Comparative Spatial Analysis of Feeder Bus Networks in the San Francisco Bay Area and Hong Kong Metropolitan Areas

Hayden Wong

ABSTRACT

Since the realization among Bay Area transportation policymakers that private automobiles cannot solve our transportation problems, there has been multiple attempts to duplicate the success of Hong Kong's public transportation system, the world's most renowned system for level of ridership. Previous studies suggest that travel time, number of transfers, and governmental influences are some of the major factors that determine the success of a public transportation system. The specific factor I proposed to compare between the San Francisco Bay Area and Hong Kong metropolitan areas is the linkage of a mass-transit railway system with its respective feeder bus network. I collected data from end-of-line stations and compared, through ArcGIS spatial analysis, the coverage of the service provided by the feeder bus networks. Based on percent map coverage, I found that the feeder bus network in Hong Kong provides services to a greater proportion of local residents than the networks in the San Francisco Bay Area do. These results support my hypothesis that a railway system as successful as Hong Kong's Mass Transit Railway (MTR) must be supported by a feeder bus network that provides better service coverage than another one otherwise would. Privatized ownership of transportation services and decentralization of bus services in Hong Kong are the two major differences that influence their transportation system. In addition, the difference in level of access between high-income and low-income districts exists to a lesser extent in Hong Kong. The results of this and previous studies should encourage city and regional planners of the SF Bay Area to implement transportation policy changes to expand feeder bus networks, especially in light of elevated gas prices and two California energy policies - Sustainable Communities and Climate Protection Act of 2008 (SB 375) and Global Warming Solutions Act of 2006 (AB 32).

KEYWORDS

public transportation, BART, MTR, high & low-income, feeder bus access

INTRODUCTION

Since the end of World War II, the primary goal among transportation policymakers was to accommodate future transportation demands rather than to regulate traffic control (McDermott, 1978). In the city of Los Angeles, for example, transportation policymakers continued with highway construction until they reached their limits on transportation budgets and finally realized "we cannot build our way out of our problems" (Wachs, 1989). Outside of Los Angeles, traffic congestion has also been a long unresolved issue to city and regional planners in most urban areas of the United States (Cervero & Gorham, 1995). During periods of rush hour, cars on the Bay Bridge in the San Francisco Bay Area are almost at a standstill (Cervero and Landis, 1997). Attempted measures, such as increasing bridge toll and encouraging commuters to car-pool, have failed to adequately curb traffic congestion (Kawabata & Shen, 2006). Alternatively, the city of Hong Kong has a very effective network of public transportation that provides for 90% of all passenger transport, the primary mode being its mass-transit railway system, the Mass Transit Railway (MTR) (Wong, 2003). The San Francisco Bay Area has a similar, though much less successful, mass-transit rail system, the Bay Area Rapid Transit (BART).

BART was the San Francisco Bay Area's answer to solving the problem of traffic congestion. However, even after almost 40 years since its inception in 1973, its level of ridership is substantially lower than that of Hong Kong's MTR (Bay Area Rapid Transit, 2010; Mass Transit Railway, 2010). BART, a 167 km long railway, provides service to nearly 4 million people and the MTR, a 175 km long railway, provides service to 7 million people (USDT, 2010; Mass Transit Railway, 2010). Out of the population to which train service is provided for, only 80 in 1000 people in the SF Bay Area take the BART, whereas, over 500 in 1000 people in Hong Kong take the MTR. Variance in population density alone cannot be responsible for this large difference in numbers of ridership. Another factor one might suggest is the difference in available asset to afford the costs associated with purchasing and maintaining a private automobile. Though variation in GDP between residents in Hong Kong and the San Francisco Bay Area does exist, the fact still remains that few people in Hong Kong find it necessary, or even convenient, to own an automobile (Wong, 2003). As demonstrated by MTR's services, it is possible for a light-railway to become the preferred mode of transport for commuters of all economic status. Indeed the MTR operates more trains and consequently shortens the waiting times for their trains, but they are only able to maintain the upkeep cost due to high patronage (Lam, Cheung, & Lam, 1999). The issue at hand is much greater than simply increasing the cost of owning cars or altering the services provided by BART to replicate that of MTR's. Increasing Bart's level of ridership and effectiveness as a mass-transit railway system will require network-wide changes to the SF Bay Area's transportation network.

