Estimate the Change of Mode Share by a Transit Project: A Case Study on the Houston METRORail Line

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Abstract

Public transit provides important services for urban commuters and transit dependent population. A key objective of most public transit projects is to increase regional transit ridership and mode share. Traditional survey has been widely used by a transit project to estimate the change of ridership. In a large metropolitan area with multiple public transit modes, it is costly and difficult to conduct survey on each transit and non-transit mode to evaluate impacts of a public transit project. A GIS-based simulation model offers a low cost way to estimate the mode share of different trips. This model utilized GIS Network Analyst functions to reconstruct travel costs for different modes impacted by facilities or services of a new transit project. A "Winner-takes-all" mechanism was applied to assign trips to optimal mode under different traffic conditions. Mode share was calculated based on the estimated trips in impacted areas.

1. Introduction

The impact of light rail service on transit access as well as residential location, employment density, and property values have been examined for a number of U.S. metropolitan areas. Green and James (1993) found significant difference of changes on employment levels between station and non-station areas of Washington, D.C.'s METRO transit system. Landis and Loutzenheiser (1995) obtained little evidence to show the benefits of light rail system on commercial properties in the service areas of San Francisco's BART system. Bollinger and Ihlanfeldt (1997) estimated the effects of rail transit on population and employment in rail station areas of Atlanta's MARTA and concluded that light rail has insignificant impact on either population or employment in the station areas of MARTA. Cervero and Landis (1997) analyzed the impacts of the Bay Area Rapid Transit System (BART) on urban development land use patterns and found that the developmental effects of light rail on shaping regional growth in the San Francisco bay Area were fairly modest.

Because a majority of previous studies found no significant effects of light rail systems on population and employment in light rail corridor or station areas, it is reasonable to assume that population and employment has not been redistributed after the open of a new light rail line, especially in a short period of time. Our study focuses on the change of transit access by a light rail. It is usually difficult to quantify the level of effects of light rail on transit service at different traffic conditions. GIS has been employed to study accessibility of urban transportation system in many empirical studies (Miller 1991; Arentze, Borgers, and Timmermans 1994; Geertman and Eck 1995; Kwan 1998; Miller 1999; Kwan 2000; Couclelis and Getis 2000; O'sullivan, Morrison and Shearer 2000; Liu and Zhu 2004). However, few of these studies had specific discussion on measuring the access to transit network, especially to a light rail transit line.

This paper began with a GIS-based simulation model that incorporates a light rail transit line into an existing transportation network. It rebuilds origin-destination matrix for work trips starting or ending in the light rail station areas in selected modes. Then, the newly opened METRORail transit line at Houston is selected for an empirical study to explore the change of model share in the light rail corridor area. It introduced available data for the population, employment, and mode share of work trips in the neighboring areas of the light rail line. Multiple scenarios were set up for auto work trips in different traffic conditions. Mode share of internal trips in station areas was estimated for each scenario. Finally, it draw conclusion and made discussion on further research.

2. Methodology

Different from the traditional survey that examines the change of ridership by a transit project, a GIS-based simulation model was developed in this study to estimate the change of transit access after the open of a light rail line. Four modes were included in the simulation model, i.e. auto, bus, rail, and walk. Auto comprises drove-alone and carpool trips. Bus is a combination of bus and street car trips. Rail is designated for light rail trips. Walk symbolizes both walk and bicycling trips. These four modes were carefully selected to represent available travel means in three reasons. First, they simplify model structure and reduced modeling efforts. Second, they cover major modes of personal travels. Third, each of them represents a unique travel mean and it may consist of one or more modes in the real world that share the same base network and have common travel characteristics.

Personal trips in a travel mode take a fixed route designated for that mode. Bus has its own routes and stops, which are different from a light rail line and its stations. Both auto trips and walking trips use generic road network. In this study, the base network includes rail line, bus route, street, and highway.

