262	4210	4068	4023	4023	4058	4065	4067	4059

Congestion Index

HEAVY RAIL	Travel Rate Index													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	1.22	1.24	1.25	1.26	1.27	1.29	1.32	1.32	1.31	1.31	1.32	1.34	1.34	1.35
Washington, D.C.-WMATA	1.31	1.29	1.30	1.32	1.34	1.36	1.38	1.39	1.39	1.39	1.38	1.39	1.42	1.42
Chicago-RTA-CTA	1.27	1.30	1.33	1.32	1.31	1.33	1.34	1.35	1.34	1.33	1.33	1.36	1.39	1.39
Boston-MBTA	1.17	1.16	1.19	1.18	1.22	1.24	1.27	1.28	1.28	1.32	1.32	1.33	1.34	1.34
Atlanta-MARTA	1.17	1.19	1.21	1.21	1.19	1.19	1.20	1.18	1.20	1.23	1.30	1.30	1.34	1.36
Philadelphia-SEPTA	1.43	1.43	1.46	1.46	1.48	1.48	1.45	1.44	1.44	1.44	1.43	1.44	1.44	1.44
San Francisco-BART	1.17	1.19	1.20	1.21	1.23	1.24	1.22	1.23	1.23	1.24	1.26	1.26	1.28	1.27
New York-PATHC	1.22	1.24	1.25	1.26	1.27	1.29	1.32	1.32	1.31	1.31	1.32	1.34	1.34	1.35
Miami-MDTA	1.22	1.24	1.24	1.26	1.29	1.31	1.30	1.31	1.34	1.36	1.34	1.34	1.33	1.36
Baltimore-MMTA	1.18	1.18	1.20	1.20	1.22	1.24	1.27	1.25	1.24	1.25	1.26	1.28	1.28	1.28
Los Angeles-LACMTA										1.47	1.46	1.50	1.50	1.51
Philadelphia-NJ-PATC	1.43	1.43	1.46	1.46	1.48	1.48	1.45	1.44	1.44	1.44	1.43	1.44	1.44	1.44
Cleveland-GCRTA	1.07	1.07	1.08	1.08	1.09	1.11	1.11	1.12	1.12	1.14	1.15	1.19	1.21	1.23
New York-MTA-SIRTOA	1.22	1.24	1.25	1.26	1.27	1.29	1.32	1.32	1.31	1.31	1.32	1.34	1.34	1.35

LIGHT RAIL	Travel Rate Index													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		1.16	1.19		1.22		1.27	1.28	1.28	1.32	1.32	1.33	1.34	1.34
San Francisco-MUNI			1.46	1.46	1.48	1.48	1.45	1.44	1.44	1.44	1.43	1.44	1.44	1.44
Philadelphia-SEPTA	1.17	1.19	1.20	1.21	1.23	1.24	1.22	1.23	1.23	1.24	1.26	1.26	1.28	1.27
Los Angeles-LACMTA								1.51	1.50	1.47	1.46	1.50	1.50	1.51
San Diego Trolley Inc.	1.19	1.21		1.27	1.31	1.31	1.34	1.33	1.34	1.34	1.34	1.35	1.34	1.36
St. Louis-BSDA											1.30	1.30	1.30	1.30
Portland-TCMTDO				1.21	1.21	1.22	1.23	1.23	1.25	1.30	1.30	1.32	1.34	1.33
Dallas-DARTA													1.28	1.30
Sacramento-RTD					1.21	1.21	1.24	1.26	1.23	1.23	1.25	1.26	1.27	1.27
Pittsburgh-PAT			1.13	1.15	1.19	1.18	1.17	1.17	1.17	1.17	1.17	1.18	1.18	1.18
Buffalo-NFTS			1.06	1.06	1.06	1.07	1.08	1.08	1.08	1.09	1.09	1.09	1.09	1.09
Baltimore-MMTA									1.24	1.25	1.26	1.28	1.28	1.28
San Jose-SCTD					1.33	1.33	1.34	1.36	1.34	1.34	1.33	1.35	1.35	1.34
New Orleans-RTA											1.26	1.27	1.26	1.25
Cleveland-GCRTA	1.07	1.07	1.08	1.08	1.09	1.11	1.11	1.12	1.12	1.14	1.15	1.19	1.21	1.23
Denver-RTD											1.28	1.31	1.31	1.34
Newark-NJTC	1.22				1.27	1.29	1.32	1.32	1.31	1.31	1.32	1.34	1.34	1.35

Employed Population of Center City

HEAVY RAIL	Employed Population													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	2,969,365	2,990,152	3,013,404	3,039,093	3,067,197	3,097,705	3,130,608	3,165,908	3,203,610	3,243,727	3,286,279	3,331,290	3,378,790	3,428,814
Washington, D.C.-WMATA	288,136	287,117	286,489	286,218	286,280	286,652	287,316	288,258	289,466	290,931	292,647	294,608	296,812	299,256
Chicago-RTA-CTA	1,191,409	1,183,916	1,177,390	1,171,797	1,167,112	1,163,308	1,160,366	1,158,266	1,156,993	1,156,534	1,156,878	1,158,017	1,159,946	1,162,662
Boston-MBTA	260,859	262,820	265,013	267,438	270,096	272,987	276,115	279,482	283,092	286,950	291,062	295,434	300,073	304,987
Atlanta-MARTA	165,624	164,545	163,727	163,135	162,740	162,520	162,454	162,526	162,723	163,032	163,446	163,955	164,555	165,239
Philadelphia-SEPTA	619,244	619,729	620,727	622,222	624,197	626,642	629,545	632,898	636,693	640,927	645,594	650,694	656,225	662,188
San Francisco-BART	489,368	492,732	496,562	500,844	505,566	510,720	516,299	522,300	528,721	535,563	542,828	550,521	558,647	567,215
New York-PATHC	2,969,365	2,990,152	3,013,404	3,039,093	3,067,197	3,097,705	3,130,608	3,165,908	3,203,610	3,243,727	3,286,279	3,331,290	3,378,790	3,428,814
Miami-MDTA	145,459	143,493	141,785	140,298	138,999	137,864	136,871	136,001	135,241	134,576	133,997	133,495	133,063	132,694
Baltimore-MMTA	299,683	299,278	299,221	299,494	300,083	300,975	302,159	303,628	305,377	307,400	309,695	312,262	315,100	318,210
Los Angeles-LACMTA										1,644,201	1,672,638	1,702,414	1,733,581	1,766,193
Philadelphia-NJ-PATC	619,244	619,729	620,727	622,222	624,197	626,642	629,545	632,898	636,693	640,927	645,594	650,694	656,225	662,188
Cleveland-GCRTA	194,645	190,789	187,192	183,833	180,695	177,762	175,020	172,456	170,057	167,813	165,714	163,750	161,914	160,197
New York-MTA-SIRTOA	2,969,365	2,990,152	3,013,404	3,039,093	3,067,197	3,097,705	3,130,608	3,165,908	3,203,610	3,243,727	3,286,279	3,331,290	3,378,790	3,428,814

LIGHT RAIL	Employed Population													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA		265,172	267,475		272,800		279,095	282,614	286,386	290,417	281,621	285,820	290,291	295,043
San Francisco-MUNI			352,770	355,563	358,683	362,121	365,872	369,929	374,290	378,954	363,872	368,667	373,765	379,172
Philadelphia-SEPTA	621,563	623,996	625,171	626,853	629,025	631,678	634,800	638,385	642,425	646,916	631,532	636,398	641,704	647,450
Los Angeles-LACMTA								1,823,551	1,854,000	1,885,852	1,791,962	1,822,462	1,854,396	1,887,820
San Diego Trolley Inc.	405,739	423,427		453,393	469,629	486,744	504,775	523,762	543,748	564,779	553,997	575,889	598,933	623,186
St. Louis-BSDA											147,323	146,778	146,322	145,951
Portland-TCMTDO				200,624	204,948	209,466	214,182	219,099	224,225	229,564	222,001	226,841	231,875	237,107
Dallas-DARTA													478,520	483,527
Sacramento-RTD					147,707	152,918	158,405	164,182	170,265	176,672	175,291	181,837	188,735	196,006
Pittsburgh-PAT			155,904	154,080	152,408	150,878	149,480	148,205	147,046	145,995	140,065	139,100	138,225	137,436
Buffalo-NFTS			127,240	127,110	127,132	127,300	127,607	128,049	128,620	129,319	125,967	126,719	127,588	128,574
Baltimore-MMTA									309,700	311,913	301,443	303,438	305,693	308,208
San Jose-SCTD					381,407	391,964	402,984	414,486	426,490	439,019	420,685	432,400	444,617	457,360
New Orleans-RTA											159,441	157,275	155,260	153,385
Cleveland-GCRTA	195,549	192,218	188,673	185,368	182,287	179,414	176,734	174,235	171,904	169,731	162,039	159,906	157,904	156,025
Denver-RTD											209,166	208,189	207,331	206,589
Newark-NJTC	2,976,172				3,082,528	3,113,209	3,146,288	3,181,765	3,219,648	3,259,947	3,162,772	3,205,433	3,250,566	3,298,205

