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Significant characteristics of the urban rail renaissance in the United States: A discriminant analysis

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Abstract

In the rebirth of light-rail in the US, there has been little quantitative work detailing the differences between cities that have built rail transit and those that have not. In this study, 18 independent variables measuring a variety of characteristics that might promote or hinder rail transit construction are examined for 13 cities that built rail and 22 that did not, but considered it. After isolating the most significant variables, a two-group discriminant analysis generates a function from a randomly chosen set of 25 cities, and then cross-validates it on a separate set of 10. That model attempts to classify the cities into their respective groups. A model with three significant independent variables is generated that correctly classifies 33 of the 35 cities. The results indicate that cities which chose to build rail already had relatively well-used bus systems. There also appears to be an image and economic development aspect associated with rail construction.

Keywords: Light rail; Transit; Urban travel; Discriminant analysis; United States

1. Introduction

Growing congestion on urban road networks and the rise of problems associated with sprawling, auto-centric development patterns have led to the rebirth of rail as a transport option for urban areas of the United States. Cities such as San Francisco, Washington DC, Atlanta, and Miami constructed heavy rail transit systems in the 1960s and 1970s, but other cities found the costs prohibitive as concern grew over consistent failures to meet ridership projections (Mackett and Edwards, 1998). Starting in the 1970s, cities such as Portland, Buffalo, Pittsburgh, Baltimore, and San Diego turned to light-rail transit as a more cost-efficient solution and as a catalyst for central city revitalization. In the last 20 years, 14 cities have opened light-rail lines (Middleton, 2003), while another 32 urban areas are extending already existing rail lines or constructing new ones (APTA, 2003; Light Rail Central, 2004).

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It is generally presumed that rail transit breeds positive benefits that continued road construction and other transit modes cannot bring. People that do not otherwise ride transit do ride trains because of the higher quality of service rail tends to provide (Ben-Akiva and Morikawa, 2002; Hass-Klau and Crampton, 1998, 2002; Hass-Klau et al., 2000, 2003). Rail also favors pedestrian-friendly development over other, more flexible-route modes because of the permanence of its infrastructure, as well as the aesthetic and functional appeal that development around rail stations usually produces (Cervero, 1998; Hass-Klau and Crampton, 1998; Hass-Klau et al., 2000, 2003). However, problems exist in consistently achieving the desired effects of rail, and passionately charged and often politically motivated debate rages over its merit. The potential impacts of rail transit are qualified by a set of nebulous criteria demanding regionally specific methods for meeting them (Knight, 1980; Knight and Trygg, 1977; Polzin, 1999; Priest, 1980). The main argument against rail transit questions its ability to achieve some of its desired goals (such as congestion relief and economic redevelopment) despite infrastructure construction that takes years to complete and can cost into the billions of dollars (Rubin et al., 1999).

As cities have weighed whether or not to build transit, there are reasons why some cities made the investment and others did not. This research assesses measures of travel and land-use and isolates their impacts on rail transit construction at the urban area level. This analysis starts with a survey and discussion of the field of knowledge about rail transit. A set of eighteen independent variables is proposed, and then discriminant analysis is performed on a set of cities that considered rail transit since 1980, determining the significant variables that predict group assignment. Finally, the results and the implications for cities considering rail transit are discussed.

2. Literature review

There is little literature dealing specifically with the differences between US cities that built rail in the last quarter-century and cities that did not. Most of the relevant research discussed here focuses on reasons cities have decided to build rail and reasons that rail transit has and has not been successful. Key results expected from building rail transit must obviously include increasing ridership and improving service. Kain and Liu (1999) studied the increases in transit ridership occurring in Houston, which utilized bus transit, and San Diego, which utilized rail transit. They found the more cost-effective investment to be the system of dedicated HOV lanes and the commuter bus program in the center of major freeways in Houston. FitzRoy and Smith's (1998) study of Freiburg, Germany attributed increased transit patronage to an expansion of services, a reduction of fares, and the introduction of a universal fare-system "smart card." Both studies saw cities implement successful service expansion policies at a time when most contemporary cities were increasing fares and reducing services to cut down costs. Babalik-Sutcliffe (2002) found success in new rail systems occurred in relative proportion to locally implemented supportive transit and development policies and, where applied, restrictive auto policies. Similar conclusions were found in several studies by Hass-Klau and Crampton (1998, 2002) and Hass-Klau et al. (2000, 2003, 2004) of the direct relationship between complimentary measures to rail transit, restrictions placed on auto travel, and success in attracting ridership in cities in Australia, Europe, and North America. Their research also detailed the stark difference between the US approach to reinstituting rail transit versus what was seen in Europe, which has also experienced a rail renaissance since the early 1980's. Most US cities have not prioritized complimentary measures, aggressive transport reform goals, or marketing of their initiatives to nearly the same levels as the European initiatives. This has been somewhat due to the complete dominance of auto travel in the US, as well as the fragmentation of jurisdictions and decision-making in many US cities that prohibits effective coordination of transport and land-use planning.

Considerable literature also says that cities are not acting rationally when they choose to build rail transit. Light rail construction has often been used to boost the political careers of local decision-makers as much as it has been to actually benefit the city (Hass-Klau et al., 2003). Johnston et al. (1988) found that significant local advocacy and political maneuvering led to the construction of the light-rail line in Sacramento, California. Pickrell (1992) found that objective forecasting and projection procedures were compromised in eight early US light-rail systems because of the incentive structure of transit grant programs and dedicated funding sources. Mackett and Edwards (1998) found overestimation of ridership on all but one of ten US rail transit systems. They note improvement over time in the projection process but stress the need for rationality in considering necessary alternatives to the automobile in urban areas. Edwards and Mackett (1996), Hass-Klau and Crampton (1998), and Hass-Klau et al., 2003) discussed a decision making process that leads to an irrational political preference for rail transit because of perceived benefits of image and permanence over other potentially more cost-effective transport investments. Due somewhat to this process and an often incomplete understanding of how the benefits of rail work, US cities have fallen into the trap of building rail where it was cheapest and/or fastest to construct, instead of where it might provide the greatest overall benefit to the city (Hass-Klau et al., 2004).

