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CAPSTONE

URBAN DECONGESTION SOLUTION: EXPANSION OF LIGHT RAIL TRANSIT

Submitted by

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Abstract

In understanding the imminent growth of world population, the overpopulation of our metropolitan cities is a real concern. Be it the massive carbon footprint created by the many accelerating factors, the housing limitability and limited affordability, or the possible economic strain for cities and citizens to manage properly, the threat of overly congested metro areas is a threat to maintaining steady economic growth. Research on overpopulation has been conducted regularly specific to targeted metropolitan areas, attempting to not only identify that area's specific issues, but to explore solutions to identified problems. This study examines the easing of overcrowded urban areas through Light Rail Transit (LRT). It tests the hypothesis that the expansion of LRT would spread the concentrated Metro-Seattle city population to surrounding cities (in this case, the Edmonds urban area), by offering living options outside of the metro areas with reliable transportation to and from city centers. The study uses a Pearson's correlation between the area populations to identify any analytical relationship. This study identifies an $r = .95$ correlation between the two areas. Although a strong correlation was identified, the study does not find plausible evidence of congestion relief based on population alone. However, it does identify future research areas that may isolate the benefits of LRT expansion. Transportation polices that are pro-LRT may be the solution to decongestion, but more research is needed.

Introduction

The study examines a possible outcome of expanding Light/Commuter Rail transit beyond high populated metropolitan areas: reducing overpopulation in metropolitan centers. The research proposes an answer to the question: Does LRT provide decongestion effects (assumed as an economic positive) in highly populated metropolitan areas?

The U.S. has focused most of its transportation infrastructure policy on commercial rail, bridges, roads, and business/vacation air travel¹. This study will suggest an overall economic benefit to an extension of current passenger rail policies. The research will focus on the Seattle metropolitan area and in particular the northern corridor leading to Everett, Washington, approximately 30 miles north of Seattle on Interstate 5.

By highlighting this benefit, studies such as this one would modify transportation policy away from streets and highways and toward light rail transit. Expansion of LRT in multiple metro areas suggest the possible interconnectivity with other geographic areas across the region and nation.

¹ “Public Transit.” US Department of Transportation, United States Department of Transportation, www.transportation.gov/public-transit.

I. Problem

Dangers of density

Congestion in urban areas, across the globe, is an issue that is a cause for concern among many. Worldwide, congestion has provided cause for major concern, especially with communication in a major or catastrophic event.

In a 2013 article by Nan Zhang, Hong Huang, Boni Su, and Hui Zhang, the authors analyzed the vulnerabilities of populations in the event of the need for evacuation and the challenges that are presented during those events². The study breaks down the methods of disseminating messages in Beijing which has a very dense population (23.7 million³). Given the massive population and the city's infrastructure, getting notification to all the inhabitants has proven to be impossible which leaves a large portion of the population at risk.

Building height and structure types and the actual characteristics of the population in dense urban areas also play a large role in preventing the dissemination of messages. An emergency plan was created in the hopes of mitigating this issue. The use of trucks that emit messages during times of disaster as well as a plan for the most efficient route were activated as a model. In all, this experiment conducted over 80 different simulations of evacuations. Each time, different variables were introduced like the speed of the trucks, the time of day, and the number of trucks used. During these

² Zhang, Nan, Huang, Hong, Su, Boni, & Zhang, Hui. (2013). Population evacuation analysis: Considering dynamic population vulnerability distribution and disaster information dissemination. *Natural Hazards*, 69(3), 1629-1646

³ Beijing Population 2013. (2014, October 06). Retrieved July 28, 2018, from <http://www.worldpopulationstatistics.com/beijing-population-2013/>

drills, the study was able to reveal vital information key to improving processes and effectiveness of evacuations.

Population density presents a great challenge when it comes to evacuations. The vulnerable populations present the most difficulties. The study notes that early notice of a disaster is key when it comes to safely evacuating a densely populated area. This would allow for safer movements of all involved and would reduce the element of panic. During disasters, normal means of communication may not work for delivering messages like radio and television due to the loss of utilities. Thus, the introduction of sound trucks. The goal of this experiment is to provide a clear, concise, uniform message to the masses in a short amount of time to allow for safe evacuation. The upshot is that urban density can be dangerous in certain situations

Most of the recent studies have focused on locations which were smaller in size and not realistic in relation to larger, more populated cities⁴. Due to the vast variety of Beijing's population, scenarios were tested at different times of the day for maximum effectiveness. At night, most of the city's inhabitants are in residential buildings. During normal office times, most of the population was more dispersed throughout the city. In the evening hours, people frequented many different locales to include stores, restaurants, and other public areas.

The study used algorithms developed and utilized to create the best route of travel based on the time of day and occupancy at the time. Through the many test runs, an optimal plan which combined multiple sound trucks with using stationary speakers in

⁴ **Overpopulation: Pakistan's biggest problem. (2017). Pulse International, 18(1), Pulse International, Jan 15, 2017, Vol.18(1).**

strategic locations was developed. The study suggests that using this method is effective and yields the safest and most positive results during the times in which an evacuation is necessary.