There have been multiple research studies undertaken that speculate, and develop theories, and hypotheses as to which characteristics of a successful mass-transit rail system are most important. Currie and Wallis (2008) claim reducing travel time is one of the most effective measures. Wener, Evans, Phillips, and Nadler (2003) found that decreasing the number of transfers passengers must make reduces their stress levels and increases their likelihood to continue using public transit to commute. Tang and Lo (2008) recognized that government transport policies are very influential in shaping the structure of a transportation network and in determining the usage of public transit. Results of these studies suggest how well a light-railway is linked to other modes of transportation is an important concern among many commuters. As of today, there is no research focused on how a transportation network with short travel times and minimal numbers of transfers should be shaped to increase ridership of a mass-transit railway. A case study with a comparative analysis focused on differences between BART and MTR could help enlighten the essential elements of a successful transportation network. What differences about the San Francisco Bay Area's and Hong Kong's network of public transportation has allowed the latter to become so much more successful?

The specific factor I investigated in this study, one that influences travel time and number of transfers, is the linkage of a mass transit railway system with the other common mode of public transport, busing. Is the network of bus routes that feeds the mass transit railway system in Hong Kong much more convenient and efficient than in SF Bay Area and if so, how? What proportion of residents living in the outskirts of a mass-transit railway system, or around the end-of-line stations, have convenient and direct bus routes taking them to a train station? I hypothesized that a railway system as successful as MTR must be supported by a feeder bus network that provides better service coverage than BART's feeder bus network.

METHODS

Study Sites

I decided to collect my data on feeder bus lines only from stations that were at or near the end of a rail line, also known as end-of-line stations, in order to focus on commuters whose residences are in the suburbs. For my project, I assumed that commuters travel to jobs located in commercial/financial districts and not in suburban areas where many residents live. Rail lines of both the MTR system and BART system follow a pattern such that they come together in urban areas and extend out to suburban areas. The purpose of this is to provide an alternative to driving for residents in the suburban areas to commute to work. If BART is to increase patronage and have more commuters use its services, it should focus on improving stations that are at the end of a rail where nearby residents are more likely to driving long distances. Thus, I selected only the last 3 stations of every rail line in both systems as my study sites to gather data on feeder bus lines.

Data collection

I travelled to each end-of-line station I selected as my study sites in the San Francisco Bay Area and in Hong Kong and noted every bus company that provides services nearby the station. From the list of bus companies, I acquired the system maps of all the bus routes and marked all the bus lines that have at least one bus stop within a ¼ mile radius of my study station. These bus lines were designated as feeder bus lines. I limited the inclusion of bus stops that are ¼ mile away from a train station because a study on designing walkable cities found that people today are willing to walk only a ¼ mile in their commute (Southworth, 2005). A sample map of identifying the feeder bus lines can be seen below (Figure 1). After identifying the feeder bus lines, I traced the bus routes and located all the satellite bus stops. These bus stops represent all the bus stops where local residents can board a bus that will take them directly to a train station. A sample map locating the satellite bus stops can be seen below (Figure 2). I limited the inclusion of these bus stops to those around a 1 mile away of my study sites, as going beyond the boundary of 1 mile will extend into the boundary of another study site. Finally, I collected publicly available census data available online for districts and cities that my study stations are located in (United States Census Bureau, 2010; Central Intelligence Agency, 2010).