Research by Richmond (2001) concurred with findings about cost-escalation in light-rail projects and suggested that the development benefits were not necessarily inherent to light rail. That research also suggested that most of the impressive ridership gains experienced by rail have been the result of route downsizing in favor of the rail line and the conversion of bus routes into rail line feeders. Black (1993) acknowledged that light-rail transit has been oversold as a panacea to urban transport problems at the expense of properly evaluating potentially cheaper bus transit alternatives. Hass-Klau and Crampton (1998, 2002) and Hass-Klau et al., 2003) described how light-rail has become the adopted proven technology for public transit investment among city decision-makers without necessarily any established evidence as to its superiority over other alternatives. Light rail has achieved a status, and has become the easiest transit mode to sell to a community. This has limited our understanding of whether there is anything inherent in rail that explains the difference in quality versus other alternative modes, assuming that investment in complementary policies and the quality of ride were equal (Hass-Klau and Crampton, 1998; Hass-Klau et al., 2000, 2003, 2004).

However, Black (1993) and Johnston et al. (1988) also stated that investment in rail transit is a worthwhile goal if it reflects the will of the people and if the municipality is willing to bear the cost. Hass-Klau and Crampton (1998) argued that the success of light-rail projects is often inaccurately limited to ridership results, when the reasons for building light-rail extend far beyond attracting ridership. Rail is built for central city revitalization and improving urban form and aesthetics as much as it is to draw riders to itself. Rail transit is used to attract development partly because its permanence lends it a perception of security and presence that make it a safe investment (Hass-Klau et al., 2003). It is also suggested that the US is "the developed world's most unfavorable transport environment," (ibid, p. 16) and that the small gains or declines in overall transit ridership in cities that built rail were probably the result of rail staving off the even sharper declines in transit use seen in cities with only bus transit. There is a direct correlation between the extent of complimentary measures employed and the prioritization of a policy goal of expanding transit ridership, with actual ridership increases in North American cities like Portland and Calgary that have chosen to do so (Hass-Klau et al., 2003, 2004). Research has also demonstrated a willingness on the part of travelers to convert from autos to public transport if investments are made to bring quality elements of transit, such as reliability and frequency, to levels closer to those inherent to automobile use. However, aggressive marketing schemes before, during, and after construction are critical to the image of the transit investment and to maximizing positive results (Hass-Klau et al., 2003).

Furthermore, the economic shortcomings found in critical assessments of light-rail performance are not solely inherent to rail transit. Flybjerg et al. (2003) showed that all transportation projects, regardless of mode, have consistently run over budget and beyond expected completion dates for more than seventy years. They state succinctly, "The problem is the pervasiveness of misinformation in the planning of transport infrastructure projects, and the systematic bias of such misinformation toward justifying project implementation" (ibid, p. 86).

A reason for focusing this research specifically on the US is the distinct difference between its experience with light rail in the latter 20th and early 21st century and experiences elsewhere. Differences were noted by Hass-Klau and Crampton (2002) between the "New World" of North American cities and the "Old World" of cities in the United Kingdom and in Continental Europe. There are historical factors at work, such as the narrow streets and mixed, non-grid street patterns that encourage a more pedestrian environment and thus a more transit-oriented environment. Car-use is restricted by the physical and structural geography of European urban areas. In contrast, US streets are wider and easier to widen, and as such are not conducive to pedestrian usage. Population densities, though of surprisingly large variation in both "Worlds," are consistently greater in Europe. Planning traditions and tools are weaker in the US, while the acceptance of cars is much greater. Most public authorities in the US focus on maintenance of the system and meeting budget constraints, usually by limiting costs (Hass-Klau and Crampton, 1998). Very few public authorities in the US actively work on prioritizing transit and increasing ridership, nor do they focus on decreasing roadway space for automotive use and discouraging vehicle trips (Hass-Klau et al., 2003).

The literature suggests that cities choose rail transit irrationally because of perceived image benefits and political circumstance, while the money might be better spent on expanding bus and service quality. Cities choose rail transit irrationally because of perceived image benefits and political circumstance, while the money might be better spent on expanding bus and service quality. However, research also indicates that rail transit may serve a positive purpose if it is supported by the public, and that the problems in meeting budgets and performance goals are not necessarily inherent in rail transit but lie in the politicization of the budgeting process. Rail transit has played a role in increasing transit ridership and expanding services when complemented by supportive policies, and has been effectively used as a tool for urban redevelopment. The US experience is worth highlighting and focusing on, since there are numerous significant historical and institutional differences in the approach to planning and transport between North American cities and cities in continental Europe and the United Kingdom that have also pursued a restoration of rail transit.

3. Methodology

Thirty-five cities are examined that have built or considered rail transit since 1983. Twenty-five are randomly chosen to be a model-generating set, while 10 are set aside for cross-validation. There are 18 independent variables. This study utilizes a two-group discriminant analysis to distinguish cities that built rail from cities that did not.

Discriminant analysis is analogous to multiple regression analysis. The independent variables are the predictors used for discriminating between cities that built rail and cities that did not. The dependent variable is a dichotomous dummy variable, coded here as "1" for cities constructing rail and "0" for cities that did not. A single discriminant function is generated that maximizes the difference between two groups of values for a set of independent variables (Tabachnick and Fidell, 2001, 1983).

A stepwise process is incorporated to reduce the set of 18 independent variables to the significant predictor set. Tabachnick and Fidell (2001) discuss the problem of predictor variables being removed based on "trivial differences in relationships among predictors in the sample that do not reflect population differences" (p. 481). Further complicating this particular analysis is the relatively high number of independent variables to the relatively small total sample size (35), unequal group assignment (22 non-rail, 13 rail cities), and small sample-size of the model-generating set (25). To combat this, several processes are used to reduce the number of independent variables to the smallest possible number of significant predictors while preserving the quality of the data. Forward stepwise regression is run with a relatively low alpha to enter, 0.20. Then backward stepwise regression is run with a higher alpha to remove, 0.01. The remaining significant independent variables are input to the discriminant analysis. The low alpha forward helps ensure entry of the most important variables by themselves, while the more stringent backward alpha will leave only the most significant of the variables after adjusting against all other variables (Tabachnick and Fidell, 2001).