In general, sophisticated multimodal personal travel was not a major concern in this simulation model. But walk time, an out-of-vehicle performance measure for transit trips, was included in the model. All bus or rail trips have to start or end with walking trips through a centroid connector, which allows all transit users in a TAZ to access transit network. Therefore, each transit route from origin to destination was separated into three parts: centroid connector with starting walk-access, network route, and centroid connector with ending walk-access. Because data for centroid connector was unavailable, it was replaced by a line connecting the centroid of a TAZ to the nearest network node.

In addition to walk time, wait time and transfer time are also usually considered as out-of-vehicle performance factors. However, they were not explicitly incorporated into this simulation model for two reasons. First, the data on wait time and transfer time for a new light rail line are usually unavailable and the data for bus routes is not updated in a short period of time after the open of the light rail line. Second, it is plausible to add wait time and transfer time implicitly into the average running time of the transit carriers and use an overall running time for modeling purpose. Therefore, we can use the average travel speed for each mode.

Unlike light rail, bus, and walk trips with fixed speeds, auto trips may have several alternative travel speeds, which represent vehicle speeds in free flow and at different congestion levels of road network. Multiple scenarios were constructed to simulate mode share at different traffic conditions in station areas.

Based on the above simplification, a simulation model for mode choice was formulated as follows:

$$m_{o,d} = Min_m(WalkToNet_o + Min_p(Net_m(o,d,p)) + WalkToZone_d) \qquad (1)$$

where, $m_{o,d}$ is the optimum mode for trips from zone o to zone d,

$WalkToNet_o$ is the walk time from the centroid of zone o to nearest network node,

$Net_m(o,d,p)$ is the travel time for mode m taking the shortest path p for zonal pair o-d,

$WalkToZone_d$ is the walk time for trips to zone d from nearest network node.

A significant step before the implementation of formula (1) was to rebuild origin-destination matrix of travel time for multiple modes. For a single mode, travel time of the shortest network path for each zonal pair was calculated and stored in a corresponding cell in an origin-destination matrix. Network analyst functions in GIS will be implemented and some utility functions will be developed to find the shortest network path between two zones and to calculate the optimal travel time using the pre-set travel speed by mode.

After the origin-destination matrix of travel time for multiple modes was created, the simulation model in formula (1) was used to find the optimal mode for each trip flow between zonal pair o and d. This optimal mode had minimal travel time, which includes walk time on centroid connector from the centroid of zone o to the network designated for the mode, minimum network travel time by mode m between the network nodes near to zone o and zone d, and walk time traveling centroid connector of zone d.

A "Winner-takes-all" mechanism was applied to assign trips to the optimal mode under different traffic conditions. Mode share was calculated based on the estimated trips in light rail corridor areas.

3. Empirical Study

The simulation model was implemented to study the change of model share in the corridor area of the newly opened METRORail transit line at Houston.

3.1. Study Area

The Houston Metro's Main Street Light Rail Transit (LRT) Line, running 7.5 miles from Downtown Houston to South Fannin Park and Ride Lot, opened January 1, 2004. It has 16 stations, providing frequent services for riders to access local employment centers such as Downtown and Texas Medical Centers. Each train has 72 seats, spaces for standing, and spots for wheelchairs, which comes up with a capacity of 200 riders. Two trains are usually hooked together to provide a total capacity of 400 passengers per trip.