Percentage of Black Population in Center City

HEAVY RAIL	Percentage													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	26.6	27.0	27.3	27.7	28.1	28.4	28.8	29.2	29.5	29.9	30.3	30.7	31.1	31.5
Washington, D.C.-WMATA	68.5	68.0	67.6	67.2	66.7	66.3	65.9	65.5	65.0	64.6	64.2	63.8	63.4	63.0
Chicago-RTA-CTA	39.5	39.4	39.4	39.3	39.2	39.1	39.0	39.0	38.9	38.8	38.7	38.6	38.6	38.5
Boston-MBTA	23.6	24.0	24.3	24.6	24.9	25.2	25.5	25.9	26.2	26.6	26.9	27.3	27.6	28.0
Atlanta-MARTA	66.8	66.8	66.9	66.9	67.0	67.0	67.1	67.1	67.1	67.2	67.2	67.3	67.3	67.3
Philadelphia-SEPTA	38.6	38.8	39.1	39.3	39.5	39.7	39.9	40.1	40.3	40.5	40.7	41.0	41.2	41.4
San Francisco-BART	23.4	23.2	23.0	22.8	22.5	22.3	22.1	21.9	21.7	21.5	21.3	21.1	20.9	20.7
New York-PATHC	26.6	27.0	27.3	27.7	28.1	28.4	28.8	29.2	29.5	29.9	30.3	30.7	31.1	31.5
Miami-MDTA	25.9	26.2	26.4	26.6	26.8	27.1	27.3	27.5	27.7	28.0	28.2	28.5	28.7	28.9
Baltimore-MMTA	56.5	56.9	57.4	57.8	58.3	58.7	59.2	59.7	60.1	60.6	61.1	61.5	62.0	62.5
Los Angeles-LACMTA										13.1	12.9	12.6	12.4	12.1
Philadelphia-NJ-PATC	38.6	38.8	39.1	39.3	39.5	39.7	39.9	40.1	40.3	40.5	40.7	41.0	41.2	41.4
Cleveland-GCRTA	44.8	45.1	45.4	45.7	45.9	46.2	46.5	46.8	47.1	47.3	47.6	47.9	48.2	48.5
New York-MTA-SIRTOA	26.6	27.0	27.3	27.7	28.1	28.4	28.8	29.2	29.5	29.9	30.3	30.7	31.1	31.5

LIGHT RAIL	Percentage													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	23.6	24.0	24.3	24.6	24.9	25.2	25.5	25.9	26.2	26.6	26.9	27.3	27.6	28.0
San Francisco-MUNI	11.9	11.8	11.6	11.4	11.2	11.1	10.9	10.7	10.6	10.4	10.3	10.1	10.0	9.8
Philadelphia-SEPTA	38.6	38.8	39.1	39.3	39.5	39.7	39.9	40.1	40.3	40.5	40.7	41.0	41.2	41.4
Los Angeles-LACMTA								13.7	13.5	13.3	13.1	12.9	12.7	12.5
San Diego Trolley Inc.	9.1	9.1	9.2	9.2	9.3	9.3	9.3	9.4	9.4	9.5	9.5	9.6	9.6	9.7
St. Louis-BSDA											48.2	48.4	48.6	48.8
Portland-TCMTDO				7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.5	7.5	7.5	7.5
Dallas-DARTA													29.6	29.6
Sacramento-RTD				14.7	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.4	16.6	16.8
Pittsburgh-PAT	24.7	24.9	25.1	25.3	25.5	25.7	25.9	26.1	26.3	26.5	26.7	26.9	27.1	27.3
Buffalo-NFTS			29.1	29.5	29.9	30.3	30.7	31.1	31.6	32.0	32.5	32.9	33.4	33.9
Baltimore-MMTA									60.1	60.6	61.1	61.5	62.0	62.5
San Jose-SCTD					4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
New Orleans-RTA	57.9	58.6	59.2	59.9	60.6	61.3	62.1	62.8	63.5	64.3	65.0	65.8	66.5	67.3
Cleveland-GCRTA	44.8	45.1	45.4	45.7	45.9	46.2	46.5	46.8	47.1	47.3	47.6	47.9	48.2	48.5
Denver-RTD											13.3	13.4	13.5	13.6
Newark-NJTC	26.6	27.0	27.3	27.7	28.1	28.4	28.8	29.2	29.5	29.9	30.3	30.7	31.1	31.5

Percentage of Black Population in Metropolitan Area

HEAVY RAIL	Percentage													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	24.4	24.7	25.0	25.4	25.7	26.0	26.4	26.7	27.1	27.5	27.8	28.2	28.6	29.0
Washington, D.C.-WMATA	25.7	25.6	25.6	25.5	25.5	25.5	25.4	25.4	25.3	25.3	25.2	25.2	25.2	25.1
Chicago-RTA-CTA	19.5	19.5	19.4	19.4	19.3	19.3	19.2	19.2	19.1	19.1	19.0	19.0	18.9	18.9
Boston-MBTA	4.1	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.1	5.2	5.3	5.5	5.6	5.7
Atlanta-MARTA	24.5	24.6	24.7	24.8	25.0	25.1	25.2	25.4	25.5	25.6	25.7	25.9	26.0	26.1
Philadelphia-SEPTA	18.8	18.9	18.9	19.0	19.0	19.0	19.1	19.1	19.2	19.2	19.3	19.3	19.3	19.4
San Francisco-BART	11.9	11.9	11.8	11.7	11.7	11.6	11.5	11.5	11.4	11.4	11.3	11.2	11.2	11.1
New York-PATHC	24.4	24.7	25.0	25.4	25.7	26.0	26.4	26.7	27.1	27.5	27.8	28.2	28.6	29.0
Miami-MDTA	18.6	18.9	19.2	19.5	19.9	20.2	20.6	20.9	21.3	21.7	22.0	22.4	22.8	23.2
Baltimore-MMTA	25.6	25.6	25.7	25.7	25.8	25.8	25.8	25.9	25.9	25.9	26.0	26.0	26.1	26.1
Los Angeles-LACMTA										10.8	10.7	10.5	10.4	10.3
Philadelphia-NJ-PATC	18.8	18.9	18.9	19.0	19.0	19.0	19.1	19.1	19.2	19.2	19.3	19.3	19.3	19.4
Cleveland-GCRTA	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.6	17.7	17.8	17.9	18.0
New York-MTA-SIRTOA	24.4	24.7	25.0	25.4	25.7	26.0	26.4	26.7	27.1	27.5	27.8	28.2	28.6	29.0

LIGHT RAIL	Percentage													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	4.1	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.1	5.2	5.3	5.5	5.6	5.7
San Francisco-MUNI	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0	7.0
Philadelphia-SEPTA	18.8	18.9	18.9	19.0	19.0	19.0	19.1	19.1	19.2	19.2	19.3	19.3	19.3	19.4
Los Angeles-LACMTA								11.0	10.9	10.8	10.7	10.5	10.4	10.3
San Diego Trolley Inc.	5.9	6.0	6.0	6.1	6.2	6.2	6.3	6.4	6.5	6.5	6.6	6.7	6.8	6.9
St. Louis-BSDA											17.0	17.0	17.0	17.1
Portland-TCMTDO				2.7	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.8	2.8
Dallas-DARTA													15.7	15.7
Sacramento-RTD				6.9	7.1	7.2	7.3	7.5	7.6	7.8	7.9	8.1	8.3	8.4
Pittsburgh-PAT	7.3	7.3	7.3	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.7	7.7	7.8	7.8
Buffalo-NFTS			9.8	9.9	10.0	10.1	10.2	10.3	10.5	10.6	10.7	10.8	10.9	11.0
Baltimore-MMTA									25.9	25.9	26.0	26.0	26.1	26.1
San Jose-SCTD					3.6	3.7	3.7	3.7	3.8	3.8	3.9	3.9	3.9	4.0
New Orleans-RTA	33.5	33.7	33.9	34.1	34.3	34.6	34.8	35.0	35.3	35.5	35.7	36.0	36.2	36.4
Cleveland-GCRTA	16.6	16.7	16.8	16.9	17.0	17.1	17.2	17.3	17.4	17.6	17.7	17.8	17.9	18.0
Denver-RTD											6.1	6.2	6.2	6.3
Newark-NJTC	24.4	24.7	25.0	25.4	25.7	26.0	26.4	26.7	27.1	27.5	27.8	28.2	28.6	29.0

