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16. Abstract Long community discussions about rail often include whether a city's spatial distribution of housing, employment and other trip generators is conducive to supporting rail transit. A city's decision to construct rail transit is based on an array of variables, some of which may indirectly relate to density. Other variables considered important are number of new riders, operating costs and construction costs. Although density is not a direct variable in the list of criteria, numerous studies show a positive correlation with ridership, confirming density as an explanation for the number of riders a system will attract. For that reason, opponents of new rail systems often raise lack of density as reason not to pursue rail. This research compares density in a few select cities with the accepted transit efficiency performance measure of operating cost per passenger mile to determine whether this statistic is better in more dense cities.			
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Another Look at the Question of Density and Rail Transit

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EXECUTIVE SUMMARY

A city's decision to construct rail transit is generally based on an array of variables, one of which may be related to density. Houston is known as one of the modern southwest cities characterized by sprawled development. The city's decade's long discussion about rail often included whether the city's spatial distribution of housing, employment and other trip generators is conducive to supporting rail transit. Other variables considered important are number of new riders, operating costs and construction costs. Although the question of density is not a direct variable in the list of criteria, numerous studies show a positive correlation with ridership, confirming density as an explanation for the number of riders a system will attract. For that reason, opponents of new rail systems often raise lack of density as reason not to pursue rail. In addition to the foundation provided by previous research, this thinking is supported by US north and east coast very dense cities that have had rail for decades. Therefore, the belief is that density is "required" for success. Houston, Texas exemplifies the type of city typical of this discussion.

Houston, Texas is often referred to as the most studied city relative to rail transit in America. As of the early 2000s, Houston area transit planners had proposed rail a minimum of five times in the preceding 25 years. Twice the public defeated rail recommendations in referenda, including 1974 and 1983 (Thomas and Murray, 1991). In 1991, a challenger to the then, 4-term mayor, campaigned on discontinuing the proposed rail system and reallocating the funds to acquisition of more police. The challenger won and followed through on the campaign promise. Over the life of rail discussions in Houston, the transit authority proposed various routes for rail and recommended heavy rail in 1969 and 1981, monorail in 1991 and light rail in 1988 and 2000. Construction began on a 7.5-mile light rail line in 2001, but still spurred two ballot initiatives in the fall of 2001, even as track was being laid. Houston finally opened its first 7.5 mile light rail line in January 2004; within the 1st year, the rail exceeded 2020 projections of 40,000 weekday passenger boardings. With light rail recently opened in Charlotte, North Carolina and other southern and mid-sized cities considering new lines or extensions, a review of how these systems perform in comparison to the traditional ideas about rail transit is in order.

This assessment examines a standard transit performance measures, operating cost per passenger mile, in the context of density for several rail cities. The findings indicate that density is not an explanation for system performance using that measure.

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Introduction

Houston, Texas is often referred to as the most studied city relative to rail transit in America. As of the early 2000s, Houston area transit planners had proposed rail a minimum of five times in the preceding 25 years. Twice the public defeated rail recommendations in referenda, including 1974 and 1983 (Thomas and Murray, 1991). In 1991, a challenger to the then, 4-term mayor, campaigned on discontinuing the proposed rail system and reallocating the funds to acquisition of more police. The challenger won and followed through on the campaign promise. Over the life of rail discussions in Houston, the transit authority proposed various routes for rail and recommended heavy rail in 1969 and 1981, monorail in 1991 and light rail in 1988 and 2000. Construction began on a 7.5-mile light rail line in 2001, but still spurred two ballot initiatives in the fall of 2001, even as track was being laid. Houston finally opened its first 7.5 mile light rail line in January 2004; within the 1st year, the rail exceeded 2020 projections of 40,000 weekday passenger boardings. In March 2007, there were 21 days with ridership greater than 40,000 passenger boardings (METRO, 2007).

Now Houston is proposing an additional 30 miles of rail with construction beginning in 2010. Over the years, the rail versus no-rail debate often centered on Houston's low to moderate residential density. As new light rail systems and proposals are pursued by cities nationwide, the question of the role of density will continue to arise. This research presents an assessment using the typical transit performance measure of cost per passenger mile.

A city's decision to construct rail transit is generally based on an array of variables, one of which may be related to density. Houston is known as one of the modern southwest cities characterized by sprawled development. The decade's long discussion about rail often included whether the city's spatial distribution of housing, employment and other trip generators is conducive to supporting rail transit. Other variables considered important are number of new riders, operating costs and construction costs. Although the question of density is not a direct variable in the list of criteria, numerous studies show a positive correlation with ridership, confirming density as an explanation for the number of riders a system will attract. For that reason, opponents of new rail systems often raise lack of density as reason not to pursue rail. In addition to the research foundation, this thinking is supported by US north and east coast very dense cities that have had rail for decades. Therefore, the belief is that density is "required" for success. Although written more than a decade ago, many people still believed an assertion from the Charlotte Observer (North Carolina) to be true. It writes, "D is for Density, which is what's required along transit corridors for mass transit to work. Charlotte is, by nature, less dense than many other major metro areas. Without density, planners say, rapid transit won't have the passenger base it needs. Rail advocates argue, 'Build it and they will come' – start rail transit and density will follow" (The Charlotte Observer, March 11, 1998).

In fact, numerous moderate density cities, among them San Diego and Portland, have successful light rail transit and many more cities are in various stages of pursuing this transportation alternative. Houston's experience with the first 7.5 miles of its system also speaks in contrast to this general thinking. As cities consider their options and existing communities consider extensions, do the opponents of rail expansion have a valid point? Should cities of

moderate density not consider rail transit? This paper explores these questions and associated complexities surrounding density when considering rail transit.