4. Dependent variable and cities examined

The dependent variable is a binary variable called "Rail Decision." A key question for the analysis is deciding when to measure the cities. For cities that did not build rail, the year of examination is the year of most recently available data, 2001. The year of examination for cities that did build rail is the calendar year occur-

Table 4.1
Rail decision "1" cities

Urban area	Year examined	Mode (subsequent additions)
Portland, Oregon	1983	Light rail
Sacramento, California	1983	Light rail
San Jose, California	1984	Light rail (commuter rail)
Los Angeles, California	1986	Heavy rail (light rail and commuter rail)
St. Louis, Missouri	1989	Light rail
Dallas-Fort Worth, Texas	1990	Light rail (commuter rail)
Denver, Colorado	1992	Light rail
Salt Lake City, Utah	1996	Light rail (commuter rail)
Houston, Texas	2000	Light rail (commuter rail)
Las Vegas, Nevada	2000	Monorail
Minneapolis-St. Paul, Minnesota	2000	Light rail
Charlotte, North Carolina	2001	Light rail
Phoenix, Arizona	2001	Light rail

Table 4.2
Rail decision "0" cities

Urban area	Year examined	System
Albuquerque, New Mexico	2001	Light rail, proposed
Austin, Texas	2001	Light rail defeated 2000; commuter rail proposed
Birmingham, Alabama	2001	Light rail, long-range planning
Cincinnati, Ohio	2001	Light rail, defeated 2002
Colorado Springs, Colorado	2001	Light rail, planned
Columbus, Ohio	2001	Light rail, under study
El Paso, Texas	2001	Light rail, planned
Honolulu, Hawaii	2001	Light rail, proposed
Indianapolis, Indiana	2001	Light rail, planned
Kansas City, Kansas	2001	Light rail, defeated 2003
Louisville, Kentucky	2001	Light rail, under study
Milwaukee, Wisconsin	2001	Light rail, proposed
Nashville, Tennessee	2001	Light rail, long-range planning
Norfolk, Virginia	2001	Light rail, preliminary design
Oklahoma City, Oklahoma	2001	Light rail, long-range planning
Orlando, Florida	2001	Light rail, under study/proposed
Rochester, New York	2001	Light rail, proposed
Salem, Oregon	2001	Light rail, proposed
San Antonio, Texas	2001	Light rail, defeated 2001
Spokane, Washington	2001	Light rail, under study
Tucson, Arizona	2001	Light rail, defeated 2003
Tulsa, Oklahoma	2001	Light rail, proposed

ring six months before construction on the system began. This eliminates biases that might arise from changes in travel patterns and development due to system construction. Rail systems where construction began later than 2001 use data from 2001.

Thirteen cities in the analysis constructed or are constructing rail systems, while 22 others considered it but did not build (see Tables 4.1 and 4.2). There are other cities that either built or considered rail but were excluded from the analysis. Atlanta (construction began in 1975), Baltimore (1976), Buffalo (1979), Miami (1979), San Diego (1979), San Francisco (1966), Pittsburgh (1980), and Washington, DC. (1969) were removed due to a lack of data availability prior to the commencement of rail transit construction. Including these cities with data after their construction would have biased the analysis because the effects of rail transit on significant variables would have already begun. This is disappointing, as it leaves out potentially intriguing comparisons between early heavy-rail and later light-rail systems.

Cities such as Boston, Chicago, Philadelphia, and New York have been operating transit continuously through the 20th century. There are thus obvious data issues as well as bias introduced by including these particularly large and old US cities. Several other cities only feature rail transit systems of a limited extent. Detroit, Jacksonville, and Morgantown (WV) feature automated guideway systems that are relatively short in system length, while Seattle is served by both a relatively new commuter rail system as well as a monorail built for the 1962 Seattle World's Fair. Places such as Galveston (TX), Memphis, New Orleans, and Tampa feature trolley lines in historic areas near downtown. As well as the data issues mentioned earlier, it is beyond the scope of this analysis to determine the start dates of these systems or whether these systems are historical artifacts, function as tourist attractions, or offer a real urban transportation option. It is thought that the inclusion of any of the above cities would compromise the homogeneity of the sample set, and as such they were excluded from the analysis.

5. Independent variables

The independent variables fall into five general categories: four "Propensity to Use Transit" variables, three "Initiative to Build Rail" variables, three "Driving" variables, four "City Geography" variables, and four "Economic" variables (see Table 5.1).

The four "Propensity to Use Transit" variables measure the likelihood of the residents of the city to already be using transit. They propose that transit service investment and expansion is likely to be more palatable in places whose residents are already familiar with transit. The variables measure annual bus boardings per capita (*Transit Boardings*), proportion of the total annual automobile and transit passenger mileage traveled in the city that is captured by transit (*Transit Market Share*[1]), the proportion of the population demographically dependent on transit (*Captive Riders*), and the existence of a large stadium within the urban area (*Sports/Event Venue*).

The three "Initiative to Build Rail" variables assess the momentum a city may have toward considering investment in an alternative mode of travel. The variables assess how much sprawl the urban area has experienced by measuring how many centerline miles of roadway exist in an urban area per person (*Roadway per person*), and how much pressure is resulting from the rate of new land being consumed by development, measured by the amount of new centerline mile roadway growth in the previous five years (*Sprawl Growth*). Rail and image appear to be closely tied, so cities might also consider rail transit investment if a major event drawing attention to the city is approaching (*Upcoming Events*).

Three "Driving" variables measure the degree that rail is considered as a response to increasing pressure on the existing roadway system. This occurs in the form of annual vehicle miles traveled per capita (*Driving*), the change in the percent of roadway experiencing congestion in the last ten years (*Congestion*), and in the amount of time required for travel over what would be experienced in free flow conditions (*Travel Time*).

There are also four "City Geography" variables measuring the residential and economic disposition toward dense corridor development that favors rail transit. That might be found in the population density of the urban area (*Density*), the proportion of people in the MSA who work in the central city (*Central City Employment*), or how much freeway lane-mileage is already built in the city relative to its physical size (*Room for Freeways*). It also could be a function of weather quality, measured by the number of extremely hot, cold, and wet days in a year (*Climate*).

[1] There is obviously a distinction between transit passenger miles and auto vehicle miles traveled, as the former measures the movement of people while the latter measures the movement of automobiles. VMT was multiplied by an estimator for average vehicle occupancy of 1.25, as suggested in the 2003 Urban Mobility Report (Schrank and Lomax, 2003) to get an estimate for vehicle passenger mileage. The resulting value is summed with transit passenger mileage to get a value for total passenger mileage.