Percentage of Hispanic Population in Center City

HEAVY RAIL	Percentage													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	21.3	21.7	22.1	22.5	22.9	23.3	23.7	24.2	24.6	25.0	25.5	25.9	26.4	26.9
Washington, D.C.-WMATA	3.6	3.8	4.0	4.3	4.6	4.9	5.2	5.5	5.9	6.2	6.6	7.0	7.5	8.0
Chicago-RTA-CTA	16.0	16.5	17.0	17.5	18.1	18.6	19.2	19.8	20.5	21.1	21.8	22.5	23.2	23.9
Boston-MBTA	7.8	8.2	8.6	9.0	9.5	9.9	10.4	10.9	11.4	12.0	12.6	13.2	13.8	14.5
Atlanta-MARTA	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5
Philadelphia-SEPTA	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7
San Francisco-BART	12.1	12.3	12.5	12.7	12.9	13.1	13.3	13.5	13.8	14.0	14.2	14.5	14.7	15.0
New York-PATHC	21.3	21.7	22.1	22.5	22.9	23.3	23.7	24.2	24.6	25.0	25.5	25.9	26.4	26.9
Miami-MDTA	58.4	59.1	59.7	60.4	61.0	61.7	62.3	63.0	63.7	64.4	65.1	65.8	66.5	67.2
Baltimore-MMTA	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Los Angeles-LACMTA										43.8	45.4	47.0	48.8	50.5
Philadelphia-NJ-PATC	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7
Cleveland-GCRTA	3.6	3.7	3.8	4.0	4.1	4.3	4.4	4.6	4.7	4.9	5.1	5.3	5.4	5.6
New York-MTA-SIRTOA	21.3	21.7	22.1	22.5	22.9	23.3	23.7	24.2	24.6	25.0	25.5	25.9	26.4	26.9

LIGHT RAIL	Percentage													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	7.8	8.2	8.6	9.0	9.5	9.9	10.4	10.9	11.4	12.0	12.6	13.2	13.8	14.5
San Francisco-MUNI	12.8	12.9	13.0	13.1	13.2	13.3	13.3	13.5	13.6	13.7	13.8	13.9	14.0	14.1
Philadelphia-SEPTA	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7
Los Angeles-LACMTA								39.0	40.4	42.0	43.5	45.2	46.9	48.6
San Diego Trolley Inc.	16.8	17.3	17.8	18.4	18.9	19.5	20.1	20.8	21.4	22.1	22.7	23.4	24.2	24.9
St. Louis-BSDA											1.2	1.2	1.2	1.2
Portland-TCMTDO				2.7	2.8	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.8	3.9
Dallas-DARTA													27.6	29.0
Sacramento-RTD				15.3	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9	17.1	17.3
Pittsburgh-PAT	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0
Buffalo-NFTS			3.6	3.9	4.1	4.4	4.7	5.0	5.3	5.6	6.0	6.4	6.8	7.2
Baltimore-MMTA									1.0	1.0	1.0	1.0	1.0	1.0
San Jose-SCTD					25.3	25.7	26.1	26.5	26.9	27.3	27.8	28.2	28.7	29.1
New Orleans-RTA	3.3	3.3	3.3	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.1
Cleveland-GCRTA	3.6	3.7	3.8	4.0	4.1	4.3	4.4	4.6	4.7	4.9	5.1	5.3	5.4	5.6
Denver-RTD											24.7	25.1	25.6	26.2
Newark-NJTC	21.3	21.7	22.1	22.5	22.9	23.3	23.7	24.2	24.6	25.0	25.5	25.9	26.4	26.9

Percentage of Hispanic Population in Metropolitan Area

HEAVY RAIL	Percentage													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	19.2	19.5	19.9	20.3	20.7	21.1	21.6	22.0	22.4	22.9	23.3	23.8	24.2	24.7
Washington, D.C.-WMATA	3.6	3.8	4.1	4.3	4.6	4.9	5.2	5.6	6.0	6.4	6.8	7.2	7.7	8.2
Chicago-RTA-CTA	9.2	9.5	9.8	10.1	10.4	10.8	11.1	11.4	11.8	12.2	12.6	13.0	13.4	13.8
Boston-MBTA	3.0	3.1	3.3	3.6	3.8	4.0	4.2	4.5	4.8	5.1	5.4	5.8	6.2	6.5
Atlanta-MARTA	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.7
Philadelphia-SEPTA	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2
San Francisco-BART	11.8	12.0	12.3	12.6	12.8	13.1	13.4	13.7	13.9	14.2	14.6	14.9	15.2	15.5
New York-PATHC	19.2	19.5	19.9	20.3	20.7	21.1	21.6	22.0	22.4	22.9	23.3	23.8	24.2	24.7
Miami-MDTA	40.5	41.8	43.2	44.6	46.0	47.5	49.0	50.6	52.2	53.9	55.7	57.5	59.3	61.3
Baltimore-MMTA	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4
Los Angeles-LACMTA										40.8	42.1	43.3	44.7	46.0
Philadelphia-NJ-PATC	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2
Cleveland-GCRTA	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.6	2.7
New York-MTA-SIRTOA	19.2	19.5	19.9	20.3	20.7	21.1	21.6	22.0	22.4	22.9	23.3	23.8	24.2	24.7

LIGHT RAIL	Percentage													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	3.0	3.1	3.3	3.6	3.8	4.0	4.2	4.5	4.8	5.1	5.4	5.8	6.2	6.5
San Francisco-MUNI	12.3	12.6	12.9	13.2	13.5	13.8	14.1	14.5	14.8	15.2	15.5	15.9	16.3	16.7
Philadelphia-SEPTA	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2
Los Angeles-LACMTA								38.4	39.6	40.8	42.1	43.3	44.7	46.0
San Diego Trolley Inc.	16.7	17.2	17.7	18.2	18.8	19.4	20.0	20.6	21.2	21.9	22.5	23.2	23.9	24.7
St. Louis-BSDA											1.1	1.1	1.1	1.1
Portland-TCMTDO				2.8	3.0	3.1	3.3	3.4	3.6	3.8	4.0	4.2	4.4	4.6
Dallas-DARTA													17.9	18.8
Sacramento-RTD				9.9	10.1	10.3	10.5	10.7	10.8	11.0	11.2	11.4	11.7	11.9
Pittsburgh-PAT	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Buffalo-NFTS			1.7	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7
Baltimore-MMTA									1.3	1.3	1.3	1.4	1.4	1.4
San Jose-SCTD					19.9	20.2	20.5	20.8	21.2	21.5	21.9	22.2	22.6	22.9
New Orleans-RTA	4.0	4.0	4.0	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.2
Cleveland-GCRTA	2.0	2.0	2.1	2.1	2.2	2.2	2.3	2.3	2.4	2.4	2.5	2.5	2.6	2.7
Denver-RTD											13.4	13.6	13.7	13.9
Newark-NJTC	19.2	19.5	19.9	20.3	20.7	21.1	21.6	22.0	22.4	22.9	23.3	23.8	24.2	24.7