Basic Research Objective

Transit's key cost related performance measures are cost per passenger and cost per passenger mile. If density matters, the expectation is that the more dense cities will have better values on these indicators than moderately dense cities. This research will extract one of those performance measures and review it in relation to area wide density for selected cities.

Discussion: The Relationship Between Density and Ridership

The arguments in favor of density as a defining variable for transit use are compelling. For example, Nelson and Nygaard (1995) found that housing density and employment density contribute 93% of the variance in explaining demand for transit. These findings confirmed those of earlier researchers who examined density in combination with other variables, such as distance from stations, distance from central business districts, parking price and parking availability. Other researchers also conducted studies showing density as a correlative with increased transit ridership (Pushkarev and Zapan, 1977; Smith, 1984; Harvey, 1990; Holtzclaw, 1990). That this relationship exists is not surprising, the interesting issue is whether the correlation contributes directly to improved performance measures.

Measuring Rail Transit

It is worthwhile to consider the expectations and goals of rail transit in order to determine whether density is a contributor to rail success. Communities set their own goals and reasons for building rail – air quality, focus on economic or redevelopment potential, progressive image for the community and moving large numbers of patrons efficiently are often cited goals. Outcomes for the first points will vary by city; the latter goal will be assessed using standard transit measures. Even those systems built for quality of life or economic reasons, must demonstrate reasonable levels of ridership.

Components of Ridership

An examination of the components of ridership shows a complex series of interactions between a number variables. In each community, the relative strength of the components may vary and is reflected in the value of coefficients linked with each variable. When projecting ridership, the general practice is for planners to conduct analyses comprised of a four-step process; trip generation (the number of travelers in the region and the locations of their origins and destinations), trip distribution (linking the origins and destinations), mode split (determining whether trips are made by auto, transit non-motorized) and trip assignment (the exact routes and streets taken). An algorithm sequence within the four-step model includes a long list of variables (Dickey, 1983; Meyer and Miller, 1984; Black, 1995). Key among them are the following:

- Magnitude and distribution (location) of population and employment
- Travel time to various locations, with the travel time to work being most important
- Availability and frequency of transit service
- Mode of accessibility to transit (walk or drive access to stop or station)
- Family income
- Household size
- Number of cars in the household
- Cost to drive
- Transit fare
- Parking availability and parking cost at destination

Changes in any one of the variables can influence ridership. For instance, higher parking costs, a shortage of parking spaces or higher gasoline prices, independently or in combination, lead to increased transit ridership. The opposite, lower parking costs, ample parking or relatively low gasoline prices, serves to suppress transit ridership. For some of the variables, it is apparent how they directly relate to density. The larger the population and the more proximate that population is to its employment or other desired destination, the more likely a person to ride transit. Since travel time is important, the more compact the urban area, the shorter the distance to be traversed, the more quickly the destination can be accessed. This is particularly the case if transit operated in its own right-of-way (having an unimpeded path) and is competing against personal vehicles caught in congestion. Also clear is how a short walk attracts patrons; the denser the area, the closer the person is to the station.

Density, or lack thereof, interacts with other variables to influence ridership. Peterson (1984) writes, “The effects of density are interrelated with employment center size, corridor level urban structure, transit service characteristics and a variety of public policies – principally the supply and price of parking” (p. 13). This point is supported by Victoria Transport Institute (2001) that provides a discussion on travel behavior in response to various land use criteria. The discussion includes density and clustering, land use mix, street, parking and building design and pedestrian conditions as among those indicators important in determining travel. The report approaches the travel and ridership issue in terms of reduction of auto use, in contrast to riders attracted to transit, but the results are transferable. The key point is that the variables enact modest changes in travel when viewed individually, but impacts are “cumulative and synergistic” with other transportation demand strategies. Both the Peterson and Victoria Transport Institute reports indicate that an accumulation of factors influence demand for travel. The point being stressed is the importance of the “package” of the built environment, not limited to the issue of density.

Service Delivery

One relevant outgrowth of density and its impact on ridership may not be readily apparent. The availability and frequency of transit service is positively affected by density. The frequency of transit service (eg., a train every 5 minutes, 10 minutes or 15 minutes) is a response to the number of riders; the more people arriving at the station at short intervals, the more service to be provided. Density fosters greater numbers of individuals arriving at intervals so as to encourage more frequent transit service. An interrelated, cyclical effect occurs because more frequent service attracts more riders and then more riders spur more frequent service.

A key point in this discussion is the differentiation between the nature of service delivery between the types of rail transit. This is important because the answer to the density questions may be linked to the type of rail and how it is constructed within an urban area. The distance between stations and where the rail is constructed are examples of decisions that will affect the density answer. The most common types of rail in urban areas are commuter rail, heavy rail (also called rapid rail) and light rail. Commuter rail typically brings suburban commuters to central business districts; it has few stations spaced far apart. With this type of rail, densities are typically very sparse with this commuter rail serving suburban travelers. The low density works because travelers are covering a long distance and basically all riders disembark in the central

business district. As the name implies, commuter service is typically provided one-way to one group of riders. This service is sometimes characterized as *many-to-one* (many origins to one destination).

The remaining three transit types serve *many-to-many* (many origins to many destinations). Heavy rail has more frequent station spacing than commuter rail and travelers may be destined anywhere in the region. Simplistically, light rail is between the high-performance, high investment heavy rail and low-investment buses on-street. Light rail has more frequent stations than heavy rail, but patrons may also be headed in multiple directions. Schumann (1988) further breaks down light rail describing two categories within this technology: Group 1 tends to have more time between trains and the trains are faster. This group of rail systems tends to serve distances farther from central business districts. Dallas' light rail system operates much in the fashion of Group 1. Although its downtown portion is in the local streets, the line services many areas far from downtown along a relatively high speed route, in its own right-of-way (not shared with other vehicles). Group 2 rail operates closer to the central business core and includes trains traveling in the streets. Houston provides an example from Group 2. It should be recognized, though, that many systems exhibit elements of both categories (Vuchic, 1999).