In addition to Beijing, the report “Traffic Congestion in the Metropolitan City of Kolkata,” Aparajita Chakrabarty and Sudakshina Gupta of the University of Calcutta tackle the large growth, India has experienced in a boom of development in its cities. The fast change also created a need for increased mobility⁵. The addition of a public transit system had not been able to keep up with the demands of the increasing population and this has resulted in a spike in personal vehicles. The city of Kolkata is one that presents this challenge. The city has experienced a shift and has become more urban; however, the road space has not changed to foster its growth. In comparison to other surrounding cities in India, Kolkata has about six percent of road space. Even though the space is not prominent as Beijing, the smaller city continues to present the challenges of any other lively urban space. This study attempts to analyze the congestion of some of the roadways of Kolkata using a mobility index method.

In a small timeframe, Kolkata experienced a rapid growth in its inner-city population. This change presents a demand for the presence of efficient modes of transportation of goods and people to support the businesses and lives within the city. Having a working traffic system allows for the movement of products, people, and the stream of utility services which, in turn, produces more growth. In recent years, developing cities are growing at a rate that is not allowing their existing roadways to

⁵ Chakrabarty, A., & Gupta, S. (2014). Traffic Congestion in the Metropolitan City of Kolkata. *Journal of Infrastructure Development*, 6(1), 43-59

keep up. The construction of new and improved roadways would mean an increase in value, new businesses, and possibly new residential areas. Due to the change in Kolkata, there has been a major increase of vehicle ownership despite no change in the roadways. Without updates, the addition of a sharp increase of vehicles creates a larger number of traffic injuries and deaths and drastically increases the amount of pollutants being introduced into the environment.

Although public transit is present in Kolkata, the desire for personal vehicle ownership has become commonplace. It is important to note that motorcycles also have been added to the equation in the city where walking and bicycling once were the dominant modes of transport. Policymakers are juggling two sides of the traffic issue: whether to focus on developing a better traffic system to accommodate the huge increase in drivers, or to limit the number of drivers to reduce the costs and effects the vehicles have on the environment. The goal of this article is to measure the amount of congestion on the streets of Kolkata due to the number of vehicles on the road nearly doubling in a small timeframe.

The article identifies three factors that contribute to road congestion: the presence of accidents or road work, the operation of the road network, and capacity of the road. The study also examines differences in incidental congestion and recurrent congestion as the two are very different and should be examined in different ways. The study concludes that due to a boom in economic growth and urbanization, Kolkata's inhabitants have experienced an increase in income and need for mobility. Though roughly 80% of its population uses public transit, the number of vehicles on its limited roadways has increased too rapidly in a short amount of time and the roadways have

not kept up with the growth. The article suggests improvement of the city's public transportation would vastly alleviate the congestion and lessen the number of accidents, delays and pollutants in the environment due to the increase of vehicles on the roads.

On the Iberian Peninsula, Spanish economists Albert Sole-Ribalta, Sergio Gomez, and Alex Arenas express such a concern through analyzing Spain's population growth, suggesting that city overpopulation will worsen the current ecological, and economic condition of the Earth⁶. While admitting the inevitability of population growth, they would propose taxation solutions in transportation, namely "congestion pricing" that charges drivers who enter the urban core, to counter the effects of city congestion, noting that their analysis offers a more effective way of dealing with the problem than current efforts.

The environmental concern was also shared here in America. Northern Kentucky University's Department of Economics and Finance representative Quing Su submitted and original study in June of 2009⁷ (yet, not published until November of 2010). The goal of this study is to determine the relationship between the amount of gasoline used and traffic related factors such as population distribution, road systems, and congestion in urban locales within the United States. It was estimated that the amount of gasoline produced domestically in 2007 was not sufficient to meet the demands of the transportation sector. Data from the same timeframe suggests that an estimated 176,000 million gallons of gasoline were used. When it comes to the amount of carbon

⁶ Sole-Ribalta, A., Gomez, S., & Arenas, A. (2018). Decongestion of Urban Areas with Hotspot Pricing. *Networks & Spatial Economics*, 18(1), 33-50

⁷ Su, Q. (2011). The effect of population density, road network density, and congestion on household gasoline consumption in U.S. urban areas. *Energy Economics*, 33(3), 445-452

dioxide being introduced into the environment an estimated one fifth of that is said to come from the use of personal vehicles.

By analyzing data gathered from the National Household Travel Survey⁸ and the Urban Mobility Report, the study concludes that in urban areas of the United States the populations are denser than most other countries (as noted previous, China and India are two countries that have more densely populated urban areas). In examining the fuel usages, gasoline consumption was lower in comparison to those who lived in urban areas with longer travel delays and higher road density. The study also suggests that gasoline consumption cannot be tied to one single variable but is more focused on ways to decrease consumption in certain areas using local policy. The findings suggest that since traffic congestion is directly related to gas consumption, that perhaps policy should be geared toward the addition of more roadways or making existing highways more efficient.

The study also notes that the consumption of gasoline is not expected to decrease without a change in price. If the price remains steady, people's desire to consume less fuel will not change. Su concluded that the prevalence of public transit access in higher density populations reduces the amount of gasoline consumed. In urban areas of the city with spatial challenges, the study notes that the lower consumption of gas can be attributed to space allowed for vehicle ownership and the average travel distance per car. In summation, the study shows that traffic flow on roadways and congestion and population distribution have a direct impact on the

⁸ National Household Travel Survey, 2007, nhts.ornl.gov/.