Table 5.1
Independent variables

Variable name	Description	Data source	High	Low
Propensity to use transit				
Transit boardings	Annual transit trips per capita	2003 Urban Mobility Study	103, Honolulu	4, Birmingham, Tulsa
Transit market share	Annual transit passenger miles divided by sum of automobile and transit passenger miles	2003 Urban Mobility Study	0.0335, Portland	0.0003, Birmingham
Captive riders	Percent of residents under age 16, women over age 65, and poverty-level incomes aged 18–64	2000, 1990, 1980 US census	54%, Kansas city	26%, Tulsa, Oklahoma City
Sports/event venue	Dummy variable for major sports venues		–	–
Initiative to build rail				
Sprawl growth	Proportional increase in roadway centerline miles from ten years previous	2003 Urban Mobility Study	1.569, Las Vegas	1.003, Nashville
Roadway per person	Roadway centerline miles per capita	2003 Urban Mobility Study	0.0069, Birmingham	0.0015, Honolulu
Upcoming events	Dummy variable for major sporting/media event coming within 5 years		–	–
Driving				
Driving	Vehicle miles traveled per capita	2003 Urban Mobility Study	17,052, Kansas city	4252, Portland
Congestion	Increase in percent of roadway experiencing congestion from 10 years previous	2003 Urban Mobility Study	25%, Indianapolis	0%, Honolulu
Travel time	Proportional delay experienced in peak hour travel versus free-flow travel conditions	2003 Urban Mobility Study	1.44, Los Angeles	1.05, Portland
City geography				
Density	Persons per square mile	2003 Urban Mobility Study	5225, Los Angeles	1105, Birmingham
Central city employment	Proportion of MSA population working in the urban area	2000, 1990, 1980 US census	52%, Austin	15%, Orlando
Room for freeways	Freeway lane miles per square mile	2003 Urban Mobility Report	2.93, Honolulu	0.61, Tucson
Climate	Sum of degree days over 90°F, under 32°F, or with 0.01 in. of precipitation	National Climactic Data Center, US Dept of Commerce	301, Rochester	57, Los Angeles
Economic				
Business	Percent increase in employed people from 5 years previous	REIS, 1967–2001	+27.6%, Salt Lake City	+1.8, Honolulu
Job growth	Percent increase of proportion of population employed from previous 5 years	REIS, 1967–2001	+8.8, Salt Lake City	−1.5%, Salem
City credit rating	Dummy variable for highest credit rating or not	Business journal online, city, state, and county websites and newspapers[a]	–	–
Enplanements per capita	Annual enplanements per capita	FAA and BTS	15.38, Charlotte	0, Salem

[a] Contact the author for a list of sources.

Lastly, a group of "Economic" variables look to the financial factors that might encourage a city to invest in rail transit. These could lie in raw business expansion as measured by the change in number of employed people in the city (*Business*) or in relative job growth in the city (*Job Growth*) over the previous five years. Since rail transit represents a significant cost to a city, its financial standing as measured by bond rating (*City Credit Rating*) could prove significant. Lastly, a variable measuring enplanements per capita (*Enplanements per* *capita*) is included to assess how much travel a city receives. This might indicate the business strength of a city, as well as tourism appeal of an urban area and/or its surroundings.

6. Discriminant analysis

Discriminant analysis is robust with respect to multicollinearity and normality when sample sizes are large and the degrees of freedom are equal to or greater than twenty, but is highly sensitive to the presence of outliers in the data set. The number of cases or observations for any one of the two groups must be greater than the number of independent variables tested. Problems can arise when the number of cases for each group gets small and the group sizes are unequal. Discriminant analysis also becomes sensitive to heteroscedastic errors under unequal and small group sizes. Since classification and inference are major goals of this analysis, homogeneity of variance–covariance matrices must be examined (Tabachnick and Fidell, 2001). Tests for multicollinearity, normality, and variance–covariance matrices homogeneity were run on the 18 independent variables to verify data quality.

6.1. Data testing

To test for multicollinearity, a correlation matrix of all 18 independent variables against each other was analyzed for danger-level correlations, set here at 0.7 as recommended by Clark and Hosking (1986) and used in other studies of rail transit (such as Kuby et al., 2004). Danger-level collinearity occurred for *Density* with four variables: *Climate*, *Roadway per Person*, *Transit Market Share,* and *Transit Boardings. Climate* and *Density* (−0.768, *p*-value 0.000) were not likely causally related; the cities with the highest density occurred in two states whose cities had the best values for *Climate*, Hawaii and California, followed by an even distribution among the rest of the cities.

However, the correlation between *Roadway per Person* (−0.797, 0.000), *Transit Market Share* (0.733, 0.000), and *Transit Boardings* (0.803, 0.000) with *Density* could be considerably more significant. The easiest solution would be to simply remove the density variable, but that was undesirable. The link between density and transit viability (Pushkarev et al., 1982) is commonly accepted and thus warranted testing in this analysis. To test the effect of *Density* collinearity on the results, the stepwise analysis (description forthcoming) was also run excluding the *Density* variable. The resulting significant variables remained the same as they were including *Density* in the analysis.

The independent variables displayed a mostly normal distribution, slightly skewed and clustered toward the lower end of the range with a few outliers at the high end of the range. This was expected, given the population distribution of the cities. Most have between 500,000 and 2,000,000 people, with a few very large population cases (Phoenix, Dallas-Fort Worth, Houston, and Los Angeles). Outliers that were true exceptions included Honolulu, which had large values for *Density*, *Transit Boardings*, and small values for *Room for Freeways*; Los Angeles, which had a large value for *Density*; Portland, which had the largest value for *Transit Market Share*; Las Vegas, which had the largest value for *Sprawl Growth*; and Kansas City, which had the largest value for *Driving*. To test the effect of these outliers, the stepwise analysis for determining significant variables was tested excluding the aforementioned outlying cities. The resulting significant variables excluding the outlier cities matched those produced when including the outlier cities.

Though robustness is assumed for variance–covariance homogeneity in discriminant analysis, the potentially dangerous sample size and small degrees of freedom warranted testing of the matrices. Box's M test was run and determined no significant difference (0.000) between the two matrices.