The following description supported by Figure 1 provides an illustration of how service delivery affects ridership and spacing for heavy rail, light rail and bus. This graphic is also designed to show the connection between station spacing, vehicle capacity and density. The scenarios, commuter rail, heavy rail, light rail would be accompanied by varying densities. Commuter rail has different service objectives and thus it is not reflected in the graphic. Using a mile as our example or base unit, each dot on the graphic represents an access point (a bus stop or rail station) for sub, light rail or heavy rail. As shown, the access points for bus are frequent; each regular bus seats 45-50 people. If as few as 8 persons boarded the bus at each stop, when the bus traversed the mile, the vehicle would be full. (For simplicity and illustrative purposes, these examples will presume no one exits the vehicles.)

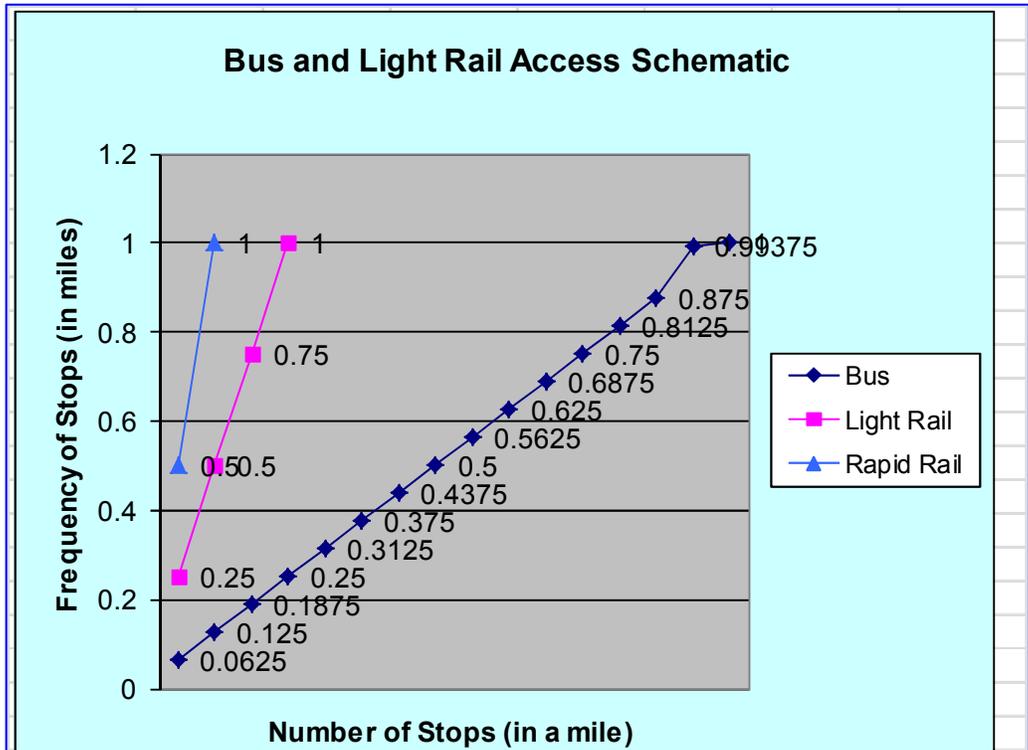


Figure 1. Bus and Rail Access Schematic

(Triangles, Diamonds, and Squares represent bus or rail stop locations)

Bus stops2-3 block intervals (15 stops per mile)

LRT ¼ to ½ mile intervals (4 stops per mile)

RRT ½ to 1 mile intervals (2 stops per mile)

For illustrative purposes only. This graphic is designed to show the fundamental variation between access for bus, light rail and rapid rail. Actual station spacing or bus stops may vary across communities or between stations within a community.

In comparison, the light rail stops are less frequent than bus, but more frequent than heavy rail. A light rail vehicle carries roughly 200 people and between two and six vehicles might be linked to form the train. Thus, the upper end of capacity of 4 stations is roughly 1200 people. Using rule-of-thumb guidelines for light rail stops at ¼ mile, we would need to board 300 people at each location to fill the train. A rapid rail vehicle has capacity for approximately 200 people per car and between two and ten vehicle might be connected to form the train. Again, in filling the train and applying the upper end of the capacity, 2000 people are required to fill the train. Standard station spacing for heavy rail is ½ to one mile, resulting in one or 2 stations in a mile; 1000 people would board at each station in the two station scenario and all 2000 would board at one station if there is only one station within the mile.

The frequent stops of bus service and lesser capacity compared to rail allow it to operate well in low density communities. Light rail, which stops less frequently than bus must amass more people at the available stops. Heavy rail vehicles must collect even more patrons at fewer locations than in the light rail mode. Therefore, the accessibility characteristics portrayed by the station and stop locations in the figure illustrate the density advantage for rail. Density is an advantage because the greater the number of persons proximate to the stations, the more likely

that rail will attract the volume of riders needed to fill the vehicles. Since heavy rail's capacity per vehicle, combined with its train linking provides more capacity than light rail, increasingly higher densities facilitate filling the heavy rail trains. If these volumes can be provided multiple times in an hour, the transit agency can provide more frequent service.