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amount of gasoline consumed by personal vehicles thereby increasing the amount of carbon dioxide into the environment.

Economic growth

The effects on economic growth are an important concern, as well as the ecological damage. A 2013 study by Matthias Sweet examined nearly ninety sets of data for metropolitan areas in the United States. It analyzed the effects of traffic congestion on employment growth from 1993 to 2008. It also dives into the productivity of each employee from 2001 to 2007⁹. By implementing strategic variables, the study suggests that the lack of an efficient traffic flow will undoubtedly lead to slower economic growth. Higher averages of daily traffic (ADT), according to studies, contributes greatly to the stifling of job and economic growth.

Most of the larger, economically thriving cities in the nation are plagued with being the most congested when it comes to traffic. Studies have yielded conflicting results previously, but there is a definite link between traffic congestion and economic growth¹⁰. The study notes that understanding how the growth of an area relates directly to the congestion of traffic is key. Understanding this would be beneficial to future planning and policy making. Previous research on this link has suggested different causalities for the congestion. Some say that only peak-period pricing can relieve the traffic issues that can lead to a city's lack of competitive edge. On the other hand,

⁹ Sweet, M. (2014). Traffic Congestion's Economic Impacts: Evidence from US Metropolitan Regions. *Urban Studies*, 51(10), 2088.

¹⁰ Roscoe, Andrew. (2011). Qatar leads road investment: The GCC states are directing major investment towards upgrading road infrastructure to ease congestion and boost economic growth.(ROADS). *MEED Middle East Economic Digest*, 55(43), 31.

researchers conclude that the congestion of traffic is more of a result of social outcomes (racial tension and low crime) and improper city planning.

Studying the impact of congestion on an area, algorithms were developed to differentiate between the different types of congestion adding variables that could distinguish time variations and the types of congestion directly relating to economic growth¹¹. The tools chosen for this study were crafted to depict both the positive and negative effects of congestion on an area. Congestion was essentially measured by utilizing a combination of average daily travel models as well as travel delay models. The formulas of this study aimed to determine if traffic congestion has a direct effect on employment growth and the actual productivity of employees.

Ultimately the studies concluded that the congestion is a drag on the economy. The higher the congestion rate, the lower the economic growth rate present. The heightened level of congestion also directly contributes to worker productivity¹². The results yielded suggest that congestion alleviating programs and policies would directly change the average daily traffic during certain times and could, in turn, produce a positive outcome in productivity and growth. The data gathered shows that the congestion add between 35-37 hours of delay per driver annually and leads to a downturn in productivity over time. The findings could be extremely useful for planning purposes and policies to relieve the amount of average daily travel during certain key

¹¹Sweet, M. (2014). Traffic Congestion's Economic Impacts: Evidence from US Metropolitan Regions. *Urban Studies*, 51(10), 2088. Figures 1&2

¹² Sweet, M. (2014). Traffic Congestion's Economic Impacts: Evidence from US Metropolitan Regions. *Urban Studies*, 51(10), 2088.

hours. Alleviating the number of vehicles on the roadway at the same time would lead to more positive economic and social outcomes.

Congestion pricing as solution

Reviving the idea of “congestion pricing,” this has been supported in metropolitan areas in the United States, at least in public opinion. However, many businesses, special interest groups, and public officials have not shown to be as supportive in such endeavors¹³.

In 2010, Bruce Schaller examined the New York City situation¹⁴. In 2007, the then mayor of New York City Michael Bloomberg gained widespread city support for his comprehensive sustainability plan (PlaNYC¹⁵) that would, among more city essential applications, set the city to join, “Singapore, London and Stockholm as the fourth large city that charges for driving into the central city core.” The wide-ranging plan maintained that its implementation had over 120 initiatives designed to make air quality the cleanest of any major U.S. city, provide 30% reduction greenhouse gas emissions by 2030, massive street repair efforts, and an expansion of the mass transit system. Yet arguably, his most ambitious part of this proposal was the \$8 daily fee for vehicles traveling within Manhattan, which boasted to generate enough revenue to offset (and succeed) the \$13 Billion price tag for the plan within 25 years. Ultimately, the plan failed due to other boroughs blocking structural measures, strong big business push for

¹³ Ulberg, C., MacFarland, Gordon, & Washington . Department of Transportation. (1995). An evaluation of public opinion about congestion pricing and tolls. Olympia, Wash.] : [Springfield, VA]: Washington State Dept. of Transportation ; [Available through the National Technical Information Service].

¹⁴ Schaller, B. (2010). New York City’s congestion pricing experience and implications for road pricing acceptance in the United States. *Transport Policy*, 17(4), 266-273.

¹⁵ http://www.nyc.gov/html/planyc/downloads/pdf/publications/full_report_2007.pdf

government distrust among the public (reducing the plan's popularity), but mainly due to the political road blocking in the New York State Legislature, causing the federal funding deadline to elapse, which was key to the project¹⁶.