Number of Jobs in Metropolitan Area

HEAVY RAIL	Jobs													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	4,601,584	4,708,416	4,792,992	4,801,198	4,859,662	4,892,119	4,832,896	4,670,637	4,620,274	4,620,552	4,661,403	4,671,130	4,673,282	4,628,369
Washington, D.C.-WMATA	2,422,529	2,564,801	2,701,614	2,835,363	2,943,828	3,038,489	3,071,296	3,008,139	2,997,982	3,048,575	3,102,994	3,140,108	3,274,598	3,294,740
Chicago-RTA-CTA	3,863,554	3,929,891	4,029,840	4,148,809	4,258,287	4,359,732	4,411,398	4,386,803	4,363,636	4,459,983	4,575,764	4,688,845	4,730,926	4,787,600
Boston-MBTA	3,090,831	3,199,294	3,289,204	3,309,358	3,403,869	3,395,230	3,298,289	3,148,345	3,178,044	3,240,294	3,317,678	3,393,515	3,329,553	3,310,310
Atlanta-MARTA	1,516,510	1,623,714	1,717,144	1,773,095	1,839,049	1,878,220	1,905,095	1,892,126	1,938,450	2,039,914	2,153,029	2,242,761	2,240,794	2,285,813
Philadelphia-SEPTA	2,409,130	2,477,791	2,531,514	2,609,663	2,666,988	2,705,872	2,703,983	2,639,800	2,624,711	2,643,654	2,679,488	2,694,783	2,745,938	2,745,579
San Francisco-BART	2,084,415	2,141,470	2,189,430	2,247,706	2,328,198	2,385,948	2,429,198	2,418,701	2,379,073	2,373,692	2,395,223	2,441,093	2,510,315	2,524,956
New York-PATHC	4,601,584	4,708,416	4,792,992	4,801,198	4,859,662	4,892,119	4,832,896	4,670,637	4,620,274	4,620,552	4,661,403	4,671,130	4,673,282	4,628,369
Miami-MDTA	972,325	991,884	1,006,932	1,004,705	1,044,305	1,067,868	1,075,103	1,060,670	1,055,119	1,092,261	1,110,842	1,126,128	1,134,046	1,145,214
Baltimore-MMTA	1,211,010	1,253,618	1,287,409	1,346,113	1,379,632	1,412,982	1,421,386	1,376,301	1,357,350	1,365,256	1,389,747	1,408,806	1,441,720	1,442,374
Los Angeles-LACMTA										4,932,443	4,962,749	5,029,233	5,197,116	5,160,461
Philadelphia-NJ-PATC	2,409,130	2,477,791	2,531,514	2,609,663	2,666,988	2,705,872	2,703,983	2,639,800	2,624,711	2,643,654	2,679,488	2,694,783	2,745,938	2,745,579
Cleveland-GCRTA	1,138,432	1,156,766	1,174,302	1,196,136	1,220,008	1,249,407	1,258,259	1,246,291	1,237,188	1,253,388	1,286,483	1,315,889	1,317,850	1,328,957
New York-MTA-SIRTOA	4,601,584	4,708,416	4,792,992	4,801,198	4,859,662	4,892,119	4,832,896	4,670,637	4,620,274	4,620,552	4,661,403	4,671,130	4,673,282	4,628,369

LIGHT RAIL	Jobs													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	3,090,831	3,199,294	3,289,204	3,309,358	3,403,869	3,395,230	3,298,289	3,148,345	3,178,044	3,240,294	3,317,678	3,393,515	3,329,553	3,338,408
San Francisco-MUNI	1,136,959	1,155,361	1,173,415	1,191,667	1,221,920	1,247,069	1,265,074	1,253,238	1,222,508	1,218,362	1,224,149	1,242,127	1,266,216	1,274,457
Philadelphia-SEPTA	2,409,130	2,477,791	2,531,514	2,609,663	2,666,988	2,705,872	2,703,983	2,639,800	2,624,711	2,643,654	2,679,488	2,694,783	2,745,938	2,765,988
Los Angeles-LACMTA								5,221,163	5,031,195	4,932,443	4,962,749	5,029,233	5,197,116	5,223,485
San Diego Trolley Inc.	1,109,205	1,172,684	1,227,519	1,291,061	1,360,782	1,417,145	1,446,052	1,455,502	1,429,037	1,416,348	1,431,053	1,449,526	1,541,257	1,570,605
St. Louis-BSDA											1,500,678	1,528,016	1,533,223	1,550,264
Portland-TCMTDO				809,016	849,471	892,602	926,296	937,894	950,228	984,087	1,031,830	1,075,250	1,089,940	1,120,013
Dallas-DARTA													2,016,593	2,049,815
Sacramento-RTD				655,804	688,391	725,545	767,941	769,206	761,420	750,950	770,391	790,808	839,026	859,848
Pittsburgh-PAT	1,118,863	1,131,422	1,136,343	1,160,831	1,190,229	1,217,269	1,244,165	1,239,257	1,249,703	1,259,393	1,275,452	1,286,659	1,314,171	1,330,331
Buffalo-NFTS			592,278	599,034	616,371	631,625	637,300	629,867	630,595	630,388	638,475	644,147	658,402	664,863
Baltimore-MMTA									1,357,350	1,365,256	1,389,747	1,408,806	1,441,720	1,455,708
San Jose-SCTD					1,015,933	1,034,633	1,048,807	1,036,610	1,014,866	1,013,603	1,033,147	1,066,839	1,074,509	1,085,252
New Orleans-RTA	699,003	688,178	667,619	657,232	669,664	677,758	690,106	693,502	692,285	702,005	719,243	734,349	717,462	721,547
Cleveland-GCRTA	1,138,432	1,156,766	1,174,302	1,196,136	1,220,008	1,249,407	1,258,259	1,246,291	1,237,188	1,253,388	1,286,483	1,315,889	1,317,850	1,331,717
Denver-RTD											1,222,783	1,259,964	1,234,951	1,254,215
Newark-NJTC	4,601,584	4,708,416	4,792,992	4,801,198	4,859,662	4,892,119	4,832,896	4,670,637	4,620,274	4,620,552	4,661,403	4,671,130	4,673,282	4,664,904

Employed Persons in Metropolitan Area

HEAVY RAIL	Employed Persons													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	3,321,257	3,343,792	3,369,183	3,397,397	3,428,410	3,462,204	3,498,771	3,538,110	3,580,228	3,625,137	3,672,858	3,723,417	3,776,849	3,833,193
Washington, D.C.-WMATA	1,758,856	1,807,423	1,858,993	1,913,662	1,971,539	2,032,744	2,097,411	2,165,686	2,237,730	2,313,715	2,393,829	2,478,274	2,567,269	2,661,048
Chicago-RTA-CTA	3,181,430	3,197,486	3,215,786	3,236,340	3,259,164	3,284,280	3,311,716	3,341,505	3,373,686	3,408,307	3,445,418	3,485,078	3,527,353	3,572,314
Boston-MBTA	2,352,508	2,376,131	2,402,014	2,430,193	2,460,715	2,493,632	2,529,006	2,566,904	2,607,404	2,650,591	2,696,556	2,745,404	2,797,244	2,852,198
Atlanta-MARTA	1,136,775	1,176,797	1,219,131	1,263,859	1,311,074	1,360,872	1,413,363	1,468,663	1,526,897	1,588,202	1,652,724	1,720,619	1,792,054	1,867,209
Philadelphia-SEPTA	1,993,683	2,016,920	2,041,964	2,068,843	2,097,590	2,128,244	2,160,848	2,195,452	2,232,109	2,270,880	2,311,829	2,355,027	2,400,550	2,448,482
San Francisco-BART	1,564,030	1,585,232	1,607,837	1,631,849	1,657,283	1,684,156	1,712,494	1,742,325	1,773,685	1,806,613	1,841,157	1,877,366	1,915,298	1,956,014
New York-PATHC	3,321,257	3,343,792	3,369,183	3,397,397	3,428,410	3,462,204	3,498,771	3,538,110	3,580,228	3,625,137	3,672,858	3,723,417	3,776,849	3,833,193
Miami-MDTA	732,874	742,430	752,806	763,962	775,867	788,494	801,821	815,832	830,515	845,860	861,862	878,519	895,832	913,803
Baltimore-MMTA	992,906	1,008,083	1,024,321	1,041,641	1,060,070	1,079,638	1,100,380	1,122,334	1,145,543	1,170,054	1,195,920	1,223,197	1,251,947	1,282,237
Los Angeles-LACMTA										3,975,147	4,047,127	4,122,065	4,200,069	4,281,254
Philadelphia-NJ-PATC	1,993,683	2,016,920	2,041,964	2,068,843	2,097,590	2,128,244	2,160,848	2,195,452	2,232,109	2,270,880	2,311,829	2,355,027	2,400,550	2,448,482
Cleveland-GCRTA	938,837	935,796	933,398	931,622	930,447	929,855	929,830	930,357	931,423	933,017	935,129	937,751	940,875	944,495
New York-MTA-SIRTOA	3,321,257	3,343,792	3,369,183	3,397,397	3,428,410	3,462,204	3,498,771	3,538,110	3,580,228	3,625,137	3,672,858	3,723,417	3,776,849	3,833,193