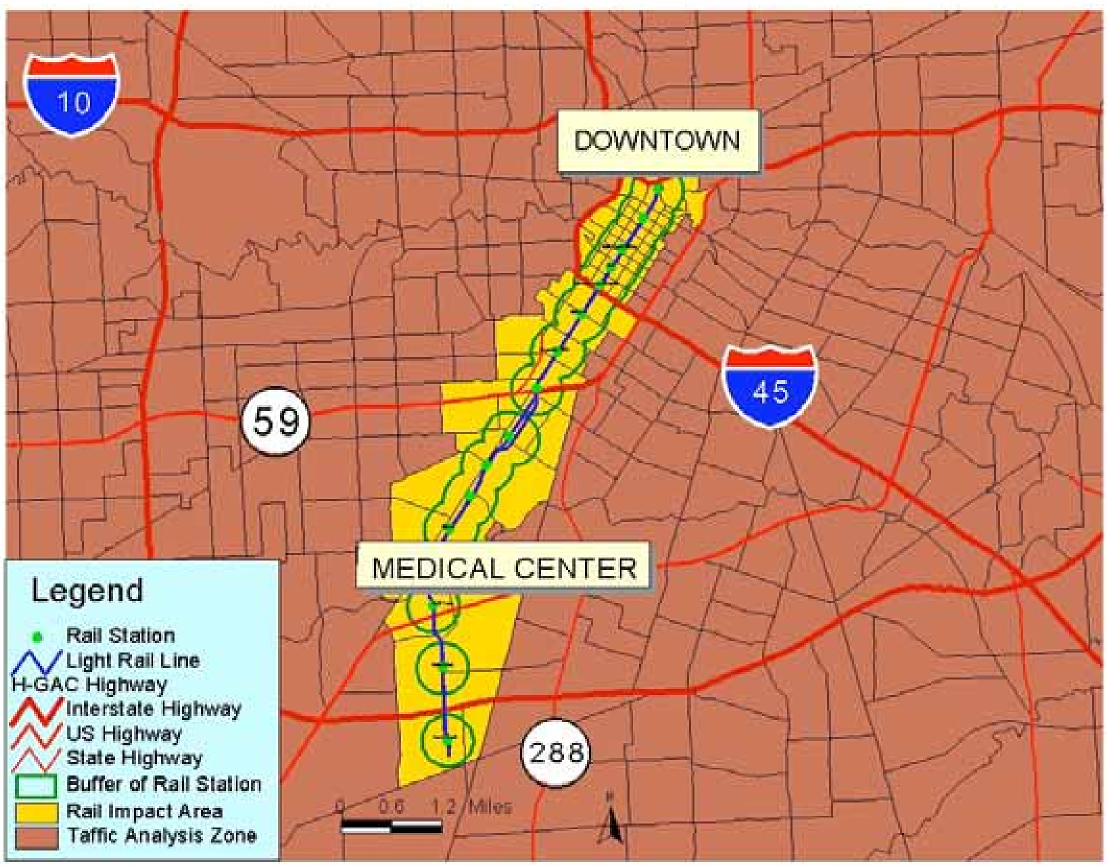

Figure 1. Study area of the Houston METRORail line

This paper defined the study area as the traffic analysis zones (TAZs) intersecting with the 0.3 mile radius of the METRORail stations (Figure 1). The 0.3 mile radius falls into the range of a quarter- to half-mile distance that has been usually used to determine the study area or impact area of light rail lines and it is also the minimum Euclidean distance intersecting with most major TAZs at Downtown Houston. GIS was employed to trace distance and determine the impact areas. The 0.3 mile radius from each rail station was created as a ring of buffer zone drawn around the station. There were 85 census TAZs located in station area in 1990 and 2000.

3.2. Data

The 2000 Census Transportation Planning Package (CTPP) included population and employment by residence area and by work place in its Part 1 and Part 2 data. It also provided number of trips and average travel time by mode by zonal pair in its part 3 OD matrix. However, light rail information was not available at the time Census conducted survey in 2000.