Tax focused policies are not a popular option in the current political atmosphere. And as grand of a plan as New York City shown, big and comprehensive can become too, toxic of a move for any metropolis. A smaller scaled focus on improving Light Rail Transit may provide an alternative to congestion pricing in the United States.

Overall, these studies allude to Light Rail Transit being a cost-effective way of reducing highway congestion, reducing carbon emissions, and expands living choices among citizens, while providing reliable access to metropolitan amenities.

II. Light Rail Transit History

The earliest introduction of a "light rail-like" system in the United States would be the streetcar system. A horse and buggy line was introduced in New Orleans in 1835¹⁷ (St. Charles Avenue line). Lines became electrified for "streetcars" by the turn of the 20th century (first in 1888 in Richmond, VA). Yet, it would not be until after World War II when metropolitan streetcars, due to advancing technologies, could operate at a more efficient scale. Great Britain coined this type of travel 'light rail'. Over the next half-century, major cities across the United States (including Seattle¹⁸) developed light rail

¹⁶ Yosef Jabareen. (2014). *An Assessment Framework for Cities Coping with Climate Change: The Case of New York City and its PlaNYC 2030*. *Sustainability*, 6(9), 5898-5919

¹⁷ Guthrie, A., & Fan, Y. (2013). *Streetcars and Recovery*. *Journal of Planning Education and Research*, 33(4), 381-394

¹⁸ *Street Railways in Seattle*. (n.d.). Retrieved July 28, 2018, from <http://www.historylink.org/File/2707>

versions of transportation (subways, elevated systems “L-Trains,” trolleys) to combat the urban congestion¹⁹, and to offer more reliable transportation options to the public. In the 1970’s the U.S. began to use the phrase Light Rail Transit, and in 1989, the Transportation Research Board’s official definition of Light Rail Transit (LRT) was established as: “A metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive rights-of-way at ground level, on aerial structures, in subways, or occasionally, in streets and to board and discharge passengers at track or car floor level” (Maier, 2009).

Since 1974, LRT has become a popular (and necessary due to metropolitan population growth) mode of public transportation²⁰ throughout the United States, though far after being pervasive in other parts of the world²¹. Even in the Puget Sound, Light Rail has had troubled beginnings. The first ballot initiative for rapid transit (Forward Thrust - Proposition 1: Rapid Transit) was failed to reach the 60% super majority (mandatory for passage) on February 12th, 1968²². This would have allowed Seattle to become one of the first cities in America to advance street car technologies and, most importantly, receive the necessary federal funding for the project. Once the measure was defeated, the federal funds were redirected to the city of Atlanta.

¹⁹ Schumann, J. (1989). Light rail transit makes headway. *Mechanical Engineering*, 111(7), 70-74.

²⁰ Ganning, J. (2018). The effects of commuter rail establishment on commuting and deconcentration. *Regional Studies*, 1-10

²¹ Zhou, Z., Jing, Z., Ma, L., & Zhu, F. (2012). Evaluation of Metropolis Commuter rail-transportation transit vehicle planning based on grey weighting relation method. *International Review on Computers and Software*, 7(5), 2461-2465

²² Seattle Daily Times, NIGHT SPORTS FINAL ed., 14 Feb. 1968, p. 1. NewsBank, infoweb.newsbank.com/apps/news/document-view?p=WORLDNEWS&docref=image/v2:127D718D1E33F961@WHNPX-12D2D07164246C9F@2439901-12D18C9026204839@0-12D18C9026204839@. Accessed 24 June 2018.

After a few decades of research and failed ballot measures, Central Puget Sound Regional Transit Authority (Sound Transit)²³ was eventually created as a public-private partnership transportation agency, in 1993. Sound Transit's early road was rocky from the start. The initial 1995 ballot measure, once again, was defeated, and shortly after the voting success of a less ambitious plan, ballooning cost, financial uncertainty, and scandal led the next decade for Sound Transit to be more of a development rollercoaster than most businesses would expect²⁴. Sound Transit has since paved the way for realistic expansion and budgeting, delving more in to public transparency of plans and operations. Though they may be on a positive track²⁵, similar issues across the nation add to the ambiguity of public transit (including LRT) being an overall positive and/or negative economic benefit for the areas of service.

LRT and property values

Daniel Baldwin Hess and Tangerine Maria Almeida's study (Impact of Proximity to Light Rail Rapid Transit on Station-area Values in Buffalo, New York – 2007), notes that Buffalo, New York has had a light rail in place for two decades. The area has been experiencing a decrease in property values as well as a decline in transit patronage. To determine the effects that light rail had on surrounding property valuation, a Hedonic model was constructed to take a deep look at independent variables that have affected properties near the transit system. The findings in the model suggest that of the

²³ "Sound Transit." Sound Transit, www.soundtransit.org/.