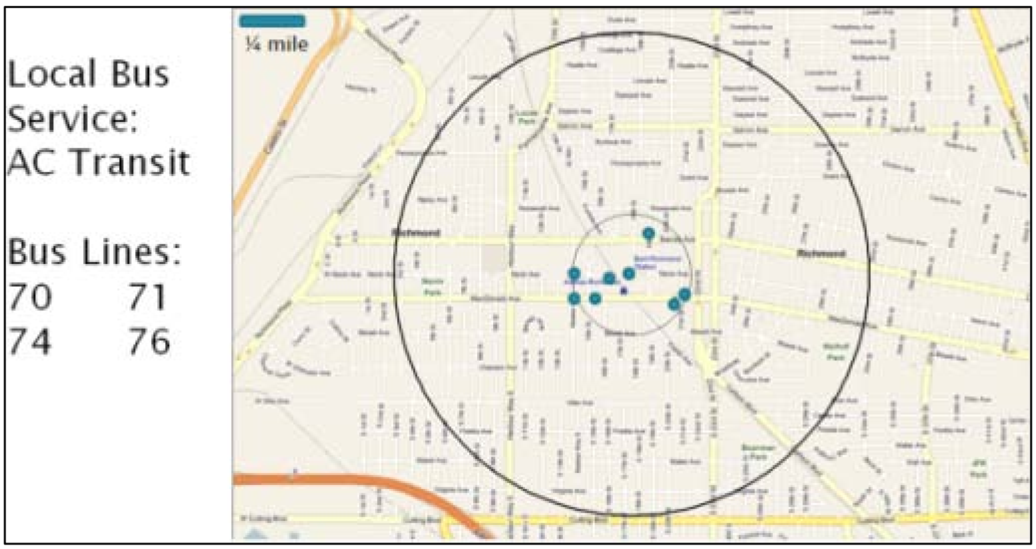

Figure 1: A sample map locating bus stops within a ¼ mile radius of a train station.

Figure 2: A sample map locating the satellite bus stops of the feeder bus lines.

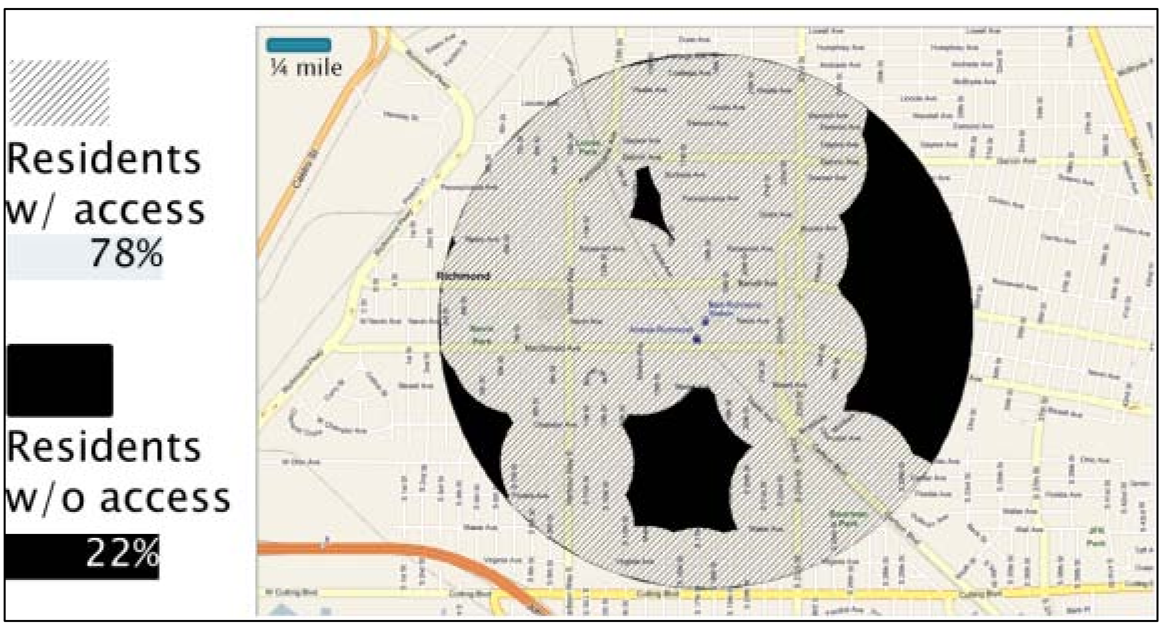

Figure 3: A sample of the spatial analysis map created in ArcGIS.