Given the components of ridership, it is clear how density contributes to transit patronage. Density places more persons within a short walk of the station enabling transit agencies to provide more frequent service. With that reality, it makes sense to evaluate how some newer rail systems in moderate density cities perform when viewed using standard transit performance variables.

Comparisons of Densities in Several Rail Cities

The Federal Transit Administration's Annual Report for New Starts (nomenclature for construction of new rail or extension to an existing rail system) show more than 10 funding recommendations for preliminary engineering, final design or full funding agreements. Of these all are medium to large-sized cities with moderate density. There are a few inherent issues in considering density, especially independently, as a predictor of transit ridership. Density figures are subject to a careful understanding of the boundaries in question and an understanding of land use categories such as parks, office parks or undevelopable land that may serve to distort appropriate application of the data. Next, it is important to note that the density of the city or region is not the critical point, rather the density of persons proximate to the rail line are at issue. Also of import, but not explored as part of this research is employment density. Although employment density is known to have a large impact on ridership, the arguments advanced about lack of density generally refer to residential density.

Analysis

Two well regarded variables, total operating expense per unlinked trip and total operating expense per passenger mile are regularly reported by all transit agencies to the US Department of Transportation. The "Operating Expenses per Unlinked Trip" show how much the transit agency spends each time a patron boards a vehicle. The "Operating Expenses per Passenger Mile" add consideration for the length of the trip taken by the passenger. For example, one passenger traveling 10 miles represents 10 passenger miles; likewise 10 passengers traveling one mile represent 10 passenger miles. A small set of cities was identified to assess the operating expenses (costs) per passenger mile (Figure 2). Represented are west coast and east coast cities, some known for their sprawl development and some are characterized as dense. Combinations of light and heavy rail cities are included. Note the figure shows the highest value (\$1.16) for the light rail system in San Francisco, a city characterized as dense. Half of the cities, a mix of high and moderate densities, have values ranging from \$.46 to \$.59 per passenger mile. One moderately dense city, Atlanta, shows the lowest costs per passenger mile at \$.32. San Francisco's heavy rail system has the second lowest value. It might be tempting to argue that the San Francisco light rail system with many short trips will not perform as well as systems attracting longer trips. The counter point is that many short trips have the potential to outperform fewer longer trips. Other cities known for moderate densities, including Houston, Dallas, Sacramento and Denver all show lower cost than San Francisco light rail and two of the moderate city's costs are lower than for Washington, D.C (Atlanta and Denver).

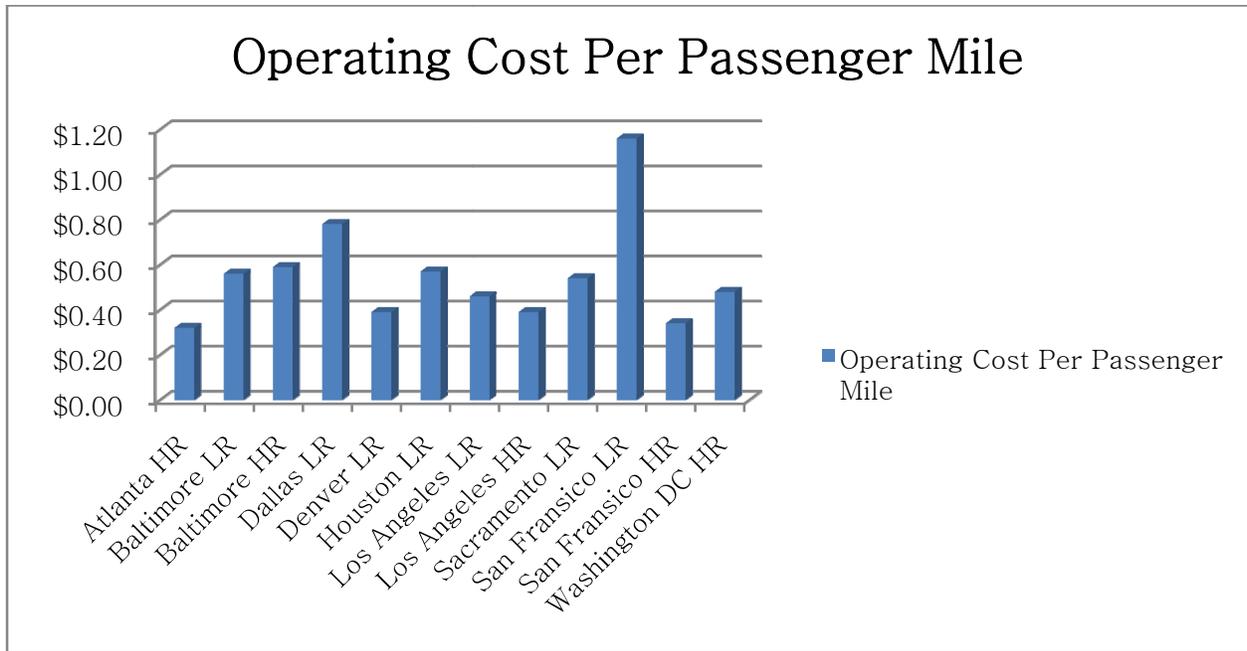


Figure 2. Operating Cost Per Passenger Mile

Figure 3 shows the operating cost per passenger mile in comparison to the density. Visual perspective seems to diminish the criticalness of density with a clustering of cities between \$.40 and \$.60 cents, regardless of density. The most positive outlier is San Francisco's heavy rail with low operating costs per passenger mile and high density.