LIGHT RAIL	Employed Persons													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	2,352,508	2,376,131	2,402,014	2,430,193	2,460,715	2,493,632	2,529,006	2,566,904	2,607,404	2,650,591	2,696,556	2,745,404	2,797,244	2,852,198
San Francisco-MUNI	730,102	734,274	739,037	744,374	750,274	756,729	763,732	771,281	779,377	788,022	797,220	806,981	817,312	828,228
Philadelphia-SEPTA	1,993,683	2,016,920	2,041,964	2,068,843	2,097,590	2,128,244	2,160,848	2,195,452	2,232,109	2,270,880	2,311,829	2,355,027	2,400,550	2,448,482
Los Angeles-LACMTA								3,839,657	3,906,023	3,975,147	4,047,127	4,122,065	4,200,069	4,281,254
San Diego Trolley Inc.	818,574	849,003	881,191	915,217	951,162	989,117	1,029,178	1,071,450	1,116,045	1,163,083	1,212,692	1,265,011	1,320,188	1,378,381
St. Louis-BSDA											1,138,869	1,154,264	1,170,396	1,187,283
Portland-TCMTDO				658,243	669,271	680,747	692,682	705,085	717,968	731,345	745,229	759,637	774,586	790,094
Dallas-DARTA													1,449,264	1,493,528
Sacramento-RTD				513,005	531,901	551,884	573,012	595,345	618,951	643,900	670,271	698,148	727,619	758,783
Pittsburgh-PAT	966,207	961,215	957,627	955,374	954,396	954,635	956,041	958,571	962,184	966,847	972,529	979,204	986,852	995,454
Buffalo-NFTS			498,228	499,783	501,752	504,130	506,908	510,083	513,649	517,606	521,951	526,684	531,806	537,317
Baltimore-MMTA									1,145,543	1,170,054	1,195,920	1,223,197	1,251,947	1,282,237
San Jose-SCTD					708,423	721,546	735,248	749,554	764,490	780,085	796,369	813,377	831,144	849,709
New Orleans-RTA	489,240	484,804	481,083	478,014	475,543	473,623	472,214	471,280	470,790	470,719	471,045	471,747	472,810	474,221
Cleveland-GCRTA	938,837	935,796	933,398	931,622	930,447	929,855	929,830	930,357	931,423	933,017	935,129	937,751	940,875	944,495
Denver-RTD											808,897	823,278	838,399	854,281
Newark-NJTC	3,321,257	3,343,792	3,369,183	3,397,397	3,428,410	3,462,204	3,498,771	3,538,110	3,580,228	3,625,137	3,672,858	3,723,417	3,776,849	3,833,193

Population of Center City

HEAVY RAIL	Population													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	7,170,960	7,196,008	7,221,143	7,246,366	7,271,677	7,297,076	7,322,564	7,348,141	7,373,807	7,399,564	7,333,253	7,359,941	7,386,726	7,413,608
Washington, D.C.-WMATA	625,569	622,418	619,283	616,164	613,060	609,972	606,900	603,843	600,802	597,775	567,094	560,423	553,830	547,315
Chicago-RTA-CTA	2,914,500	2,892,285	2,870,240	2,848,363	2,826,652	2,805,107	2,783,726	2,762,508	2,741,452	2,720,556	2,731,743	2,705,816	2,680,135	2,654,698
Boston-MBTA	567,483	568,610	569,740	570,873	572,007	573,144	574,283	575,424	576,568	577,714	547,725	546,221	544,721	543,226
Atlanta-MARTA	412,337	409,226	406,138	403,073	400,032	397,013	394,017	391,044	388,093	385,164	396,052	393,266	390,499	387,752
Philadelphia-SEPTA	1,646,383	1,636,089	1,625,859	1,615,694	1,605,592	1,595,553	1,585,577	1,575,663	1,565,812	1,556,022	1,524,249	1,508,755	1,493,419	1,478,239
San Francisco-BART	1,048,757	1,056,515	1,064,331	1,072,208	1,080,145	1,088,142	1,096,201	1,104,321	1,112,504	1,120,749	1,101,602	1,110,297	1,119,061	1,127,893
New York-PATHC	7,170,960	7,196,008	7,221,143	7,246,366	7,271,677	7,297,076	7,322,564	7,348,141	7,373,807	7,399,564	7,333,253	7,359,941	7,386,726	7,413,608
Miami-MDTA	351,492	352,658	353,828	355,002	356,180	357,362	358,548	359,738	360,931	362,129	373,024	375,746	378,488	381,250
Baltimore-MMTA	766,063	760,971	755,913	750,888	745,897	740,939	736,014	731,122	726,262	721,434	702,979	695,107	687,323	679,626
Los Angeles-LACMTA										3,657,964	3,448,613	3,500,897	3,553,974	3,607,855
Philadelphia-NJ-PATC	1,646,383	1,636,089	1,625,859	1,615,694	1,605,592	1,595,553	1,585,577	1,575,663	1,565,812	1,556,022	1,524,249	1,508,755	1,493,419	1,478,239
Cleveland-GCRTA	545,500	538,641	531,867	525,179	518,576	512,055	505,616	499,258	492,980	486,781	492,901	485,465	478,141	470,928
New York-MTA-SIRTOA	7,170,960	7,196,008	7,221,143	7,246,366	7,271,677	7,297,076	7,322,564	7,348,141	7,373,807	7,399,564	7,333,253	7,359,941	7,386,726	7,413,608

LIGHT RAIL	Population													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	567,483	568,610	569,740	570,873	572,007	573,144	574,283	575,424	576,568	577,714	578,862	580,012	581,165	582,320
San Francisco-MUNI	696,622	701,106	705,618	710,159	714,730	719,330	723,959	728,618	733,308	738,027	742,777	747,557	752,368	757,210
Philadelphia-SEPTA	1,646,383	1,636,089	1,625,859	1,615,694	1,605,592	1,595,553	1,585,577	1,575,663	1,565,812	1,556,022	1,546,293	1,536,625	1,527,017	1,517,469
Los Angeles-LACMTA								3,978,908	4,044,034	4,110,227	4,177,504	4,245,883	4,315,381	4,386,018
San Diego Trolley Inc.	962,898	986,067	1,009,794	1,034,091	1,058,974	1,084,455	1,110,549	1,137,271	1,164,636	1,192,660	1,221,358	1,250,746	1,280,841	1,311,661
St. Louis-BSDA											376,142	371,175	366,273	361,437
Portland-TCMTDO				414,771	422,180	429,722	437,398	445,211	453,164	461,259	469,499	477,885	486,422	495,111
Dallas-DARTA													1,074,010	1,085,634
Sacramento-RTD				338,353	348,389	358,724	369,365	380,322	391,604	403,220	415,181	427,497	440,178	453,235
Pittsburgh-PAT	401,426	395,987	390,622	385,330	380,109	374,959	369,879	364,868	359,924	355,048	350,237	345,492	340,811	336,194
Buffalo-NFTS			339,713	336,778	333,868	330,983	328,123	325,288	322,477	319,691	316,928	314,190	311,475	308,784
Baltimore-MMTA									726,262	721,434	716,639	711,875	707,143	702,443
San Jose-SCTD					748,956	765,410	782,225	799,409	816,971	834,919	853,261	872,006	891,163	910,741
New Orleans-RTA	532,445	526,356	520,336	514,385	508,502	502,687	496,938	491,255	485,637	480,083	474,592	469,164	463,799	458,495
Cleveland-GCRTA	545,500	538,641	531,867	525,179	518,576	512,055	505,616	499,258	492,980	486,781	480,660	474,616	468,648	462,755
Denver-RTD											458,060	455,703	453,359	451,026
Newark-NJTC	7,170,960	7,196,008	7,221,143	7,246,366	7,271,677	7,297,076	7,322,564	7,348,141	7,373,807	7,399,564	7,425,410	7,451,346	7,477,373	7,503,491