Data analysis

I compared data from the feeder bus networks in the SF Bay Area to data on the feeder bus networks in Hong Kong in order to tease out what Hong Kong has done to promote the use of municipal transit that the SF Bay Area is not. I then compared train stations located in high-income districts to train station located in low-income districts. This helped reveal a possible trend in how city and regional planners of areas with different economic status manage the municipal services of their residents. For my GIS spatial analysis of service coverage, I used ArcGIS10 to place a ¼ mile buffer around each satellite bus stop of every feeder bus line. The reasoning for using ¼ mile is the same as discussed before. The marked areas within these buffer zones represent residential areas where residents inside have direct access to a feeder bus line. Using ArcGIS, I conducted a spatial analysis to calculate the proportion of residents with access and without access (Figure 3).

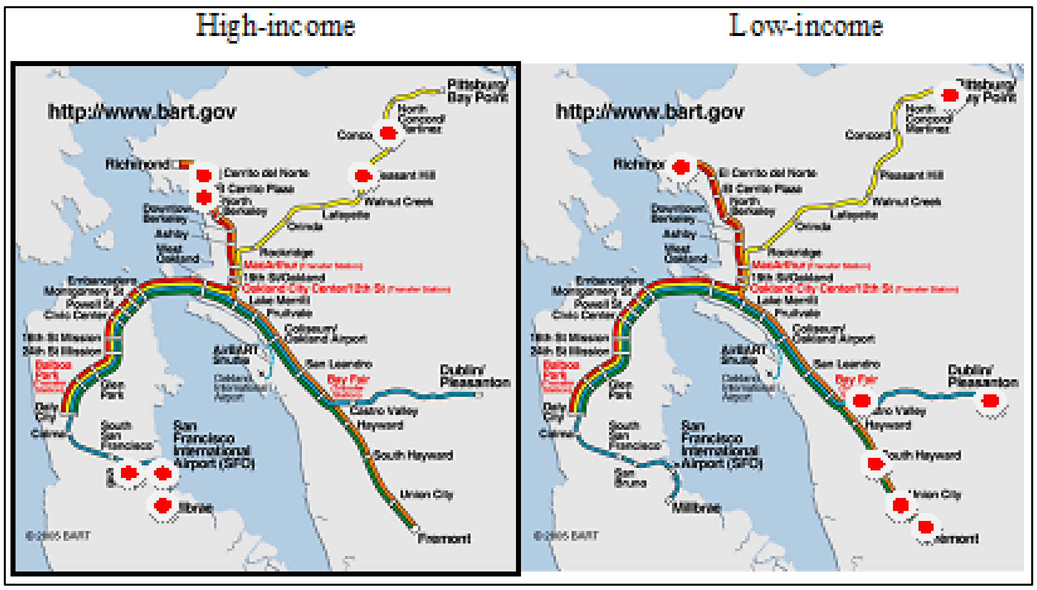

Figure 4: BART stations under study.

RESULTS

Study Sites

From the two systems I selected to study, I found 5 lines including 14 stations for BART and 5 lines including 15 stations for MTR. The following figures indicate the stations that were under study and also whether they were considered in high-income or in low-income districts, depending on the districts' per capita income according to the US Census Bureau 2000 Census income data by congressional district and the 2006 population By-census.