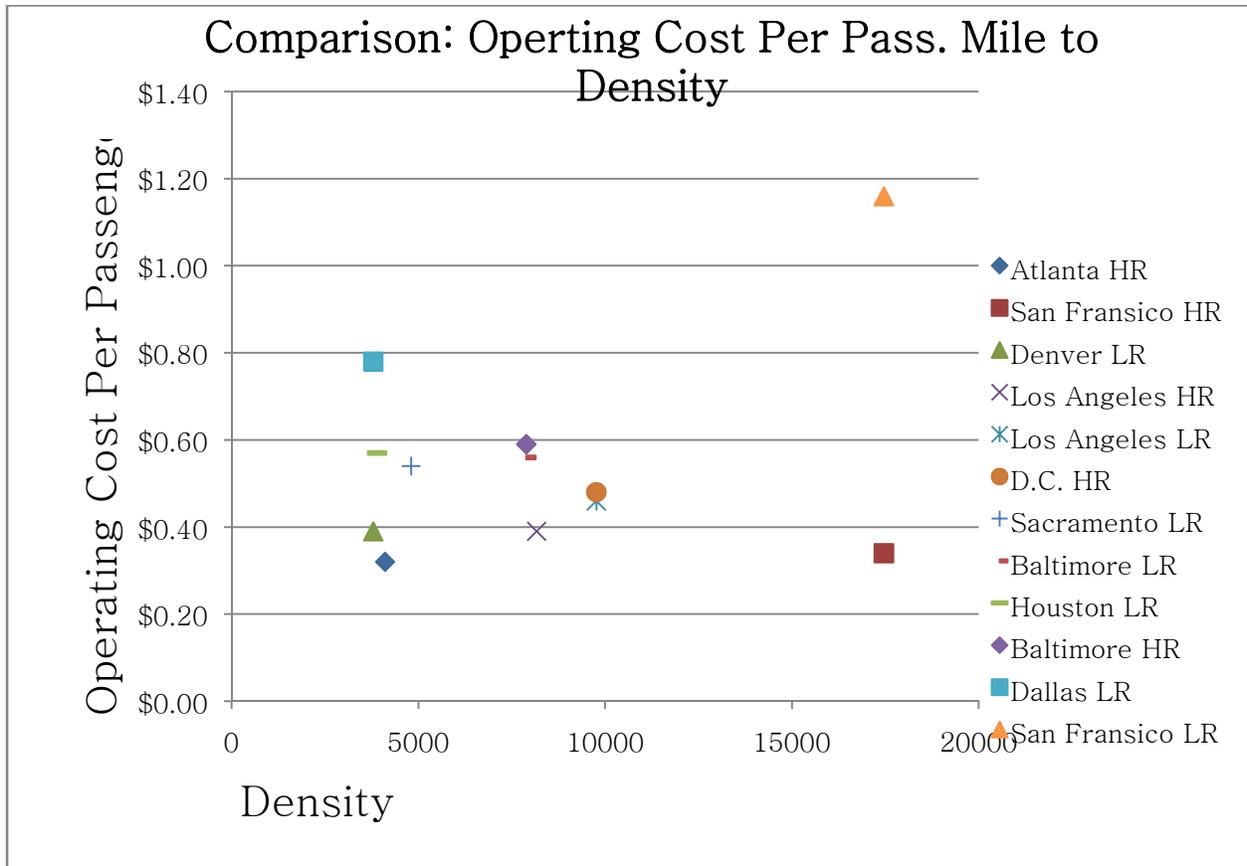


Figure 3. Comparison for Density and Per Mile Costs

To consider these variables another way, the operating costs per passenger mile are divided by the density to yield a value, thus allowing comparison of the value with the density considered. Table 1 shows the relative comparisons – the lower the value the less spent per passenger mile including density consideration. Based on this assessment, the cities with higher density exhibit the best values. The final column shows the rank of the cities by operating costs per passenger mile. To some degree, this density value shows how key indicators, such as the operating costs per passenger mile can be devalued by intense focus on density. For instance, Atlanta exhibits the best operating cost per passenger mile, but is 8th in the list by density value. Other higher density cities are in the top five using the density value, suggesting that higher density can be a positive condition for rail. On the other hand, Denver is 3rd in operating costs per passenger mile and 9th in the density value column. The analysis strengthens the perspective that density alone is not a predictor of successful system performance or rail efficiency.

Table 1. Cities in Rank Order Per Density Value and Operating Costs/Passenger Mile

City/Technology	Density Value⁽⁻⁴⁾	Density	Operating Cost Per Passenger Mile	Rank by Operating Costs/ Passenger Mile
San Francisco, HR	.195	17,462	\$.34	2
Los Angeles, HR	.477	8,169	.39	3
Washington D. C., HR	.492	9,766	.48	5
Los Angeles, LR	.563	8,169	.46	4
San Francisco, LR	.664	17,462	1.16	11
Baltimore, LR	.710	7,888	.56	7
Baltimore, HR	.748	7,888	.59	9
Atlanta, HR	.779	4,106	.32	1
Denver, LR	1.028	3794	.39	3
Sacramento	1.124	4803	.54	6
Houston, LR	1.463	3897	.57	8
Dallas, LR	2.056	3794	\$.78	10

Sources: Operating expenses are from the national transit database (retrieved November 20, 2010) and densities are from city-data.com (retrieved June 23, 2010):

Discussion

The explanation for density values for moderate density cities showing as competitive to those for more dense cities may be due to a cadre of reasons. One is in the way density is viewed. A community's regional density is sometimes presumed to apply to all areas of a city. The application of this practice and the resulting error it belies may be viewed in the context of two US cities synonymous with sprawl. The first is Houston, Texas and second is Los Angeles, California. Without question, Houston is one of the most expansive cities in the country. Many of its areas residents occupy single family homes far from the urban core. Yet, views of key sub-areas within the Houston region show a very different perspective. Houstonians describe their city in terms of concentric rings defined by area freeways. The inner ring, Loop 610, forms the basis of the urban core and is often referred to as "downtown", although it is larger than officially defined central business district. The residential density inside the Loop far exceeds that in the next three rings formed roughly by Beltway 8, FM1960/State Highway 6 and beyond.