Population of Metropolitan Area

HEAVY RAIL	Population													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	8,452,488	8,491,429	8,536,768	8,560,842	8,575,866	8,567,356	8,547,307	8,538,328	8,554,100	8,594,455	8,616,335	8,631,273	8,631,187	8,634,540
Washington, D.C.-WMATA	3,811,686	3,895,283	3,992,731	4,099,557	4,203,296	4,283,270	4,337,837	4,397,252	4,459,504	4,520,978	4,580,420	4,630,957	4,752,097	4,816,816
Chicago-RTA-CTA	7,289,936	7,301,085	7,319,224	7,343,845	7,357,678	7,387,481	7,424,644	7,476,636	7,538,046	7,594,695	7,643,864	7,685,517	7,690,745	7,738,738
Boston-MBTA	5,173,652	5,216,797	5,243,357	5,274,203	5,315,442	5,348,803	5,351,729	5,330,791	5,333,792	5,357,004	5,383,759	5,416,699	5,433,047	5,443,957
Atlanta-MARTA	2,483,526	2,577,191	2,671,021	2,764,493	2,846,202	2,912,195	2,977,832	3,054,316	3,136,415	3,231,521	3,337,767	3,440,738	3,494,759	3,575,887
Philadelphia-SEPTA	4,807,372	4,818,838	4,853,388	4,893,959	4,922,173	4,926,849	4,925,373	4,934,257	4,935,701	4,943,678	4,951,447	4,952,955	4,988,918	4,995,909
San Francisco-BART	3,428,080	3,479,465	3,523,866	3,558,999	3,603,440	3,656,981	3,690,431	3,727,581	3,769,599	3,802,057	3,819,448	3,837,896	3,907,563	3,941,897
New York-PATHC	8,452,488	8,491,429	8,536,768	8,560,842	8,575,866	8,567,356	8,547,307	8,538,328	8,554,100	8,594,455	8,616,335	8,631,273	8,631,187	8,634,540
Miami-MDTA	1,755,583	1,776,908	1,801,410	1,831,362	1,868,311	1,908,921	1,942,135	1,971,193	1,993,473	1,985,373	2,011,571	2,046,076	2,083,774	2,110,202
Baltimore-MMTA	2,244,735	2,255,970	2,285,633	2,309,719	2,340,870	2,360,610	2,389,232	2,412,214	2,430,166	2,444,430	2,458,234	2,468,007	2,508,307	2,529,664
Los Angeles-LACMTA										9,087,015	9,080,732	9,077,853	9,355,763	9,419,682
Philadelphia-NJ-PATC	4,807,372	4,818,838	4,853,388	4,893,959	4,922,173	4,926,849	4,925,373	4,934,257	4,935,701	4,943,678	4,951,447	4,952,955	4,988,918	4,995,909
Cleveland-GCRTA	2,242,677	2,232,001	2,220,801	2,213,756	2,202,004	2,203,366	2,203,406	2,210,342	2,217,328	2,220,392	2,231,773	2,232,199	2,217,415	2,221,815
New York-MTA-SIRTOA	8,452,488	8,491,429	8,536,768	8,560,842	8,575,866	8,567,356	8,547,307	8,538,328	8,554,100	8,594,455	8,616,335	8,631,273	8,631,187	8,634,540

LIGHT RAIL	Population													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	5,173,652	5,216,797	5,243,357	5,274,203	5,315,442	5,348,803	5,351,729	5,330,791	5,333,792	5,357,004	5,383,759	5,416,699	5,433,047	5,451,643
San Francisco-MUNI	1,550,134	1,570,618	1,582,993	1,589,693	1,593,098	1,601,143	1,602,932	1,612,308	1,623,019	1,633,918	1,639,458	1,645,160	1,654,783	1,662,641
Philadelphia-SEPTA	4,807,372	4,818,838	4,853,388	4,893,959	4,922,173	4,926,849	4,925,373	4,934,257	4,935,701	4,943,678	4,951,447	4,952,955	4,988,918	5,001,751
Los Angeles-LACMTA								8,939,252	9,036,378	9,087,015	9,080,732	9,077,853	9,355,763	9,452,412
San Diego Trolley Inc.	2,066,419	2,126,090	2,196,834	2,275,309	2,364,284	2,444,380	2,513,581	2,551,105	2,597,117	2,606,660	2,614,669	2,626,714	2,771,353	2,826,136
St. Louis-BSDA											2,531,322	2,539,844	2,554,984	2,564,828
Portland-TCMTDO				1,415,447	1,446,277	1,479,070	1,526,705	1,571,587	1,608,201	1,647,739	1,681,796	1,717,079	1,738,718	1,772,209
Dallas-DARTA													3,019,322	3,072,855
Sacramento-RTD				1,202,738	1,245,576	1,290,239	1,353,507	1,394,468	1,416,112	1,429,828	1,441,490	1,460,302	1,535,357	1,571,326
Pittsburgh-PAT	2,504,749	2,466,170	2,440,272	2,419,507	2,405,482	2,396,221	2,395,128	2,399,270	2,405,450	2,407,588	2,400,458	2,389,475	2,369,642	2,362,026
Buffalo-NFTS			1,184,555	1,179,756	1,181,174	1,185,954	1,190,145	1,191,447	1,192,273	1,191,879	1,187,849	1,181,974	1,186,707	1,186,503
Baltimore-MMTA									2,430,166	2,444,430	2,458,234	2,468,007	2,508,307	2,530,100
San Jose-SCTD					1,472,234	1,498,121	1,497,905	1,509,924	1,527,179	1,543,841	1,555,229	1,573,606	1,591,110	1,606,777
New Orleans-RTA	1,350,467	1,349,897	1,347,337	1,327,369	1,310,318	1,296,918	1,284,037	1,290,503	1,299,527	1,304,787	1,310,282	1,314,167	1,286,712	1,282,289
Cleveland-GCRTA	2,242,677	2,232,001	2,220,801	2,213,756	2,202,004	2,203,366	2,203,406	2,210,342	2,217,328	2,220,392	2,231,773	2,232,199	2,217,415	2,217,144
Denver-RTD											1,795,112	1,830,343	1,811,171	1,833,153
Newark-NJTC	8,452,488	8,491,429	8,536,768	8,560,842	8,575,866	8,567,356	8,547,307	8,538,328	8,554,100	8,594,455	8,616,335	8,631,273	8,631,187	8,642,824

Employed Population Density of Center City

HEAVY RAIL	Employed persons per square mile													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	7,935	7,971	8,012	8,057	8,106	8,158	8,215	8,275	8,340	8,409	8,482	8,559	8,640	8,726
Washington, D.C.-WMATA	3,530	3,523	3,516	3,510	3,506	3,502	3,500	3,499	3,499	3,500	3,503	3,506	3,511	3,516
Chicago-RTA-CTA	4,493	4,451	4,411	4,373	4,338	4,304	4,271	4,241	4,212	4,185	4,160	4,136	4,113	4,092
Boston-MBTA	4,540	4,548	4,558	4,570	4,583	4,597	4,614	4,631	4,651	4,672	4,694	4,719	4,744	4,772
Atlanta-MARTA	1,025	1,020	1,016	1,011	1,007	1,003	1,000	997	994	991	988	985	983	981
Philadelphia-SEPTA	3,937	3,936	3,937	3,940	3,945	3,951	3,959	3,968	3,979	3,991	4,005	4,020	4,037	4,055
San Francisco-BART	3,820	3,834	3,849	3,864	3,880	3,897	3,914	3,933	3,952	3,971	3,992	4,013	4,036	4,059
New York-PATHC	7,935	7,971	8,012	8,057	8,106	8,158	8,215	8,275	8,340	8,409	8,482	8,559	8,640	8,726
Miami-MDTA	3,496	3,452	3,410	3,370	3,330	3,292	3,255	3,220	3,185	3,152	3,119	3,088	3,056	3,026
Baltimore-MMTA	3,249	3,237	3,227	3,218	3,211	3,205	3,201	3,198	3,197	3,197	3,198	3,201	3,205	3,210
Los Angeles-LACMTA										2,749	2,787	2,825	2,865	2,906
Philadelphia-NJ-PATC	3,937	3,936	3,937	3,940	3,945	3,951	3,959	3,968	3,979	3,991	4,005	4,020	4,037	4,055
Cleveland-GCRTA	2,175	2,136	2,099	2,064	2,031	1,999	1,969	1,941	1,914	1,889	1,864	1,842	1,820	1,799
New York-MTA-SIRTOA	7,935	7,971	8,012	8,057	8,106	8,158	8,215	8,275	8,340	8,409	8,482	8,559	8,640	8,726

LIGHT RAIL	Employed persons per square mile													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	5,490	5,548	5,582	5,621	5,664	5,713	5,766	5,825	5,888	5,956	5,761	5,833	5,910	5,992
San Francisco-MUNI	7,457	7,526	7,573	7,628	7,690	7,759	7,835	7,916	8,004	8,099	7,772	7,869	7,973	8,083
Philadelphia-SEPTA	4,582	4,603	4,615	4,631	4,650	4,673	4,699	4,728	4,762	4,798	4,687	4,726	4,769	4,815
Los Angeles-LACMTA								3,508	3,564	3,621	3,438	3,493	3,551	3,612
San Diego Trolley Inc.	1,262	1,315	1,359	1,405	1,453	1,504	1,558	1,615	1,674	1,737	1,701	1,767	1,835	1,907
St. Louis-BSDA											2,372	2,362	2,352	2,345
Portland-TCMTDO				1,702	1,706	1,712	1,718	1,724	1,732	1,740	1,651	1,656	1,661	1,667
Dallas-DARTA													1,374	1,385
Sacramento-RTD				1,483	1,534	1,588	1,645	1,705	1,767	1,833	1,819	1,886	1,957	2,032
Pittsburgh-PAT	2,881	2,845	2,808	2,774	2,743	2,715	2,688	2,665	2,643	2,623	2,516	2,497	2,481	2,466
Buffalo-NFTS			3,097	3,103	3,113	3,126	3,143	3,163	3,187	3,214	3,140	3,168	3,199	3,234
Baltimore-MMTA									3,828	3,853	3,722	3,744	3,769	3,798
San Jose-SCTD					2,263	2,307	2,353	2,400	2,450	2,502	2,378	2,424	2,473	2,523
New Orleans-RTA	1,013	997	984	973	963	955	947	941	936	932	918	915	912	910
Cleveland-GCRTA	2,501	2,464	2,425	2,389	2,355	2,324	2,295	2,269	2,244	2,222	2,126	2,104	2,083	2,063
Denver-RTD											1,197	1,153	1,112	1,072
Newark-NJTC	9,776	9,847	9,899	9,960	10,028	10,103	10,185	10,275	10,373	10,477	10,140	10,252	10,371	10,497