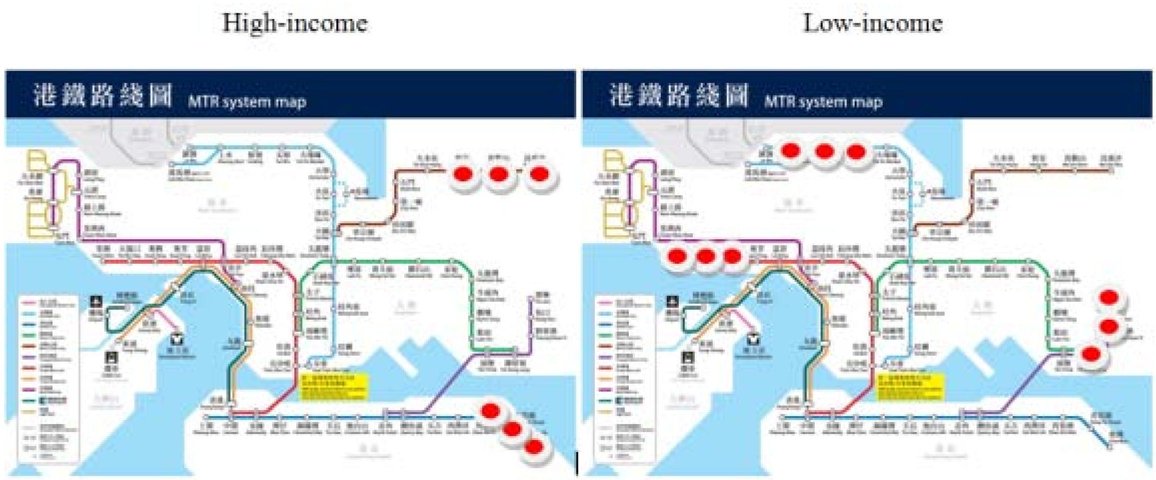

Figure5: MTR stations under study.

San Francisco Bay Area versus Hong Kong

Based on percent map coverage, I found that the feeder bus lines of the train stations in Hong Kong provide services to a greater percentage of local residents than the feeder bus lines in the San Francisco Bay Area do. The service provided by the feeder bus lines to MTR stations covers 95% of the map within the boundary, whereas the service provided by the feeder bus lines to BART stations covers only 66% of the map. The following tables contain the summary data of the feeder bus network in SF Bay Area (Table 1) and the feeder bus network in Hong Kong (Table 2).

Table 1: Service coverage provided by the feeder bus network in SF Bay Area.

	Total Area (sq. m)	Residential Area w/o Access	Residential Area w/ Access	Percent Area w/ Access
Richmond Line	23970722	8775122	15195600	65
Fremont Line	22079082	5239890	16839192	76
Dublin/ Pleasanton Line	16272092	5120239	11151853	69
Pittsburg/Bay-Point Line	16841216	5116233	11724983	64
Millbrae Line	20299776	8520614	11779162	58
			Average	66

Table 2: Service coverage provided by the feeder bus network in Hong Kong

	Total Area (sq. m)	Residential Area w/o Access	Residential Area w/ Access	Percent Area w/ Access
Island Line	486193	21614	464579	96
Tsuen Wan Line	872224	72576	799648	92
Ma On Shan Line	355900	26943	328957	92
East Rail Line	970024	22439	947585	98
Kwun Tong Line	549065	0	549065	1
			Average	95

High-income districts versus low-income districts

Based on percent map coverage, I found that the feeder bus networks of the train stations in lower-income districts provide services to a greater proportion of local residents than the feeder bus networks in higher-income districts do. The service provided by the feeder bus lines in lower-income districts covers 86% of the map within the boundary, whereas the service provided by the feeder bus lines in higher-income districts covers only 77% of the map. Summary data categorized in high- and low-income districts can be found below (Tables 3 & 4). I included the average excluding the Pittsburg/Bay Point Station because the area is still under development and I am assuming that the public transit system there is not well established yet.

Table 3: Percent area w/ access in higher-income districts.

Stations in higher-income districts in SF Bay Area	Percent Area w/ Access
del Norte	58
El Cerrito	53
North Concord	57
Concord	92
Milbrae	43
San Bruno	51
South SF	81
Average	**62**
Lines in higher-income districts in Hong Kong	**Percent Area w/ Access**
Island Line	96
Tsuen Wan Line	92
Ma On Shan Line	92
Average	**93**

Table 4: Percent area w/ access in lower-income districts.