Figure 4 displays these concentric rings and the relative development densities of the populations (measured as acres consumed). The inner Loop is more than double the density of

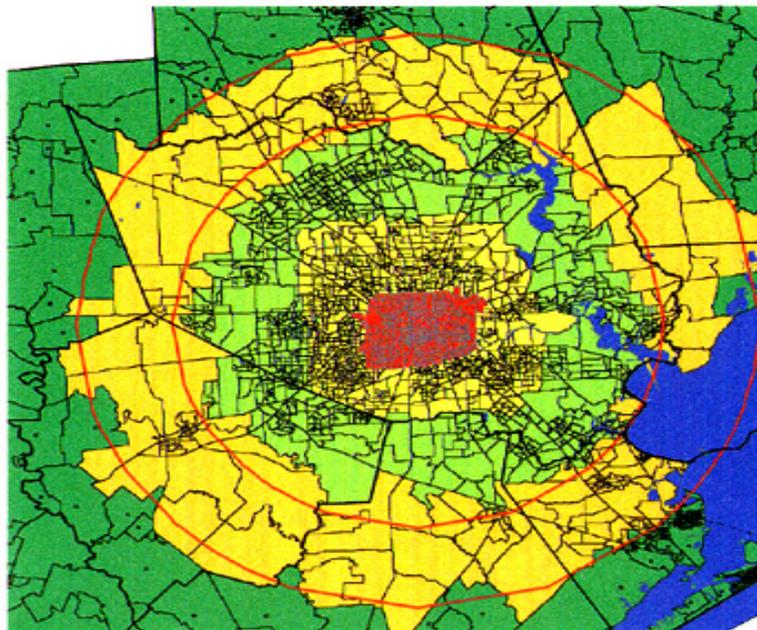


Figure 4. Houston Area Density by Concentric Rings

Density Index (acres consumed)	
Loop 610 (red).....	(.48)
Belt (yellow).....	(.20)
Outer Belt (light green).....	(.16)
Parkway (gold)	(.07)

Source: Houston Galveston Area Council, 2001

the next ring. To apply the same perception of residential density to the area inside Loop 610 as to the densities in the outer rings is clearly misleading.

The case is further supported about the Los Angeles area by the following excerpt from *Demographia*, a publication dedicated to information about demographic issues.

Many urban planners now recognize that sprawling Los Angeles is the most dense urban area in the US. Few, however, are aware of the comparative extent of its density. Los Angeles has the greatest geographical expanse of over 10,000 per square mile density in the developed new world. Compared to “smart growth” Portland, Los Angeles is a virtual Mumbai. At all points except the outer suburbs, Los Angeles is more than 1.5 times as dense as Portland. While some transit planners have claimed that Portland corridor densities are higher than that of Los Angeles, in fact, urban corridor densities in Los Angeles are between two and 3.5 times as great as Portland. Among major urban areas, Portland has among the lowest core densities, with generally lower densities than Phoenix (www.demographia.com, 05/10/01).

Recognize that the quote does not indicate that Los Angeles has the greatest density among cities; rather that it has the greatest amount of land with residential densities exceeding 10,000 persons per square mile. More recently, Eidlin (Fall 2010) writes, “If we measure sprawl by population density, LA would not sprawl at all. In fact, it would be the least sprawling urbanized area in the country” (p. 4). The author’s point is to challenge planners to focus on what is desired to be achieved in calling for more compact urban areas, while recognizing the perceptions compared to the actualities of city densities.

Other Considerations

The moderate density cities showing cost efficient systems according to the operating cost per passenger mile variable likely have a core of employment in their downtown areas that provides a foundation for rail ridership. Time and financial constraints do not allow a solicitation of parking costs in these downtowns, but practice is to price downtown parking so as to discourage driving and encourage transit utilization. Houston, although having one of the lowest density of those displayed, has the largest downtown. Transit agency planners for the Houston light rail envision that the large employee base, as well as a number of recreational and entertainment attractions compensate for the lower residential density.

Other variables to keep in mind are park and ride lots and feeder bus service that allow more disparate residential bases to be aggregated for the line haul (rail) portion of the trips. More dense areas also have feeder bus, but do not provide park and ride lots as frequently.

Summary

This review does not question previous research showing a relationship between density and rail. In fact, that density is beneficial for rail ridership is confirmed. Density allows the transit agency to spend less money to provide the service; the more people who can access the service on foot, the fewer miles the agency must provide in feeder service. A residual benefit is that density actually increases the frequency of service provided. However, this analysis shows there are reasons to question density as a primary determinant of the success of rail transit, particularly for light rail. Several examples of cities across the US that could be characterized as having moderate density are presented here; these cities are operating light rail transit systems competitively using the operating cost per passenger mile variable.

Several premises are at work in these cities as follows:

- The cities may have a strong employment base in the central urban areas, in many cases resulting in “employment density.”
- The lack of residential density may be somewhat offset by ensuring parking spaces and a high level of feeder and connecting bus service.
- Overall city or regional density may be quite unrelated to density in specific subareas or corridors of the city. This means that densities proximate to the rail line may be higher and more important for ridership than reflected in city density statistics.
- Light rail operating at lower densities shows competitive cost-efficiency values when compared with values in higher density cities.