²⁴ Garber, Andrew. "Half-billion allocated for Sound Transit." Seattle Times, The (WA), First ed., sec. Local News, 20 Jan. 2001, p. B1. NewsBank, infoweb.newsbank.com/apps/news/document-view?p=WORLDNEWS&docref=news/0EB53AA226B7EAC5. Accessed 24 June 2018

²⁵ Kawada, Eijiro. "Sound Transit costs jump off track - LIGHT RAIL: Project could cost taxpayers \$2.6 billion eventually." The News Tribune, sec. Front Page, 13 Dec. 2000, p. A1. NewsBank, infoweb.newsbank.com/apps/news/document-view?p=WORLDNEWS&docref=news/0EFA5CE31B57CA04. Accessed 24 June 2018

properties that are located within a half of a mile of a station, the valuation increases the closer the home is to the station. The model also notes that other variables like whether the property is located on the East or West side of the city as well as the features of the homes like the actual parcel size and number of bathrooms also affect the value. The study also notes a difference in valuation depending on whether the straight-line distance or the network distance is used to measure the walking distance to a station. The study suggests that the effects of being close to a station are not even across the board for the 14 station radiuses that were analyzed.

Based on the results of the 14 station models, the study concludes that other factors in a locale have more influence on property value. Different stations yielded different results based on Buffalo's unique makeup. The increase in value was dependent upon the location of the station being a commercial area or a residential area in some cases. The analysis of the other variables in the study, the number of bathrooms, area of the property, and whether the location was on the East or West, show that these factors are more influential than the proximity to a station. This holds true especially when comparing Buffalo to other cities or metropolitan areas that are experiencing economic growth. A decline in economic development and a decrease in population were also shown to influence property value. Given the findings in the study, it could not be concluded that light rail transit would absolutely increase the value of homes nearby.

Though many pitches for adding transit systems make promises of benefits for both those who use them and those who don't, the light rail in Buffalo does not make a significant impact on land value and in some cases even yields negative impacts.

Property value was not affected at all in locations that did not place a high worth on proximity to a station. The study's results suggest that the availability of the stations do not make a large impact on property values. There has not been much of a push to extend the service area offered by the transit system. Stakeholders find it hard to support expansion because it does not offer regional accessibility and forces patrons to ride to a point and then transfer to another mode of transport like busses to complete their intended commute. The study concludes by suggesting that developers take advantage of affordable properties located in established neighborhoods which could increase the quality of life.²⁶

Another study, written by Reid Ewing, Guang Tian, Allison Spain, and J.P. Goates of the University of Utah focused on the possible effects adding Light-Rail Transit (LRT) to Salt Lake City²⁷. Mainly, LRT would decrease the amount of pollutants in the air, traffic congestion, and the consumption of energy. The goal of the study was to produce actual quantitative data which would be an asset in planning policies to come involving transportation. The project focused on traffic data both before and after the University of Utah's TRAX LRT line opened to present a full view of the effects.

They coupled this data with a quasi-experiment design which allowed for more control. According to the study, traffic with LRT was reduced significantly due directly to the ease and access of an efficient transit system which provided transport to the university as well as along the line. In addition, traffic on the 400/500 road in the study

²⁶ Hess, D., & Almeida, T. (2007). **Impact of Proximity to Light Rail Rapid Transit on Station-area Property Values in Buffalo, New York.** *Urban Studies*, 44(5-6), 1041-1068

²⁷ Ewing, R., Tian, G., Goates, A., & Spain, J. (2014). **Effects of light-rail transit on traffic in a travel corridor.** *Journal of Public Transportation*, 17(4), 93-113.

was also decreased greatly even though heavy construction and alteration to the university and corridor were happening simultaneously. After analyzing the data, the study predicts that the LRT will stop an estimated 7 million pounds of carbon dioxide from being released into the environment and cut gasoline consumption by over 360,000 gallons.

The study's hope was to provide invaluable statistics that could help officials properly plan future projects and policies such as air pollution and the costs of parking. Data from Utah Department of Transportation and the Utah Transit Authority concluded that the University is the state's second-largest traffic generator and pushed heavily to have people who drove switch to using transit to commute back and forth to the campus. Their data shows that traffic levels were beginning to reach record lows that had not been matched since the 1980's.

Before this experiment, studies on traffic congestion provided widely varying results. Where one study would conclude that the growth of congestion declined in several cities in the nation, another would argue that the addition of LRT would only make a minimal impact on ridership. The actual effects of LRT on the pollutants in the air are not conclusive either. It has been concluded by some that the amount of fuel used by public transport will not guarantee that energy is saved (though Seattle's LRT rely on electricity, making Seattle's LRT less of a pollutant factor²⁸). The authors of this

²⁸ Central Puget Sound Regional Transit Authority, United States. Federal Transit Administration, & Seattle. (1999). Central Link light rail transit project, Seattle, Tukwila, and SeaTac, Washington : Preliminary draft final environmental impact statement. Seattle, Wash.]: [Sound Transit].

study were unable to find a project that successfully estimated the effects of transit on the above factors by using a highly controlled testing method.

The initial transit system was initiated in 1999 and stretches from the suburban areas surrounding Salt Lake City to the heart of its downtown area. In the following years, several extensions were added one by one to increase the system's coverage area²⁹. This study uses each of the extensions as a natural experiment for analyzation to provide actual data showing the change in traffic patterns. The university extension was chosen as the "treatment" for this study because it offered unique factors such as the dynamics of its ridership. Ticketholders for sporting events on campus and students could ride TRAX free of charge and the extension has the highest reported patronage. The year the extension was added, 2001, serves as the last year before the initial treatment, and the following years serve as their own separate treatments.