Stations in lower-income districts in SF Bay Area	Percent Area w/ Access
Richmond	78
Fremont	74
Union City	83
Hayward	70
Dublin	73
Castro Valley	64
Pittsburg	43
Average	**69**
Average (exluding Pittsburg)	**74**
Lines in lower-income districts in Hong Kong	**Percent Area w/ Access**
East Rail Line	98
Kwun Tong Line	1
Average	**99**

DISCUSSION

My study measured residential access to a high quality feeder bus network amongst high-income and low-income districts distant from the city centrals in the San Francisco Bay Area and Hong Kong. Results from my spatial analysis supported my main hypothesis that the level of accessibility to a feeder bus line of the MTR system in Hong Kong is superior to that of the BART system in the San Francisco Bay Area. Additionally, the results show that the level of accessibility to a feeder bus network in lower-income districts is greater than in higher-income districts with Hong Kong having a substantially smaller discrepancy. Although a commuter's decision on his or her mode of travel is complex and influenced by multiple factors, these patterns reveal the importance of a well designed feeder bus network.

BART System versus MTR System

The spatial analysis I conducted using ArcGIS 10 supports my hypothesis that MTR, the more successful system, is fostered by a feeder bus network with wider map coverage than BART's. Although the success of a mass-transit rail system is affected by multiple variables, my hypothesis and results are in agreement with the current literature on municipal transportation and the bus services. A comparative study on the service coverage of subways and buses found a negative correlation between walking distance and riding frequency for both modes of travel (Kim, 2010). Another study presenting a model to represent and analyze the design of a feeder bus line network reaffirms the importance of bus-route spacing and bus-stop spacing (Kuah, 1988). Thus, the influence of feeder bus lines is well established and the properties directly related to an efficient feeder bus network should also be explored and understood. As previously noted, the municipal transportation system of Hong Kong differs from that of the SF Bay Area in that the MTR is heavily supported by their government transportation policies and, more significantly, they have privatized ownerships of all public transportation services (Tang and Lo, 2008). Privatization of transportation services encourages two things. For one, the mass-transit railway company/corporation has an increased incentive to expand its services and control its own feeder buses, designing the routes that best supports the railway. In the case of Hong Kong, the MTR Corporation owns and runs the Kowloon Motor Bus Co and the KMB buses' end destinations are train stations (Wang & Po, 2001). The purpose of the services that these buses provide is not to transport passengers cross districts and counties but to strictly pick-up commuters and feed the MTR train system. Privatization also encourages decentralization and allows for the development of a collaboration of individually owned and operated buses. In Hong Kong, other than the large buses provided by MTR or other separate bus companies, residents may also arrive at a train station via mini-buses. Mini-buses are individually owned by the drivers and market-based incentives efficiently designed the bus routes to maximize ridership, usually in areas less concentrated than main streets and less efficient for large buses. As demonstrated in Hong Kong, the MTR Corporation, other bus companies, and all the individual mini-bus owners reap the benefits of a competitive open market for transportation, profiting them while helping the environment by reducing the number of cars on the road.

Privatized ownership of transportation services and decentralization of bus services are not a quick fix to transportation problems in the SF Bay Area. Consideration for privatization and decentralization must include implications from political, labor, and economic perspectives. In a similar case of transportation in the SF Bay Area, it was decided that the ownership of the trucks transporting goods and produce from the port of Oakland to grocery stores should be decentralized and individually owned by the truck driver (Dinkelspiel, 2009). The truck drivers are responsible for signing their own delivery contracts with store owners and this arrangement created a market-based incentive to maximize the efficiency of each delivery trip. However, as an unforeseen consequence of eliminating centralized companies and corporations, individual drivers could not afford to purchase new and more gas efficient trucks or sometimes even unable to properly maintain their vehicles. In order for privatization and decentralization to take their effect, the bus service providers must have the appropriate support from government subsidies and/or abundant patronage. With the ever increasing cost of car ownership and gas prices, more and more people will be looking to cut their transportation costs. Privatized ownership is undeniably an option the SF Bay Area should look into.