6.2. Analysis

The sets of cities for the analysis are depicted in Table 6.1. When utilizing cross-validation, the cities set aside should be chosen at random from the overall sample set (Tabachnick and Fidell, 2001). A size of $n = 25$ for the model-generating set and $n = 10$ for the cross-validation set was formed from the overall sample

Table 6.1
Cities in the analysis

Model generating cities	Rail decision	Cross-validation cities	Rail decision
Albuquerque	0	Austin	0
Birmingham	0	Louisville	0
Cincinnati	0	Milwaukee	0
Colorado Springs	0	Nashville	0
Columbus	0	Orlando	0
El Paso	0	Salem	0
Honolulu	0	Dallas	1
Indianapolis	0	Portland	1
Kansas City	0	Salt Lake City	1
Norfolk	0	San Jose	1
Oklahoma City	0		
Rochester	0		
San Antonio	0		
Spokane	0		
Tucson	0		
Tulsa	0		
Charlotte	1		
Denver	1		
Houston	1		
Las Vegas	1		
Los Angeles	1		
Minneapolis	1		
Phoenix	1		
Sacramento	1		
St. Louis	1		

Table 6.2
Function scores for Model-Generating Cities

City	Function score
Las Vegas	4.823
Denver	3.952
Los Angeles	3.336
Sacramento	2.851
Minneapolis	2.600
Houston	2.591
Charlotte	2.027
St. Louis	1.227
Phoenix[a]	−0.504
Albuquerque	−0.631
Cincinnati	−0.657
Kansas City	−0.917
Colorado Springs	−1.171
Birmingham	−1.189
Tulsa	−1.192
Indianapolis	−1.217
Oklahoma City	−1.433
Spokane	−1.442
Columbus	−1.564
Honolulu	−1.689
El Paso	−1.723
Rochester	−1.760
Tucson	−1.805
Norfolk	−1.872
San Antonio	−2.641

[a] Misclassified city.

Table 6.3
Function scores for Cross-Validation Cities

City	Function score
Portland	7.636
Salt Lake City	4.391
Dallas	1.695
San Jose	0.956
Orlando[a]	0.536
Nashville	−0.395
Louisville	−1.973
Salem	−2.198
Austin	−2.378
Milwaukee	−3.348

[a] Misclassified city.

of $n = 35$. A random number generator was used to select cities for the cross-validation set from the entire sample, weighted so the ratio of Rail Decision "1" ($n = 13$) to Rail Decision "0" ($n = 22$) cities was close to the overall ratio of roughly 2:3. Therefore, the model generating set has $n = 9$ cities as "1" and $n = 16$ cities as "0", while the cross-validation set has $n = 4$ cities as "1" and $n = 6$ cities as "0". The model generating cities were used for the analysis and model production. The model was then tested using the cross-validation cities. The statistical packages SPSS and Minitab were utilized for the analysis.

Forward stepwise regression was run on the model-generating cities starting with all 18 independent variables and a relatively low alpha to enter, 0.20. Nine steps where required to determine the following significant variables: *Enplanements per capita* (p-value 0.000); *Transit Market Share* (0.002); *Sprawl Growth* (0.004); *Sports/Event Center* (0.005); *Transit Boardings* (0.010); *Driving* (0.035); *Business* (0.054); *Central City Employment* (0.075); and *Density* (0.624). Backward stepwise regression was then run using those nine variables with the more stringent alpha to remove, 0.01. *Transit Boardings*, *Transit Market Share*, and *Enplanements per capita* (all p-values 0.000) were left as the most significant predictor variables.

Transit Boardings, *Transit Market Share*, and *Enplanements per capita* were implemented as the predictor variables in the discriminant analysis, generating the following functions.

6.2.1. Standardized form

Rail Decision = 1.786(*Transit Market Share*) − 1.651(*Transit Boardings*) + 1.066(*Enplanements per capita*).

6.2.2. Unstandardized form

Rail Decision = − 1.634 + 370.231(*Transit Market Share*) − 0.081 (*Transit Boardings*) + 0.302(*Enplanements per capita*).

These functions accurately assigned group membership for 24 of the 25 cities, a 96% accuracy rate (see Table 6.2). All 16 cities in the Rail Decision "0" group were correctly predicted for that group, while eight of the nine cities in the Rail Decision "1" group were properly assigned; Phoenix was misclassified into Rail Decision "0".

6.3. Cross validation

Cross validation was run using the technique available in SPSS. Nine of the ten cross-validated cities were correctly classified; five of the six non-rail cities are correct, while all four rail cities are accurately assigned. Orlando is misclassified as having rail transit, when it does not (see Table 6.3).

7. Discussion

The functions generated appear to be useful models, accurately predicting all but two cities' group assignment out of the sample of 35. Phoenix, from the model-generating set of cities, is constructing a 20-mile light-rail line slated to open in 2007; however, the model classified it as a no-build city (−0.504). Orlando, which was one of the

Table 7.1
Mean and median values for significant variables

Variable	Non-rail mean	Rail mean	Non-rail median	Rail median
Transit use	23	30	20	28
Transit proportion	0.00236	0.01332	0.0025	0.00130
Flights per capita	3.7	6.7	2.5	6.0

cross-validation cities, was classified as a rail city (0.536), even though it is not building rail. Phoenix has the lowest values for *Transit Boardings* (14 annual trips per capita) and *Transit Market Share* (0.15% of auto and bus passenger miles were traveled on transit) of any city that built rail in the sample; its value for *Enplanements per capita* (5.7 annual trips per capita) is below the rail group mean and not high enough to classify it as a rail city. Meanwhile, Orlando also has low values for *Transit Boardings* (18 trips) and *Transit Market Share* (0.14%), but has a very high value for *Enplanements per capita* (10.3 annual trips per capita) that is most likely caused by the presence of major tourist destinations such as the nearby Walt Disney World theme park.

7.1. Transit boardings

As Table 7.1 shows, rail cities in this sample average seven more transit trips per person, three more annual enplanements per person, and nearly six times the proportion of miles traveled on transit than their non-rail counterparts. It is clear that cities that built rail have transit systems that experience greater use and represent a larger amount of the total travel in a city than cities that did not construct rail. Cities that built rail also have busier airports per capita.