Employed Population Density of Metropolitan Area

HEAVY RAIL	Employed persons per square mile													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	2,896	2,915	2,937	2,961	2,987	3,016	3,048	3,081	3,118	3,156	3,197	3,241	3,287	3,335
Washington, D.C.-WMATA	270	278	286	294	303	312	322	333	344	355	368	380	394	408
Chicago-RTA-CTA	625	629	633	638	643	648	654	660	667	674	682	691	699	709
Boston-MBTA	422	426	431	436	441	447	454	460	468	475	483	492	501	511
Atlanta-MARTA	183	190	197	205	213	222	231	240	250	261	272	284	296	309
Philadelphia-SEPTA	516	522	529	536	544	552	560	570	579	590	600	612	624	637
San Francisco-BART	631	640	649	659	669	681	692	704	717	731	745	760	776	792
New York-PATHC	2,896	2,915	2,937	2,961	2,987	3,016	3,048	3,081	3,118	3,156	3,197	3,241	3,287	3,335
Miami-MDTA	376	381	386	392	398	405	412	420	427	436	444	453	462	472
Baltimore-MMTA	380	386	392	399	406	414	422	430	439	449	459	470	481	493
Los Angeles-LACMTA										980	998	1,017	1,036	1,056
Philadelphia-NJ-PATC	516	522	529	536	544	552	560	570	579	590	600	612	624	637
Cleveland-GCRTA	346	345	344	344	343	343	343	344	344	345	346	347	348	350
New York-MTA-SIRTOA	2,896	2,915	2,937	2,961	2,987	3,016	3,048	3,081	3,118	3,156	3,197	3,241	3,287	3,335

LIGHT RAIL	Employed persons per square mile													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	422	426	431	436	441	447	454	460	468	475	483	492	501	511
San Francisco-MUNI	719	723	727	733	738	745	752	759	767	776	785	794	804	815
Philadelphia-SEPTA	516	522	529	536	544	552	560	570	579	590	600	612	624	637
Los Angeles-LACMTA								946	963	980	998	1,017	1,036	1,056
San Diego Trolley Inc.	194	202	209	218	226	235	245	255	265	277	289	301	314	328
St. Louis-BSDA											178	180	183	186
Portland-TCMTDO				131	133	135	138	140	143	145	148	151	154	157
Dallas-DARTA													235	242
Sacramento-RTD				125	130	135	140	146	152	158	165	171	179	187
Pittsburgh-PAT	209	208	207	206	206	206	207	207	208	209	211	212	214	216
Buffalo-NFTS			317	318	320	321	323	325	328	330	333	336	340	343
Baltimore-MMTA									439	449	459	470	481	493
San Jose-SCTD					549	559	570	581	592	605	617	631	644	659
New Orleans-RTA	137	137	137	137	138	138	139	140	141	142	143	145	146	148
Cleveland-GCRTA	346	345	344	344	343	343	343	344	344	345	346	347	348	350
Denver-RTD											215	219	223	227
Newark-NJTC	2,896	2,915	2,937	2,961	2,987	3,016	3,048	3,081	3,118	3,156	3,197	3,241	3,287	3,335

Population Density of Center City

HEAVY RAIL	Persons per square mile													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	23,555	23,580	23,605	23,630	23,655	23,680	23,705	23,730	23,756	23,781	23,511	23,539	23,567	23,596
Washington, D.C.-WMATA	10,061	10,031	10,001	9,972	9,943	9,913	9,884	9,855	9,827	9,798	9,315	9,225	9,136	9,048
Chicago-RTA-CTA	12,797	12,705	12,613	12,522	12,431	12,342	12,252	12,164	12,076	11,989	12,043	11,933	11,824	11,717
Boston-MBTA	11,902	11,896	11,889	11,883	11,877	11,871	11,865	11,860	11,854	11,848	11,206	11,147	11,090	11,032
Atlanta-MARTA	3,140	3,114	3,089	3,064	3,039	3,014	2,990	2,965	2,941	2,917	2,998	2,975	2,952	2,930
Philadelphia-SEPTA	12,138	12,070	12,003	11,935	11,869	11,802	11,736	11,671	11,605	11,541	11,313	11,205	11,099	10,993
San Francisco-BART	10,353	10,404	10,455	10,507	10,559	10,611	10,663	10,716	10,769	10,821	10,610	10,667	10,724	10,782
New York-PATHC	23,555	23,580	23,605	23,630	23,655	23,680	23,705	23,730	23,756	23,781	23,511	23,539	23,567	23,596
Miami-MDTA	10,095	10,090	10,086	10,082	10,079	10,075	10,072	10,068	10,065	10,062	10,327	10,365	10,401	10,437
Baltimore-MMTA	9,516	9,447	9,379	9,310	9,243	9,176	9,109	9,043	8,977	8,912	8,679	8,576	8,475	8,375
Los Angeles-LACMTA										7,772	7,320	7,423	7,529	7,635
Philadelphia-NJ-PATC	12,138	12,070	12,003	11,935	11,869	11,802	11,736	11,671	11,605	11,541	11,313	11,205	11,099	10,993
Cleveland-GCRTA	6,976	6,906	6,836	6,768	6,700	6,633	6,566	6,501	6,436	6,371	6,469	6,388	6,307	6,228
New York-MTA-SIRTOA	23,555	23,580	23,605	23,630	23,655	23,680	23,705	23,730	23,756	23,781	23,511	23,539	23,567	23,596

LIGHT RAIL	Persons per square mile													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	11,902	11,896	11,889	11,883	11,877	11,871	11,865	11,860	11,854	11,848	11,843	11,837	11,832	11,826
San Francisco-MUNI	14,975	15,061	15,149	15,236	15,324	15,413	15,502	15,592	15,682	15,773	15,865	15,956	16,049	16,142
Philadelphia-SEPTA	12,138	12,070	12,003	11,935	11,869	11,802	11,736	11,671	11,605	11,541	11,476	11,412	11,348	11,285
Los Angeles-LACMTA								7,655	7,773	7,893	8,015	8,139	8,264	8,392
San Diego Trolley Inc.	2,994	3,062	3,132	3,204	3,277	3,351	3,428	3,506	3,586	3,667	3,751	3,837	3,924	4,013
St. Louis-BSDA											6,057	5,972	5,889	5,806
Portland-TCMTDO				3,519	3,515	3,511	3,508	3,504	3,500	3,496	3,492	3,488	3,484	3,480
Dallas-DARTA													3,085	3,109
Sacramento-RTD				3,516	3,619	3,726	3,836	3,949	4,065	4,185	4,308	4,435	4,565	4,700
Pittsburgh-PAT	7,236	7,135	7,036	6,938	6,841	6,746	6,653	6,560	6,469	6,379	6,290	6,203	6,116	6,031
Buffalo-NFTS			8,270	8,222	8,175	8,128	8,082	8,036	7,990	7,945	7,900	7,855	7,810	7,766
Baltimore-MMTA									8,977	8,912	8,847	8,783	8,719	8,656
San Jose-SCTD					4,444	4,505	4,566	4,629	4,693	4,757	4,823	4,889	4,956	5,024
New Orleans-RTA	2,778	2,774	2,769	2,765	2,760	2,756	2,752	2,747	2,743	2,738	2,734	2,730	2,725	2,721
Cleveland-GCRTA	6,976	6,906	6,836	6,768	6,700	6,633	6,566	6,501	6,436	6,371	6,308	6,245	6,182	6,119
Denver-RTD											2,622	2,525	2,431	2,341
Newark-NJTC	23,555	23,580	23,605	23,630	23,655	23,680	23,705	23,730	23,756	23,781	23,806	23,831	23,857	23,882