These findings are extremely positive for cities like Houston, known for their sprawl and overall low density development. The key is to appropriately locate the rail facilities carefully and focus on those characteristics that compensate for elements contributed by density in more traditional rail cities.

References

- Black, Alan. (1995). *Urban Mass Transportation Planning*. McGraw-Hill, Inc., New York, San Francisco, Toronto.
- Cannon, Connie. (May 7, 2000). *Survey*. MARTA. Atlanta, GA.
- Demographia*. (May 10, 2001). www.demographia.com.
- Denver Regional Transit District. (May 11, 2001). Home Page, <http://www.rtd-denver.com>
- Dickey, John. (1983). *Metropolitan Transportation Planning*. 2nd Ed. McGraw-Hill, New York.
- Eidlin, Eric (Fall 2010). What Density Doesn't Tell Us About Sprawl. **Access:** Transportation Research at the University of California; Number 37.
- Federal Transit Administration. (May 14, 2001). *Table 30*. www.fta.dot.gov.
- Gibbons, Bob. (May 8, 2001). *Survey*. Minneapolis Metropolitan Transit. Minneapolis, MN.
- Gower, Robert. (May 7, 2001). *Survey*. Niagra Frontier. Buffalo, NY.
- Harvey, G. (1990). *Relation of Residential Density to VMT Per Resident: Oakland*. Metropolitan Transportation Commission.
- Holtzclaw, J. (April 19, 1990). *Explaining Urban Density and Transit Impacts on Auto Use*. Paper presented to the state of California Energy Resource Conversation and Development commission by Natural Resources Defense Council and the Sierra Club.
- Houston Galveston Area Council. (February 2001). Presented at the Conference "Building Choices" Sponsored by the Gulf Coast Institute at the University of Houston. Graphic presented by Max Beauregard and forwarded via e-mail.
- Houston Metropolitan Transit Authority. (May 10, 2001). *Home Page*, <http://www.hou-metro.harris.tx.us>.
- Larson, Karen. (October 10, 2001). *Telephone Interview*, GIS Analyst, METRO Data Resource Center.
- Los Angeles Metropolitan Transit Authority. (May 9, 2001). *Home Page*. <http://www.mta.net>.

- Metropolitan Transit Authority of Harris County by KPMG Pean Marwick. (June 10, 1995). *1990 Houston Long-Range Patronage Forecasting Model Validation*.
- Meyer, M. and Miller, E. (1984). *Urban Transportation Planning*. McGraw-Hill, New York.
- Minneapolis Metropolitan Council. (May 9, 2001). *Home Page*, <http://www.metrocouncil.org>.
- Monestine, Reynold. (May 7, 2001). *Telephone Interview*, Miami-Dade Transit, Miami FL.
- Nelson and Nygaard Consulting Associates. (1995). "Land Use and Transit Demand: The Transit Orientation Index", Chapter 3, *Primary Network Study* (Draft). Portland, OR: Tri-Met
- Nuby, Tim. (May 8, 2001). *Telephone Interview*, DART Dallas TX.
- Peterson, R. (1984) Population Density Considerations For Urban Rail Transit Systems, *ITE Journal*, Volume 54, Issue 4, 3 p.
- Pushkarev and Zapan. (1977). *Public Transportation and Land Use Policy*. Bloomington: Indiana University Press.
- Pushkarev and Zapan. (1982). "Where Transit Works: Urban Densities for Public Transportation." *Urban Transportation: Perspectives and Prospects*. Ed. By H. Levinson and R. Weant, Westport CT, Eno Foundation.
- Sacramento Regiona Transit. (May 10, 2001) *Home Page*, <http://sandbag.com>
- Schumann, J. (1988). "What's New in North American Light Rail Transit Project?", *Light Rail Transit: New System Success at Affordable Prices*. *Transportation Research Board National Research Council, Special Report 221*.
- Smith W. (1984). "Mass Transit for High-Rise, High Density Living" *Journal of Transportation Engineering*, 110, 521-535.
- Thomas, Robert D. and Richard W. Murray. (1991). *ProGrowth Politics Change and Governance in Houston*. IGS Press Institute of Governmental Studies, University Of California at Berkeley.
- Van Ness, Laura. (November 1, 2001). *Telephone Interview* Coordinator, Houston Downtown Management District.
- The Charlotte Observer (posted, March 11, 1998) *A to Z on the Mass Transit Debate*, <http://www.charlotte.com/observer/special/transit/pub/platoz.htm>.

Tri-County Metropolitan Transportation District of Oregon. (May 8, 2001) *Home Page*,
<http://www.census.gov>

US Census Bureau (April 19, 2001) *Home Page*, <http://www.census.gov>.

Vuchic, Vukan R. (1999) *Transportation for Livable Cities*. Center for Urban Policy Research,
Rutgers, The State University of New Jersey.

Victoria Transport Policy Institute (March 10, 2001) “Land Use Impacts on Transport:
How Land Use Patterns Affect Travel Behavior”, *TDM Encyclopedia*,
<http://www.vtppi.org/tdm20.htm>

www.bts.gov, Bureau of Transportation Statistics; also 1-800-853-1351.

www.drog.org/reg-growth/reg-data/socio-forecasts.htm, (October 28, 2001).

Appendix A

History and Data Sources for the Selected Transit Systems

Several cities/metropolitan areas were selected to view the values of operating costs per passenger mile and density. The areas reflect examples from both coasts and the central portion of the country. Both light rail and heavy rail systems are included. Cities perceived as relatively dense are included, Washington, DC and San Francisco, as are moderate density cities (such as Houston, Denver, and Dallas). History and values (Table A1) are below.