By analyzing data from before the addition of LRT and the data from the years following the addition of the extension, the study was able to offer three levels of data. Their short-term statistics show that after the introduction of the extension, the number of vehicle per day did, in fact, decrease in an amount that was estimated to match the increase in patronage in transit use. The mid-term analysis shows that by comparing two sections of the road with similar conditions and factors, the annual average of daily traffic was lower after the introduction of LRT on the road that was focused on for the study.

²⁹ Nelson, A., Eskic, D., Hamidi, S., Petheram, S., Ewing, R., & Liu, J. (2015). Office Rent Premiums with Respect to Light Rail Transit Stations: Case Study of Dallas, Texas, with Implications for Planning of Transit-Oriented Development. *Transportation Research Record: Journal of the Transportation Research Board*, 2500(2500), 110-115.

The final analysis notes that the adding additional length in the corridor studied should have theoretically shown an increase in the number of new trips generated in the area. Instead, the data indicates that the average number of vehicles per day was about 50% lower. Given these findings, the study estimates that the addition of LRT did in fact result in saving about 362,300 gallons of gasoline, prevented almost 7 million pounds of carbon dioxide from entering the air, and decreased the average number of vehicles per day by over 20,000.

In Los Angeles, Steven Spears, Marlon G. Boarnet, and Douglas Houston's report determined whether the effects that light rail transit in Los Angeles, California has on the number of miles a vehicle travels thereby analyzing the amount of gasses being emitted within the transport sector³⁰. The study introduces an experimental-control group design to do so. A seven-day analysis was conducted annually of a group of households located near the intended Los Angeles' Expo light rail line both before the start of service and after. The results suggest that those who live within one kilometer of the new light rail drove about 10 miles less per day in comparison to households that were not as close. In addition, the patronage of the rail transit system nearly tripled for those same households located in walking distance. The results of the study insinuate that a combination of policy and investment in expanding the light rail investment could help make a positive impact on environmental and climate change policy in the future.

³⁰ Spears, S., Boarnet, M., & Houston, D. (2017). Driving reduction after the introduction of light rail transit: Evidence from an experimental-control group evaluation of the Los Angeles Expo Line. *Urban Studies*, 54(12), 2780-2799.

To reduce greenhouse gas emissions, the state of California's land use planning and expansion of public transit systems are working hand in hand³¹. State mandates require that cities plan and invest in ways that will allow for affordable housing and foster economic growth all while meeting greenhouse gas regulations in transportation. The ultimate hope is that by implementing an efficient, environmentally friendly transit system, the use of personal vehicles will be reduced, and the use of other eco-friendlier means would increase. This study shows ways that the use of light rail transit can meet policy standards and simultaneously positively affect climate change.

To select the households to participate in the experiment, the group purchased over 20,000 addresses and mailed out information on the study but did not specify that it was directly related to the Expo Line to minimize the possibility of influencing their choices during the study. 651 households responded with interest and were asked to log their travel for 7 days for each member of the household over the age of 12. They were also given a mileage log for each vehicle and a baseline survey. The first batch of data was received one month before the rail service started and of the responses, 285 had usable data. Each household that participated was given a supermarket gift card in the amount of \$15-30. About five months after the transit line opened, the participants in the experiment were contacted again. The amount of the gift card compensation was increased to \$50-75 to maintain interest. After two months, the group had collected 208 usable responses. The final collection of data took place about eighteen months after the initial opening of the transit line. This time, 173 usable responses were received.

³¹ Houston, Dang, Wu, Chowdhury, & Edwards. (2016). The cost of convenience; Air pollution and noise on freeway and arterial light rail station platforms in Los Angeles. *Transportation Research Part D*, 49, 127-137

After a thorough analysis of the data, the study concludes that the presence of an active light rail transit system effectively reduces the number of miles households drive daily when they live near a station. Given these findings, it is safe to infer that light rail transit aids in the reduction of greenhouse gas emissions due to shortened car trip lengths.

A quantitatively larger study was conducted by Kenneth Dueker and Martha Bianco evaluation living and transportation trends of Portland, Oregon's East Side light rail line. The study suggested three outcomes; 1) Outer LRT corridor households drove less than those in the farther zoned (Bus Zoned) households, 2) Those same households use transit more than the control group, and 3) Single family housing within the LRT corridor is aggressively and competitively higher priced³² (Dueker & Bianco, 1999).

These economic and environmental studies highlight important economic analysis. However, the results are limited to the cities technically defined by their formal boundaries. Cities can have unique combinations of features that, individually, they share with other cities (factors such as population size, geographic location, climate, cultural makeup, etc.). Yet, the unique combination of features for a city makes it difficult to identify what is the best economic move for an area with respect to transportation. This fact, combined with the datedness of surveys, means that miscalculations are a real possibility. I find these studies to be generally sound, yet, out-of-date and relevant only to the city studied. The study will concentrate on LRT for the Puget Sound

³² Dueker, K., & Bianco, M. (1999). Light-Rail-Transit Impacts in Portland: The First Ten Years. *Transportation Research Record: Journal of the Transportation Research Board*, 1685, 171-180

area³³economic benefits (much like the feasibility study done in 2010³⁴). I hypothesize that the study will show that current analysis suggests, we can expand the economic benefits to lesser served areas.