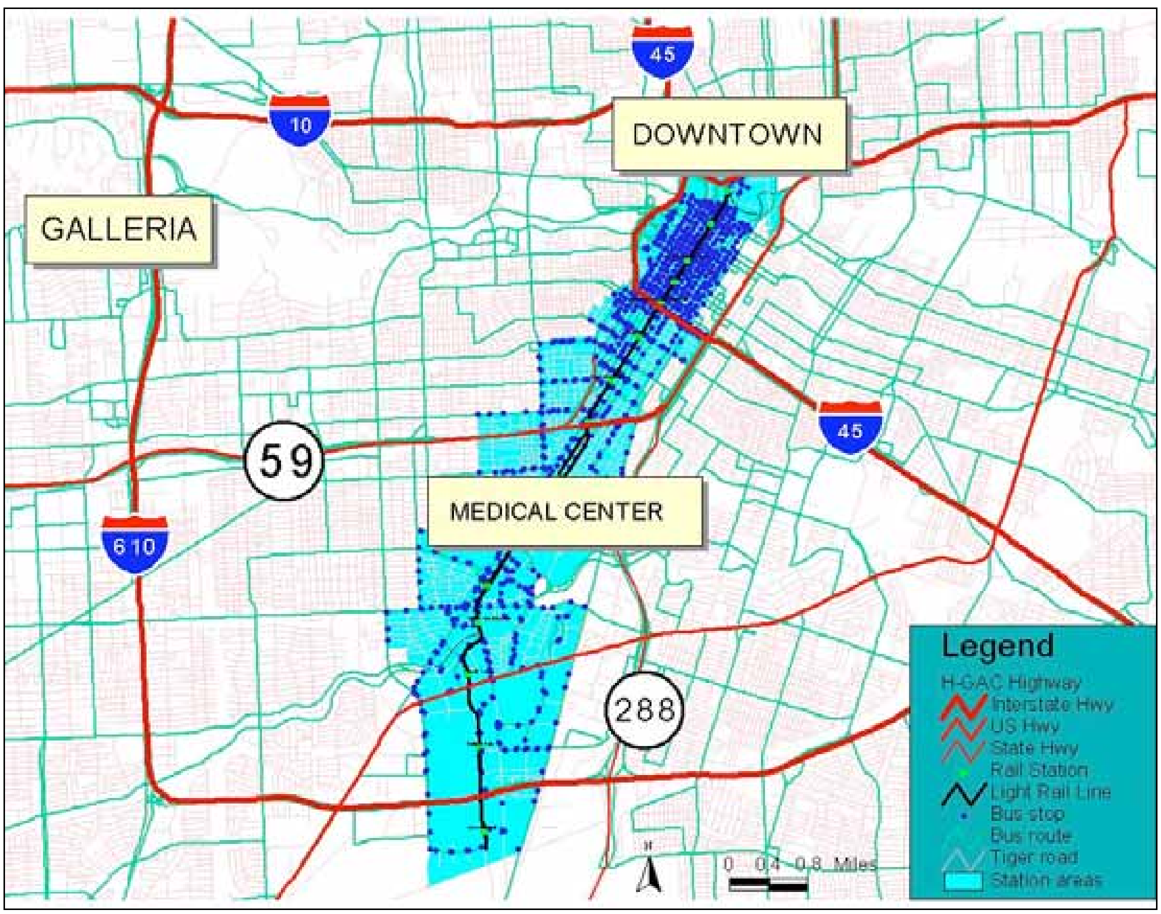

Figure 2. Base network for simulation model

In the previous discussion, base network includes rail line, bus route, and generic road network. Route and station data for bus and light rail were obtained from local transit authority, i.e. Metropolitan Transit Authority (METRO) of Harris County. Road network was built on Census Tiger maps, which were downloaded from Geography Network. The base network for the simulation model was shown in Figure 2.

In addition to the base network, it is also critical to determine the average speed for each mode. Though light rail train can travel over 60 mph on test runs, the average speed of light rail including stops is less than 20 mph. Based on survey results and local knowledge, average speed of personal trips taking light rail was set as 18 mph in the simulation model, which includes wait time, run time, stop time, and transfer time, etc. taken by riders on light rail line. It costs about 25 minutes to complete a one way trip on the 7.5 mile rail line from downtown Houston to Fannin South. Similarly, average speed of bus travel time was set as 10 mph on the base of secondary sources and local knowledge.