Atlanta, Georgia

An ideal system for Atlanta Transportation plan was recognized in the 1950's. A 66-mile five county rail system with a feeder bus operation and a park-and-ride facility was recommended by the Metropolitan Atlanta Transit Study Commission report. Atlanta Transit System was purchased in 1972 for 12.9 million dollars. <http://www.itsmarta.com/marta-past-and-future.aspx>

Baltimore, Maryland

Maryland Transit system has been transforming transportation for 200 years. Maryland Metropolitan Transit Authority was originally known as Baltimore Metropolitan Transit Authority, then the Mass Transit Administration until it was changed to its present name. MTA incorporated light rail system in 1992 and a Metro Subway in 1983. <http://www.mta.maryland.gov/about/transitprofiles/>

Dallas, Texas

Dallas Area Rapid Transit (DART) was created in 1983 with 58 percent of the voters in 14 cities voted in favor for the regional transportation system. In 1984 DART was appointed to inherit the responsibilities of Dallas Transit System. As soon as, DART controlled Dallas Transit System it cut bus fares from 70 to 50 cents and senior fares from 25 to 15 cents. <http://www.dart.org/about/history.asp>

Washington, DC

Washington Metropolitan Area Transit Authority (WMATA) came into existence in 1967 on February 20. March 1, 1968 (WMATA) adopted a 97.2 mile regional system. Furthermore, the 97.2 mile regional system included 38.4 miles of District of Columbia, 29.7 in Maryland, and 29.1 in Virginia. On February 6, 1978 the red line extended in routes to Silver Spring, which in return added four new stations. http://www.wmata.com/about_metro/docs/history.pdf

Denver, Colorado

In 1969 Colorado General Assembly developed the Regional Transportation District. By the end of 1972 a plan was comprised to create a 98-mile network of Personal Rapid Transit System, which included a reliable bus system. In the year of 1973 Colorado citizens voted for a utilization plan to finance a regional public transportation system. <http://www.rtd-denver.com/Archive/History/index.html>

Los Angeles, California

Los Angeles public transit has been serving the Los Angeles community since 1973. Some of the past components of the transit system included horse cars, cable cars, incline railways, steam trains, electric streetcars, inter-urban cars, trolley buses, and gas powered buses. One of the key figures in the transportation system was David B. Waldron who formed the main street railroad company in Los Angeles, California. <http://www.metro.net/about/>

Sacramento, California

Sacramento Regional Transit began its operations on April 1, 1973. That very same year 103 buses were purchased by the regional transit system. An 18.3-mile light rail system was opened in 1987, connecting the northeastern and eastern sections with downtown Sacramento. <http://www.sacrt.com/rthistory.stm>

San Francisco, California

San Francisco Muni known globally as Muni, is the oldest transit organization in the world. Municipal Railway originated in 1912 and is the largest transit system in the Bay Area and the seventh largest transit organization in the U.S. On average the transit system serves more than 200 million customers a year. <http://www.sfmta.com/cms/ahome/indxabmu.htm>

Miami, Florida

Miami-Dade transit is known as the 14th largest public transit organization in the United States. There are four sectors of the transit system which includes the Metro bus fleet, Metrorail, Metro mover, and a Special Transportation Service (STS). Presently, Miami-Dade transit operates over 326,000 boarding's daily. http://www.miamidade.gov/transit/about_facts.asp

Operating expenses per passenger mile as follows:

Atlanta-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/4022.pdf

Baltimore-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/3034.pdf

Dallas-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/6056.pdf

Denver-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/8006.pdf

Houston-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/6008.pdf

Los Angeles-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/9154.pdf

Sacramento-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/9019.pdf

San Francisco-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/9015.pdf

Washington D.C.-

http://www.ntdprogram.gov/ntdprogram/pubs/profiles/2009/agency_profiles/3030.pdf

Density as follows:

Atlanta-

<http://www.city-data.com/city/Atlanta-Georgia.html>

Baltimore-

<http://www.city-data.com/city/Baltimore-Maryland.html>

Dallas-

<http://www.city-data.com/city/Dallas-Texas.html>

Denver-

<http://www.city-data.com/city/Denver-Colorado.html>

Houston-

<http://www.city-data.com/city/Houston-Texas.html>

Los Angeles-

<http://www.city-data.com/city/Los-Angeles-California.html>

Sacramento-

<http://www.city-data.com/city/Sacramento-California.html>

San Francisco-

<http://www.city-data.com/city/San-Francisco-California.html>

Washington D.C.-

<http://www.city-data.com/city/Washington-District-of-Columbia.html>

Notes:

- (1) The Transit Performance Indicators are compiled according to guidelines and specifications established by the Federal Transit Administration (FTA). They are a component of the National Transit Database (NTD) and represent the best source for facilitating comparisons across transit systems. All transit authorities that receive federal money must submit the report as scheduled and according to the parameters set by FTA. The operating costs include labor and fringe, materials and supplies (fuels, lubricants, tires), depreciation and leases and other items. The methodology provides the basis for comparison of individual system decisions.

- (2) The algorithm for one transit authority (Metropolitan Transit Authority of Harris County – METRO) that predicts rail ridership, includes a density consideration (residents per acre) as a part of the variable that determines the number of people who will walk from home to the station or bus. This variable is the “Mode of Accessibility” variable listed on page 6 of their manual. A nested logit model is employed by METRO is based on nationwide experience of other transportation systems and is calibrated including model inputs that tailor the coefficients to Houston specific circumstances. This highest value coefficient in the model equation is the “CBD indicator” at .81, which measures downtown employment. The next highest values are associated with the Nesting Coefficients for Auto and Transit, which include characteristics such as travel time and price of travel. There is a residential density equation term that has a value of .14