III. Methodology

This study draws from the idea that the suburban areas would provide population relief to metropolitan³⁵, and using public transportation (Light Rail Transit, specifically) as a means to facilitate this idea. In 1998 the Transportation Research Board published an overview of transit implementation, at the end of which, provided case studies suggesting the population benefits throughout the United States³⁶. Based on this, the study makes the supposition that here is a population when there is a population decrease in Seattle, there will be an increase in Edmonds. Therefore, using Sound Transit Sounder (commuter rail) as a proxy for LRT, the method of examination will be a benefit analysis³⁷ of population correlation between Edmonds and Seattle, in the years

³³ Central Puget Sound Regional Transit Authority, & Adolfson Associates. (1998). Tacoma-to-Seattle commuter rail : Environmental assessment. Washington, D.C.] : [Seattle, Wash.]: Federal Transit Administration ; Central Puget Sound Regional Transit Authority.

³⁴ Washington . Department of Transportation, author, HDR Engineering, author, Blaydes Consulting, author, & Hendricks - Bennett, PLLC, author. (2010). Executive summary, Southeast King County commuter rail feasibility study. Seattle, WA: Washington State Department of Transportation, Strategic Planning and Programming Division, Urban Planning Office

³⁵ Light Rail resurgence benefits US cities: In more and more medium-size cities throughout North America, light rail is becoming the system of choice for moving people comfortably, cleanly, and economically. (Rapid Transit Review). (2001). International Railway Journal, 41(8), 32.

³⁶ Byrd, R., Murray, Gail, Crain & Associates, Omniversed International, United States. Federal Transit Administration, Transit Development Corporation, & National Research Council . Transportation Research Board. (1998). Using public transportation to reduce the economic, social, and human costs of personal immobility (TCRP web document ; 7). Washington, D.C.]: [National Academy Press]

³⁷ Radin, B. (2013). Beyond Machiavelli : Policy analysis reaches midlife (2nd ed.). Washington, DC: Georgetown University Press.

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2000 through 2016 (years prior and post commuter rail construction). This is due to LRT not being expanded to Edmonds.

This assumed population transfer would show an ease to the Seattle metropolitan congestion and the gain of this populous in Edmonds, highlighting the difference in area population. I used secondary sources to compute and compare the relevant data. Sources for this data were the National Historical Geographic Information Systems (NHGIS)³⁸ Integrated Public Use Microdata Series (IPUMS), and the United States Census data. I have used a Pearson's model (measuring how strong the relationship is between the variables) to show whether there is a correlation between cities and then highlighting the possible changes between the time periods before the Sounder and after.

IV. Results

To describe the demographic landscape of the area, analysis of an analysis both areas was conducted. As of 2016, Edmonds is a city, north of Seattle's urban boundary, with a population of around 41,000. The racial demographic makeup of Edmonds consists of 78.6% White, 9.1% Asian, 4.9% Hispanic and 7.4% as Other (1.1% of which is Black). Along gender lines, women are 53.9% of the population; 47.1%, of whom, poses a bachelor's degree or higher. Males make up 46.1% of the population with 51.0% of male attaining the same educational standard³⁹. The city of Seattle boasts a

³⁸ Steven Manson, Jonathan Schroeder, David Van Riper, and Steven Ruggles. *IPUMS National Historical Geographic Information System: Version 12.0 [Database]*. Minneapolis: University of Minnesota. 2017. <http://doi.org/10.18128/D050.V12.0>

³⁹ U.S. Census Bureau (2012-2016). *Sex by Educational Attainment for the Population 25 Years and Over American Community Survey 5-year estimates*. Retrieved from

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population of around 704,000, 65.7% White, 14.1% Asian, 7.0% Black and 13.2 Other (6.6% of which is Hispanic).⁴⁰ Figures are shown in the demographics section of the Appendix.

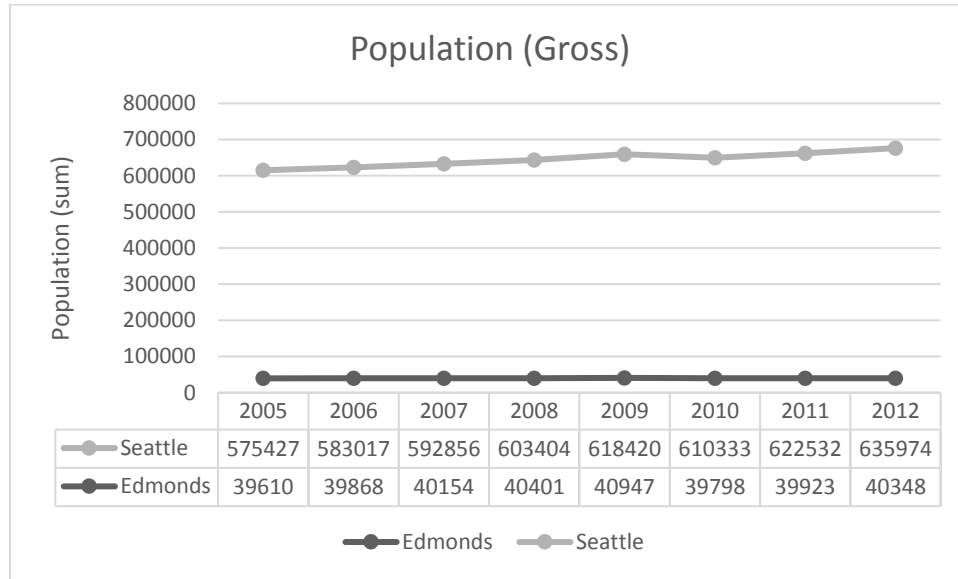
<https://censusreporter.org/data/table/?table=B15002&geo_ids=16000US5363000,01000US,16000US5320750&primary_geo_id=16000US5363000>