The *Transit Boardings* variable measures annual transit trips per capita. However, it is likely that the variable actually captures something else: the proportion of citizens in the city that use transit regularly. Transit trips, unlike car trips, are not likely to be discretionary travel. Fixed routing and scheduling dictate that transit trips are usually planned ahead of time. High levels of transit trips might be a result of a large population that is demographically or economically dependent on transit. In this study though, the variable measuring the proportion of people who need transit based on socioeconomic and demographic characteristics proved insignificant. Another cause of high *Transit Boardings* might be the presence of a strong CBD or preponderance of jobs in the central city; however, the variable measuring proportion of jobs in the central city also proved insignificant. The lack of significance in those factors implies that the variance in transit trips between cities is a function not of the number of people who require transit for mobility, but instead the amount of the population who regularly chooses to use transit when they have a choice between it and automobile travel. Cities with higher values for *Transit Boardings* might be offering a higher quality of transit service that makes the system more accessible to users who might otherwise consider driving.

The *Transit Boardings* variable has a negative coefficient in both forms of the model. This seems peculiar at first, especially given the noticeable difference in the mean and median values between each group. However, prior research (such as Hass-Klau et al., 2000, 2003 and Hass-Klau and Crampton, 2002) suggested that rail has been built to attract new riders to transit who are economically past needing it for mobility. Therefore, they would choose to ride rail in order to avoid road congestion, or because the higher quality of travel makes rail more attractive than bus transit (ibid). The quantitative results of this analysis concur with the impressions given by surveys of public officials in other research and by the general public. Rail, while built in cities that were already more conducive to transit use in terms of mileage traveled, was not necessarily built as a service improvement for the individuals already using the transit system. Rather, the negative coefficient for annual bus boardings per capita implies that cities built rail to attract new riders to the transit system.

7.2. Transit market share

The large difference between the groups for the *Transit Market Share* variable implies that cities which built rail featured a relatively large portion of the total travel in the city as captured by the transit system. Cities that built rail transit already had a relatively strong and well-used transit system in place. This result concurs with other research that examines transit patronage and city travel patterns on a per capita basis (such as Hass-Klau and Crampton, 2002).

Cities with a relatively large amount of the population already using transit probably have what might be termed as a relatively large transit constituency. There are a greater number of users of the system, thus there is a stronger acceptance of transit in the city as well as a larger voice for rail transit in public meetings, advocacy groups, and at the ballot box.

There is also the possibility that there is a greater prevalence of land-uses conducive to transit use in cities that built rail. It is an important result of this analysis that density, long held as a singular barometer for assessing transit viability, did not prove significant at an urban area level. Other research (most recently Kuby et al., 2004 and Hass-Klau and Crampton, 2002) suggested that the important land-use rubric is not overall urban area density, but is instead only within a short range of the (potential) rail station (such as 1/4 or 1/2 mile) or the rail corridor.

Rail transit implementation plans are often discussed as finding a suitable corridor, particularly for so-called "starter" lines. These corridors might include the CBD, but also could include a major university, a museum or art district, another non-central business district or other collection of employment, and clusters of development exhibiting characteristics sought in transit-oriented development (TOD) projects. These characteristics include a mix of residential, commercial, and retail uses relatively close to one another. These corridors feature a string of activity nodes that experience a high amount of travel between them, but these do not necessarily have to be the densest parts of a city (Hass-Klau and Crampton, 2002; Hass-Klau et al., 2004).

Cities that have a higher amount of travel captured by the existing transit system probably feature a corridor or corridors suitable to rail, as well as are conducive to high levels of *Transit Boardings*, and are thus a more successful candidate for rail transit. Related to market share captured and land uses, rail has the potential to be less costly to run than bus in such high-use corridors because of the difference in load factors between rail and bus, the need for fewer drivers, and the potentially lower maintenance costs of transit (Hass-Klau et al., 2000, 2003). Cities with high levels of *Transit Market Share* might also have been seeking to minimize costs as well as affect development.

7.3. Transit boardings, transit market share, and implications for other cities

The *Transit Market Share* variable is an assessment of the amount of passenger mileage traveled in a city in both automobiles and public transit that was captured by the city's transit system. It can vary because of low or high values of total auto travel mileage, as well as low or high values of total transit travel mileage. Therefore, high values of *Transit Market Share* are a function of longer transit trips and/or shorter, less frequent drives, while low values are a function of shorter transit trips and/or longer, more frequent drives. Cities with large values for *Transit Market Share* might benefit from a large amount of transit travel, but might also experience less driving on their roadways.

High values of *Transit Boardings* but low values of *Transit Market Share* are a function of either transit system characteristics or auto travel characteristics. The transit system might have most of its ridership on a few routes between very dense activity areas within close proximity to each other. Or, the city might have a transit system that has long ride lengths but is also subject to proportionately longer auto travel distances and greater auto trip frequency. If an urban area features strong corridors well served by transit, but also rapid suburban growth in its peripheries, that might result in the quandary of having a strong propensity toward both auto travel and transit use. For this sample of cities, the negative correlation between the *Driving* variable and *Transit Boardings* (−0.306, *p*-value 0.137) and *Driving* and *Transit Market Share* (−0.286, 0.166), while suggesting that as driving per capita increases, transit usage per capita decreases, is nonetheless statistically insignificant. The relationship between auto travel and bus travel might not be a zero-sum game for urban areas.

In light of this, the distribution of the values for the cities should be addressed. Upon examination, clusters of cities are revealed (see Appendix A). All of the rail cities except Dallas (15 annual trips) and Phoenix (14) have robust values of *Transit Boardings*. Following those are a range of eight non-rail cities with values for

Transit Boardings below the Group 0 mean of 23. However, eight of the twelve lowest scoring cities in the discriminant function have values for *Transit Boardings* greater than the Group 0 median. There are then a group of cities that have a relatively large amount of people who use the transit system regularly but did not build rail. Cities such as Tucson (23 annual transit trips per capita, 0.0025 proportion of total auto and bus miles traveled on bus transit), San Antonio (37 trips, 0.0034), Austin[2] (45, 0.0041), Milwaukee (51, 0.0049), and Honolulu (103, 0.0134) have *Transit Boardings* values greater than the mean for Group 1 cities, as well as *Transit Market Share* values greater than the mean in their own Group 0 set of cities. The discussion implies that these cities might have transit systems strong enough to support a rail component.