High-Income Districts versus Low-Income Districts

The combined results of my spatial analysis comparing access to feeder bus lines among high-income and low-income districts show that in both the SF Bay Area and Hong Kong, the level of access in high-income districts is generally inferior to the level in low-income districts, though this difference is smaller in Hong Kong. The results are in agreement with the current literature on municipal transportation and the economic welfare of a district. In a study using both descriptive statistics and estimation of a logit choice model to investigate various factors influencing an individual’s choice of residence location and the role of the commute trip on that decision, the importance of commute distance decreases with increase level of income, level of education, and number of cars in one's household (Prashker, 2008). In other words, results of this study demonstrate the inclination for people with higher income to live further away and drive private automobiles when commuting. Moreover, in another study, Lin (2008) investigated the interaction between neighborhood environment and household travel behavior, the results suggest household mode of travel and residential location are not independent, with residents in high-income districts more inclined to drive. Interestingly though, transit availability tends to increase the usage of public transit regardless of household automobile ownership and income level. A related case study by Munoz-Raskin (2010) used hedonic modeling, which related quality to independent variables, to find the relationship between bus transit and residential property values within walking distance to the system. The study found that housing market places value premiums on the properties in the immediate walking proximity of feeder lines. Ultimately, even though residents in high-income districts are more inclined to drive private automobiles, commuters do want and will ride a feeder bus line if it is available and in close proximity. This point is demonstrated in Hong Kong by the fact that feeder bus networks of stations located in high-income districts provide only slightly less service coverage than those in low-income districts.

Limitations

The result of this study demonstrated a relationship between the feeder bus network and the mass-transit rail system's level of ridership. The strength of this relationship, though, cannot be accurately determined until more mass-transit rail systems and their respective feeder bus networks are analyzed. If given additional time and resources, I could also have looked at higher resolution of the population densities in low-income places like East and West Oakland and Richmond that have huge geographic expanses, further away from BART lines. Although I was unable to look closely into this, it could hold implications for my results (the high-income vs. low-income comparisons). I only focused on end of the line stations, but there is a huge amount of areas that are far from BART that are not around the end of the line.

Future Directions

Although applying the concept of wide feeder bus line service coverage can potentially produce significant changes to any mass transit railway system not operating at its full potential, it is important to take into consideration the influence of other factors if transportation policies are to be changed. Other factors including gas prices, costs of owning and maintaining an automobile, population density, cultural background, environmental awareness, etc. all play roles in a commuter's decision for his or her mode of travel. Future studies could examine these and other variables, including the strength of the relationship with educating commuters about the environment and benefits of using public transportation. Once all the variables have been described and documented, it would be very informative to conduct a multi-variable analysis to assign weight for each factor's influence on transportation decisions. If and when city planners decide to implement transportation policy changes, knowing the strength of each variable will help them pick the sector where allocating their budget will be most beneficial and efficient.

Broader Implications & Conclusion

The results of this and previous studies should encourage city and regional planners of the San Francisco Bay Area to implement transportation policy changes and increase the amount of feeder bus lines to train stations, especially in light of two California energy policies **-** Sustainable Communities and Climate Protection Act of 2008 (SB 375) and Global Warming Solutions Act of 2006 (AB 32) (California Environment Protection Agency Air Resources Board, 2010). SB 375 requires California's Air Resources Board (CARB) to develop regional reduction targets and plans for reduction in emissions from vehicle use throughout the state. AB 32, the Global Warming Solutions Act of 2006, set into law that by 2020 emission levels must be reduced to 1990 levels. Both SB 375 and AB 21 require a dramatic reduction in regional greenhouse gas emissions and a reduction in the number of commuters driving automobiles should thus rank as one of California's top policy priorities. There is, however, a continual emphasis on the provision of more funding for research in automobile technology and attaining better gas mileage. Even the most optimistic scenarios in which automobile efficiency is increased, our emission reduction goals will still remain out of reach until a notable reduction of the number of cars on the road is achieved. After years of automobile dependency, transition towards public transportation will be difficult unless the beneficial properties of driving are transferred over. If commuters are to prefer public transportation over private automobiles, the cities' municipal department must first improve the level of access to its transportation services.

ACKNOWLEDGEMENTS

I could not have complete this research project and conclude my senior thesis without the guidance and mentorship from Professor Elizabeth Deakin and the assistance and counseling from Seth Shonkoff. I am also grateful for Patinza Mendez and Kurt Spreyer and their efforts in organizing the senior thesis program.