Population Density of Metropolitan Area

	Persons per square mile													
agency	1,984	1,985	1,986	1,987	1,988	1,989	1,990	1,991	1,992	1,993	1,994	1,995	1,996	1,997
New York-MTA-NYCT	7,370	7,403	7,441	7,461	7,473	7,464	7,445	7,436	7,449	7,483	7,500	7,512	7,511	7,512
Washington, D.C.-WMATA	586	599	613	630	646	658	666	675	685	694	703	711	729	739
Chicago-RTA-CTA	1,433	1,436	1,441	1,447	1,451	1,457	1,466	1,477	1,490	1,503	1,514	1,523	1,525	1,536
Boston-MBTA	929	936	941	946	954	960	960	956	956	961	965	971	974	976
Atlanta-MARTA	400	416	432	448	463	474	486	500	514	531	550	568	578	593
Philadelphia-SEPTA	1,244	1,247	1,257	1,268	1,276	1,277	1,277	1,280	1,281	1,283	1,286	1,287	1,297	1,299
San Francisco-BART	1,383	1,404	1,423	1,437	1,456	1,478	1,492	1,507	1,525	1,538	1,546	1,554	1,583	1,597
New York-PATHC	7,370	7,403	7,441	7,461	7,473	7,464	7,445	7,436	7,449	7,483	7,500	7,512	7,511	7,512
Miami-MDTA	900	911	924	940	960	981	999	1,014	1,026	1,022	1,036	1,055	1,075	1,089
Baltimore-MMTA	858	863	875	884	897	904	916	925	932	938	944	948	964	972
Los Angeles-LACMTA										2,240	2,239	2,239	2,308	2,324
Philadelphia-NJ-PATC	1,244	1,247	1,257	1,268	1,276	1,277	1,277	1,280	1,281	1,283	1,286	1,287	1,297	1,299
Cleveland-GCRTA	826	823	819	817	813	813	814	817	819	821	825	826	821	823
New York-MTA-SIRTOA	7,370	7,403	7,441	7,461	7,473	7,464	7,445	7,436	7,449	7,483	7,500	7,512	7,511	7,512

LIGHT RAIL	Persons per square mile													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	929	936	941	946	954	960	960	956	956	961	965	971	974	977
San Francisco-MUNI	1,526	1,546	1,558	1,565	1,568	1,576	1,578	1,587	1,597	1,608	1,614	1,619	1,629	1,636
Philadelphia-SEPTA	1,244	1,247	1,257	1,268	1,276	1,277	1,277	1,280	1,281	1,283	1,286	1,287	1,297	1,300
Los Angeles-LACMTA								2,202	2,227	2,240	2,239	2,239	2,308	2,332
San Diego Trolley Inc.	491	505	522	541	562	581	598	607	618	620	622	625	660	673
St. Louis-BSDA											396	397	399	401
Portland-TCMTDO				282	288	294	304	313	320	328	334	341	345	352
Dallas-DARTA													490	499
Sacramento-RTD				294	305	316	332	342	347	351	354	359	377	386
Pittsburgh-PAT	541	533	527	523	520	518	518	519	521	521	520	517	513	512
Buffalo-NFTS			755	752	753	756	759	760	761	761	758	755	758	758
Baltimore-MMTA									932	938	944	948	964	972
San Jose-SCTD					1,140	1,160	1,160	1,170	1,183	1,196	1,205	1,220	1,234	1,246
New Orleans-RTA	378	381	384	381	379	378	378	383	388	393	398	403	397	399
Cleveland-GCRTA	826	823	819	817	813	813	814	817	819	821	825	826	821	821
Denver-RTD											477	486	481	487
Newark-NJTC	7,370	7,403	7,441	7,461	7,473	7,464	7,445	7,436	7,449	7,483	7,500	7,512	7,511	7,519

Consumption of Electric Energy

HEAVY RAIL	Annual Kilowatt hours of power (000)													
agency	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New York CTA	1,960,107	1,669,871	1,740,907	1,857,533	1,851,099	1,911,512	1,891,786	1,805,034	1,745,754	1,772,756	1,875,576	1,836,096	1,705,161	1,634,226
Washington, D.C.-WMATA	192,264	249,356	276,650	290,345	298,413	295,241	298,755	306,975	317,333	328,559	341,832	346,380	336,666	328,621
Chicago-CTA	297,358	322,617	326,683	334,275	345,043	343,786	332,779	340,708	330,947	327,716	315,134	306,052	337,677	334,060
Boston-MBTA	158,810	170,209	167,539	174,843	185,707	148,853	143,853	162,623	170,737	178,933	183,739	191,402	195,398	179,744
Atlanta-MARTA	40,451	60,516	66,618	62,096	68,989	73,717	75,227	73,838	72,741	73,468	86,828	93,706	95,854	109,495
Philadelphia-SEPTA	120,042	116,887	121,053	119,010	121,881	123,043	119,050	112,415	107,113	128,922	132,670	129,199	138,260	123,589
San Francisco-BART	169,484	175,336	179,144	174,289	172,502	172,260	199,420	190,824	199,449	211,001	210,173	215,046	231,457	245,172
New York-PATH	75,590	73,958	75,463	77,617	86,306	88,051	88,090	94,240	93,240	95,700	98,100	97,580	97,670	96,252
New York-PATH	8,410	18,265	39,686	44,278	35,739	43,187	43,600	44,463	42,851	43,375	44,513	44,067	44,847	44,732
Baltimore-MTA	15,732	14,862	14,809	19,989	31,218	24,328	31,622	30,956	28,483	29,576	28,794	29,338	26,946	23,845
LA-LACMTA/SCRTD										11,150	25,305	25,990	27,771	48,065
Lindenwold-PATCO	31,011	31,012	31,219	38,603	31,981	34,047	33,043	34,300	33,140	35,404	36,167	36,167	42,884	34,414
Cleveland RTA	22,903	24,908	25,999	26,357	27,313	28,000	27,150	29,642	32,799	30,821	29,615	28,075	28,266	28,557
NY-MTA-SIRTOA	16,564	17,016	18,883	18,755	17,750	18,807	19,379	22,142	18,671	19,202	22,996	22,400	23,427	21,739

LIGHT RAIL	Annual Kilowatt hours of power (000)													
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Boston-MBTA	18,000	19,342	19,596	20,450	54,085	49,543	36,146	36,394	36,565	37,917	38,936	40,550	41,397	61,055
San Francisco-MUNI	33,064	38,881	40,970	40,531	40,223	40,503	43,338	43,150	53,126	52,684	32,669	29,706	33,677	34,809
Philadelphia-SEPTA	62,455	61,001	62,831	61,293	63,247	63,188	60,751	57,094	54,427	29,081	28,831	28,563	32,132	29,122
LA-SCRTD								25,029	31,492	32,578	31,841	31,299	41,789	46,707
San Diego Trolley	7,790	7,631	8,138	9,831	9,670	11,298	19,728	25,164	25,518	24,497	24,175	22,818	24,590	29,305
St. Louis-Bi-State											11,762	16,006	18,618	17,716
Portland Tri-County MTD				7,988	9,205	8,615	8,957	9,993	10,257	10,234	10,593	13,621	10,977	10,963
Dallas-DART													7,627	18,577
Sacramento RTD				3	8,645	6,899	7,200	10,643	11,600	12,327	12,081	11,901	15,097	15,407
Pittsburgh-PAT	7,642	9,784	14,137	24,817	24,817	24,828	25,461	24,479	22,770	24,275	22,151	21,058	21,058	20,201
Buffalo-Niagara Frontier			6,666	8,295	9,665	9,302	9,503	9,451	9,017	8,868	8,832	8,744	8,744	9,007
Baltimore-Maryland DOT									1,615	11,818	18,234	17,384	17,349	19,175
Santa Clara County TD					3,295	7,411	6,585	10,934	17,791	15,546	16,706	16,656	17,664	18,540
New Orleans Public Svc	2,890	2,858	2,859	2,974	3,141	2,120	2,817	2,909	2,987	2,626	3,300	3,244	3,130	2,966
Cleveland RTA	9,576	11,405	11,872	12,187	12,678	13,726	13,217	13,503	14,934	13,898	14,715	16,479	17,117	16,907
Denver-RTD											881	3,909	4,205	4,892
Newark-NJT Corp	3,008	3,320	469	959	2,167	2,470	2,894	2,601	2,703	2,586	3,173	3,116	3,086	2,929

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