7.4. Enplanements per capita

As mentioned earlier, cities that built rail averaged almost twice the number of flights per capita each year than cities that did not. However, the significance of this variable is not as definitive as the *Transit Boardings* and *Transit Market Share* variables. Cities might have high values for *Enplanements per capita* for three reasons: the people in such a city fly more than people in a city with low *Enplanements per capita* values; they are hubs for airlines, and thus experience a disproportionately large number of enplanements of people who are not actually spending any time in the city; or there are a large number of people who travel to the city for business or pleasure purposes. Personal air travel is usually a function of disposable income, and it is assumed that this does not vary enough between urban areas to make a difference in this study. The idea that this variable might have captured air hubs is intriguing, and might render the significance of the *Enplanements per capita* variable moot. Enplanements in hubs are often transfers from one plane to another as airlines that have almost universally adopted the hub-and-spoke method of transporting passengers move people between non-major centers. There are ten hub cities in the sample: Charlotte (15.38 annual enplanements per person), Salt Lake City (11.07), Denver (8.88), Dallas (8.18), Minneapolis (6.96), Cincinnati (6.47), Houston (5.97), Phoenix (5.7), St. Louis (4.81), and Los Angeles (1.78). Of these, only Cincinnati has not built rail, while they are evenly distributed around the Group 1 mean of 6.7 annual enplanements per person. Eight of the thirteen built-rail cities have airline hubs, while only one of the twenty-two non-rail cities has an airline hub. This casts doubt on the relevance of the *Enplanements per capita variable*. However, the largest *Enplanements per capita* cities were Charlotte (15.38 annual enplanements per person), Las Vegas (13.95), Honolulu (11.13), Salt Lake City, and Orlando (10.33). Of these, Salt Lake City and Charlotte are airline hubs, while Las Vegas, Honolulu, and Orlando are well known American tourist destinations. Salt Lake City is a burgeoning depot for winter sports in the Rocky Mountains, while Charlotte is the second largest financial center in the US in terms of headquartered assets (Charlotte Chamber of Commerce, 2006). The enplanements occurring in these cities appear not to be the result of hubs necessarily. It is thus not definitively clear if the variable has accidentally captured airline hubs.

One notion is that cities have built rail to serve busy airports. This falls apart when it is realized that none of the original rail systems reached their respective airports when opening. St. Louis and Portland have since built extensions to their airport, while Dallas and Minneapolis are currently constructing such segments. Furthermore, most people who are visiting cities in the US either for business or pleasure typically do not use transit systems to get around, with the potential exception of major cities excluded from this analysis. Instead, rental cars, cabs, and other informal transport arrangements are usually made for visitor travel from airports.

If the relationship between air hubs and rail transit is unclear, and the lines were not built to serve busy airports, then a large value for *Enplanements per capita* might imply that there are a large number of people in an urban area at any given moment that do not already live there. The significance of the variable might have something to do with preserving or enhancing an image that attracts a non-resident population. A city with such a population is constantly exposed to outsiders, directly to the visitors and indirectly to the busi-

[2] Since the completion of this analysis, Albuquerque has begun operation of commuter rail, and Austin has approved a referendum authorizing construction of a commuter rail line, slated to open in 2008. These developments after the completion of the analysis further contribute to the notion of more cities capable of choosing and supporting rail than indicated by the discriminant function alone.

nesses that pertain to visitors (related to either work or pleasure). Such a situation likely leads to an emphasis on image, which as previously mentioned is an important concept in the rail transit discussion. Rail transit and image are often talked about in the same sentence; rail is said to have an attractive element that bus transit cannot match (Ben-Akiva and Morikawa, 2002; Edwards and Mackett, 1996; Hass-Klau and Crampton, 1998, 2002; Hass-Klau et al., 2000, 2003, 2004). The image of public transport is critically important in determining how well it is used. Rail transit generally has a positive public perception, especially among interest groups with strong or loud influence (Hass-Klau et al., 2003, 2004).

Furthermore, rail transit construction and city redevelopment projects are frequently intertwined. Transit-oriented development (TOD) in the mode of the Smart Growth or New Urbanist movements is often promoted around rail stations. Businesses looking for progressive cities to invest in or locate to might see rail transit and TOD as a sign of progressive development. Economic development and redevelopment are central themes of almost any city administration, as it has become political suicide to not focus on such things (Rubin, 1988). Evidence suggests that light rail, if not responsible for instigating development, at least serves to speed it up (Hass-Klau et al., 2004). Cities themselves see rail transit in a positive image associated with economic development, as well as from motivations stemming from personal political benefit and competition with other similar cities (Hass-Klau et al., 2003, 2004). Rail is used to boost the image of public transport in a city, and is also an instrument or tool for producing or preserving a modern image to attract people and jobs, even though that image was obtained without rail transit. The *Enplanements per capita* variable might have indirectly captured these processes at work.

8. Conclusions

This study searched for consistent characteristics that define cities that built rail transit in the US since 1983 from cities that did not. Three variables proved significant and effective in classifying the cities into groups that did and did not build rail. *Transit Boardings*, a variable measuring the annual transit trips per capita of an urban area; *Transit Market Share*, measuring the proportion of total miles traveled in autos and buses that was captured by buses prior to the construction of rail transit; and *Enplanements per capita*, the annual enplanements per capita at a city's airport(s), correctly classified 24 of 25 cities in a set that generated a discriminant function. That function was cross-validated on another set of 10 cities, of which it correctly assigned nine.

The results of the analysis indicate that cities that built rail transit in the last 20 years already had relatively well used transit systems prior to rail construction. Some cities appear to have strong enough transit systems to support rail investment, as it appears possible that urban areas are both auto-dependent and conducive to transit use. Cities that built rail transit also have busier airports per capita.

The systematic behavior of cities with strong existing transit systems deciding to built rail contradicts conclusions found in Johnston et al. (1988), Pickrell (1992), Black (1993), Edwards and Mackett (1996), Mackett and Edwards (1998) that cities were not acting rationally by investing in rail transit. While this study does not address issues of politics or coercion that occurred in those cases, it does say that cities appear to have added a rail component to an already relatively well-used transit system. This is a reasonable conclusion to draw. Cities that built rail had transit systems that were popular and attractive relative to other contemporary cities. There clearly is a greater measure of comfort and familiarity with transit in these cities, contributing to their higher patronage. We might furthermore deduce that the existing transit quality before rail construction was already relatively high, that service was proliferate and frequent, and that there is a relatively strong voice for transit in these cities. This is in line with conclusions from Hass-Klau and Crampton (2002), which also examined transit patronage and travel behavior in specific per capita measures and found that cities with rail transit feature relatively high levels of transit prioritization and transit service.