REFERENCES

Bay Area Rapid Transit. (2010). *History of Bart*. Retrieved from http://www.bart.gov/about/history/index.aspx

California Environment Protection Agency Air Resources Board. (2010). Senate Bill 375 – Regional Targets. Retrieved from http://www.arb.ca.gov/cc/sb375/sb375.htm

California Environment Protection Agency Air Resources Board. (2010). Assembly Bill 21: Global Warming Solutions Act. Retrieved from http://www.arb.ca.gov/cc/ab32/ab32.htm

Central Intelligence Agency. (2010). The World Factbook. Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/hk.html

Cervero, R., & Gorham, R. (1995). Commuting in transit versus automobile neighborhoods. *Journal of the American Planning Association, 61*(2), 210.

Cervero, R., & Landis, J. (1997). Twenty years of the bay area rapid transit system: Land use and development impacts. *Transportation Research Part A: Policy and Practice, 31*(4), 309-333.

Currie, G., & Wallis, I. (2008). Effective ways to grow urban bus markets-A synthesis of evidence. *Journal of Transport Geography, 16*(6), 419 p.

Kawabata, M., & Shen, Q. (2006). Commuting inequality between cars and public transit: The case of the San Francisco bay area, 1990–2000. *Urban Studies, 44*(9), 1759-1780.

Kim, K. W., Lee, D. W., & Chun, Y. H. (2010). A comparative study on the service coverages of subways and buses. *Asce Journal of Civil Engineering, 14*(6), 915-922.

Kuah, G. K., & Perl, J. (1988). Optimization of feeder bus routes and bus-stop spacing. *Journal of Transportation Engineering-ASCE, 114*(3), 341.

Lam, W. H. K., Cheung, C., & Lam, C. F. (1999). A study of crowding effects at the hong kong light rail transit stations. *Transportation Research Part A: Policy and Practice, 33*(5), 401-415.

Lin, J., & Long, L. (2008). What neighborhood are you in? Empirical findings of relationships between household travel and neighborhood characteristics. *Transportation, 35*(6), 739-758.

Mass Transit Railway. (2010). MTR. Retrieved from http://www.mtr.com.hk/eng/homepage/corp_index.html

McDermott, D. R. (1978). Mass transit issues from a marketing perspective. *Transportation Journal, 18*(1), 28.

Munoz-Raskin, R. (2010). Walking accessibility to bus rapid transit: Does it affect property values? The case of Bogotá, Colombia. *Transport Policy, 17*(2), 72-84.

Prashker, J., Shiftan, Y., & Hershkovitch-Sarusi, P. (2008). Residential choice location, gender and the commute trip to work in tel aviv. *Journal of Transport Geography, 16*(5), 332.

Southworth, M. (2005). Designing the walkable city. *Journal of Urban Planning and Development, 131*(4), 246-257.

Tang, S., & Lo, H. K. (2008). The impact of public transport policy on the viability and sustainability of mass railway transit – the Hong Kong experience. *Transportation Research Part A: Policy and Practice, 42*(4), 563-576.

United States Census Bureau. (2010). Annual Estimates of the Population of Combined Statistical Areas: April 1, 2000 to July 1, 2008. Retrieved from http://www.census.gov/popest/metro/tables/2008/CBSA-EST2008-02.xls

United States Department of Transportation. (2010). Compliance review of the San Francisco Bay Area Rapid Transit District (BART).

Wachs, M. (1989). Regulating traffic by controlling land use-the southern california experience. *Transportation, 16*(3), 241.

Wang, J. J., & Po, K. (2001). Bus routing strategies in a transit market: A case study of hong kong. *Journal of Advanced Transportation, 35*(3), 259-288.

Wener, R. E., Evans, G. W., Phillips, D., & Nadler, N. (2003). Running for the 7:45: The effects of public transit improvements on commuter stress. *Transportation, 30*(2), 203.

Wong, M. L. (2003). Hong Kong vs. Toronto: Getting around without a car. *Women and Environments.no.62*, (62)