Same as auto trips, walking trips used Census Tiger Street as base network due to data availability. Average walking speed was set to be 5 mph in the simulation model, which is between regular walk speed and bicycling because walk mode in this study is a conceptual mode representing both walk and bicycle in real world.

Different from the fixed speeds for light rail, bus, and walk trips, auto trips had three alternative travel speeds, 20 mph, 15 mph, and 10 mph, which represent vehicle speeds in low congestion, medium congestion, and heavy congestion traffic on local streets. Four different scenarios were constructed in this study to simulate different traffic condition in station areas.

3.3. Results

Four 85 by 85 O-D matrix were constructed to store the optimal network travel time between two zones within 85-TAZ station areas for the four selected personal travel modes.

The 2000 travel time and mode share in station areas were extracted and calculated using CTPP 2000 data. Table 1 reported that Auto is the dominant mode with about 74 percent of mode share and average travel time is 13.2 minutes while bus is the second largest mode sharing about 15 percent of trips and its average travel time is about 21.9 minutes in 2000.

The results of mode share for internal trips in station areas in multiple scenarios were also summarized in Table 1. It showed that auto is the dominant mode with speed above 10 mph. Auto accounted for 100 percent of personal trips when auto speed was 20 mph. When auto speed was reduced to 15 mph, rail and bus gained a small percent of trips. Light rail attracted 1.93 percent and bus gained 1.13 percent of total trips in station areas.

When auto speed was reduced to 10 mph, auto mode share was dramatically reduced to 58.33 percent. Light rail became a major mode with 33.14 percent of trips. Bus also gained a large portion of personal trips, i.e. 8.33 percent. Walk trips were still zero because they follow the same route as auto trips and their speed is less than auto. The mode share of walk would not be zero in this model if parking, gas, and vehicle maintenance costs are considered in auto travel cost. However, it is not the major concern of this simulation model.

Table 1. Mode share for internal trips in station areas in different scenarios

Mode	2000 Travel time (Min)	2000 Mode share (%)	Auto-speed 20 mph			Auto-speed 15 mph			Auto-speed 10 mph		
			# of od pairs	Estimated Trips	Mode share (%)	# of od pairs	Estimated Trips	Mode share (%)	# of od pairs	Estimated Trips	Mode share (%)
Auto	13.2	73.97%	7132	8,304	100%	6638	8,050	96.94%	3030	4,860	58.53%
Rail	--	--	4	0	0%	478	160	1.93%	3256	2,752	33.14%
Bus	21.9	15.67%	4	0	0%	24	94	1.13%	854	692	8.33%
Walk	--	0%	0	0	0%	0	0.00%	0.00%	0	0	0.00%
Sum	14.6	89.64%*[1]	7140	8,304	100%	7140	8,304	100%	7140	8,304	100%

Note: Motorcycle and others accounted for 11.69% personal trips in the station areas (CTPP 2000, Part 3 table), which are excluded from this table.
Source: Author calculation using the simulation model.

4. Conclusion

Simulation results showed that a large portion of personal trips in the station areas will be carried by public transit if auto speed is reduced to 10 mph in heavy congestion condition and the mode share of public transit is over 41 percent, 33.14 percent by light rail and 8.33 percent by bus, which is consistent with mode share reported by CTPP 1990 and 2000.

It is too early to analyze the impact of the Houston light rail on regional population and employment now. In our further research, the impacts of the Houston light rail on population, employment, and property values in the corridor areas will be examined. Similar to the planning agencies in Atlanta and other metropolitan areas, local planning agencies in Houston have expected the light rail system to accelerate urban development and strengthen employment centers along the rail line but they has made no effective policy to promote economic development in station areas. In comparison with metropolitan areas of the East Coast and the West Coast, the development of Metropolitan Houston is more similar to the low-density sprawl of the West Coast's Los

Angeles than the compact knot clusters in the East Coast's New York. Therefore, we expect that market forces, such as the increase of accessibility, will play dominant role in inducing possible mode change and encouraging economic development in light rail corridor.

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