While the meaning of the *Enplanements per capita* is not perfectly evident, it may be a surrogate for city vitality and the strength of local economic development initiatives. Rail and image as mentioned earlier are often intertwined, and a city with a large amount of people in it who do not live there will likely be more concerned with its image. Even if the city is a hub – thus explaining the high number of enplanements per person – there must have been some initiative or desire to attract that hub. Such urban development motivation and success likely follows toward rail transit. Though this is not directly related to the actual number of enplanements per capita at a city's airports, this conclusion seems logical given the image perception and the lack of other variables tested in this study to explain otherwise.

Previous research (Hass-Klau and Crampton, 1998, 2002; Hass-Klau et al., 2000, 2003, 2004) has detailed the significant difference between the US and Europe in terms of prioritization of transit and transit-supportive policies. This research further supports previous conclusions about that relationship within cities of the US. According to this research and the model generated, cities considering rail transit investment should analyze the strength and quality of their current public transport systems, as well as how they promote their image in the city. Prioritization of transit, both in public policy and in the physical infrastructure of transport networks, is directly related to successful rail implementation. Cities should also consider the significance and importance of the image they want to portray to potential new residents or businesses and assess their willingness to prioritize transit, in order to assess the viability of a rail investment.

8.1. Future research

While a representative sample, there are still other cities that considered or built rail transit. As mentioned earlier, data was unavailable for cities with older transit systems that preceded the current wave of light-rail construction. There are also a list of cities that have vintage trolleys and people-mover systems that proved too difficult to incorporate into this analysis. Some are historical tourist relics, while others are true transit systems and are even pieces of planned larger rail systems. Inclusion of these cities would provide interesting comparisons and might strengthen the conclusions of this analysis.

Future research might look at solving quantification problems of variables such as inter-jurisdictional cooperation and service operation, and expand upon the economic measures tested here. Future research might also look at the results of rail investment by examining current ridership against pre-rail figures. A comparison should be made between rail ridership improvement and bus ridership change, as should changes in bus service as a result of rail construction. It should be examined whether rail is replacing highly-used bus lines to increase efficiency and decrease long-term operating costs, or if it is being utilized to bring a new transit alternative into an area. Also, many of the newer light rail systems appear to have met or exceeded ridership expectations, and it would be valuable to examine if there has been a ''learning curve'' of estimating ridership and employing successful development policies around rail transit projects in the US.

The insignificance of variables outside of transit patronage and image/economic development also suggests further inquiry. While insignificant at a high confidence level, variables assessing the growth of sprawl in the city, the presence of a major sport or event venue, the amount of driving in the city, business growth in the city, the strength of the central business district, and overall city density were significant at a less strenuous confidence level. The conditions indicated by these variables might have some underlying effect on rail transit construction. Future research should pursue these potential relationships.

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Appendix A. Table 9.1

This table shows the function scores, the values for the three significant variables, and the difference between each city's value and the median. The median for Transit Use was 20.5; the median for *Transit Market Share*, 0.0025 (0.25%); and for Flights per capita, 3.31.

Table 9.1
Score and mean/median comparison of cities

City	Group	Function score	Transit use	Difference from median	Transit proportion	Percent difference from median (%)	Flights per capita	Difference from median
Portland	Rail	7.636	45	25	0.0335	1238.31	1.84	−1.47
Las Vegas	Rail	4.823	42	21	0.0152	507.97	13.95	10.64
Salt Lake City	Rail	4.391	28	8	0.0134	435.94	11.07	7.76
Denver	Rail	3.952	36	15	0.0157	526.39	8.88	5.57
Los Angeles	Rail	3.336	54	33	0.0238	850.62	1.78	−1.53
Sacramento	Rail	2.851	20	0	0.0154	516.02	1.49	−1.82
Minneapolis	Rail	2.600	33	12	0.0130	419.20	6.96	3.65
Houston	Rail	2.591	30	9	0.0130	421.90	5.97	2.66
Charlotte	Rail	2.027	23	2	0.0023	−8.76	15.38	12.07
Dallas	Rail	1.695	15	−5	0.0057	126.09	8.18	4.87
St. Louis	Rail	1.227	23	3	0.0089	254.39	4.81	1.50
San Jose	Rail	0.956	27	6	0.0118	371.93	1.31	−2.00
Orlando[a]	No rail	0.536	18	−2	0.0014	−44.46	10.33	7.02
Nashville	No rail	−0.395	10	−10	0.0007	−73.29	6.09	2.78
Phoenix[a]	Rail	−0.504	14	−6	0.0015	−40.05	5.70	2.39
Albuquerque	No rail	−0.631	14	−7	0.0014	−43.97	5.25	1.94
Cincinnati	No rail	−0.657	19	−1	0.0016	−35.64	6.47	3.16
Kansas city	No rail	−0.917	18	−3	0.0008	−66.29	6.17	2.86
Colorado Springs	No rail	−1.171	6	−14	0.0008	−66.94	2.23	−1.08
Birmingham	No rail	−1.189	4	−16	0.0003	−88.47	2.32	−0.99
Tulsa	No rail	−1.192	4	−17	0.0004	−85.63	2.02	−1.29
Indianapolis	No rail	−1.217	11	−10	0.0008	−69.30	3.31	0.00
Oklahoma City	No rail	−1.433	6	−15	0.0005	−80.17	1.54	−1.77
Spokane	No rail	−1.442	27	6	0.0030	18.04	4.25	0.94
Columbus	No rail	−1.564	18	−2	0.0016	−36.04	3.14	−0.17
Honolulu	No rail	−1.689	103	82	0.0134	434.59	11.13	7.82
El Paso	No rail	−1.723	21	1	0.0025	0.35	2.34	−0.97
Rochester	No rail	−1.760	18	−2	0.0023	−9.12	1.73	−1.58
Tucson	No rail	−1.805	23	2	0.0025	−0.09	2.48	−0.83
Norfolk	No rail	−1.872	13	−8	0.0012	−52.07	1.11	−2.20
Louisville	No rail	−1.973	20	0	0.0016	−36.41	2.38	−0.93
Salem	No rail	−2.198	19	−1	0.0027	6.47	0.00	−3.31
Austin	No rail	−2.378	45	24	0.0041	65.42	4.51	1.20
San Antonio	No rail	−2.641	37	17	0.0034	34.69	2.58	−0.73
Milwaukee	No rail	−3.348	51	30	0.0049	94.70	2.02	−1.29

[a] Misclassified city.

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