⁴⁰ U.S. Census Bureau (2012-2016). Hispanic or Latino Origin by Race American Community Survey 5-year estimates. Retrieved from

<https://censusreporter.org/data/table/?table=B03002&geo_ids=16000US5363000,01000US,16000US5320750&primary_geo_id=16000US5363000>

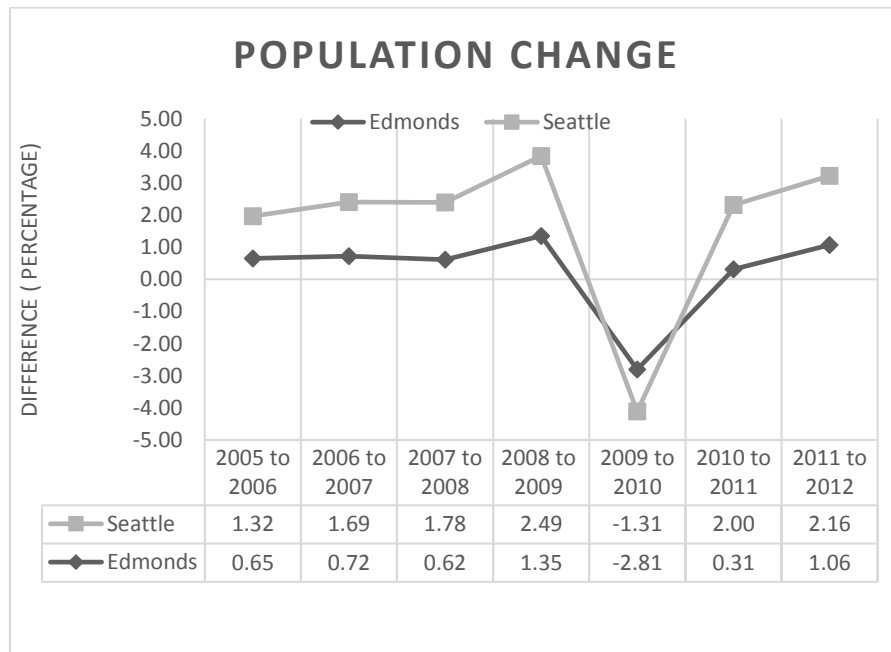
The population correlation of the two cities are charted as follows:

	2005	2006	2007	2008	2009	2010	2011	2012
<i>Edmonds</i>	39610	39868	40154	40401	40947	39798	39923	40348
<i>Seattle</i>	575427	583017	592856	603404	618420	610333	622532	635974



The percentage of change from the previous year is as follows:

	2005 to 2006	2006 to 2007	2007 to 2008	2008 to 2009	2009 to 2010	2010 to 2011	2011 to 2012
<i>Edmonds</i>	0.65	0.72	0.62	1.35	-2.81	0.31	1.06
<i>Seattle</i>	1.32	1.69	1.78	2.49	-1.31	2.00	2.16



V. Analysis

The resulting analysis proved to be less than anticipated; the notion being the population difference would show an inverse effect between the two areas (leading to the identification of a need to expand LRT to help in the decongestion efforts). However, the data signified the areas share a strong resemblance population tendency. Furthermore, suggesting that whatever the population trend is for Seattle, it is very likely that the same similarities would be present in Edmonds. Therefore, indicating the hypothesis of LRT decongestion benefits to be unsupported by this study.

In searching for a suggested solution to the congestion situation of Seattle, I was able to find that the similarities of the two cities made it very difficult to obtain city specific information on the smaller city (Edmonds⁴¹), outside of population information. All information and data gathered has been complied mostly using Census and GIS data. The data discovered failed to produce adequate information for in-depth observation of the housing difference between the two areas. Therefore, the study cannot demonstrate whether there is an economic benefit of expanding to surrounding cities of Metro-Seattle. Conducting a more comprehensive study would possibly highlight results.

The data did provide information for a population analysis. Therefore, determination was made to conduct a Pearson correlation formula to observe whether

⁴¹ U.S. Census Bureau (2012-2016). Sex by Age American Community Survey 5-year estimates. Retrieved from <https://censusreporter.org/data/table/?table=B01001&primary_geo_id=16000US5320750&geo_ids=16000US5320750,05000US53061,31000US42660,04000US53,01000US>

there is a relationship between Seattle and Edmonds' populations prior to and post Sounder construction.

Pearson Correlation:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Of Which:

x = the percentile population increase of Seattle

y = the percentile population increase of Seattle

Pearson Correlation (r = 0.969, p <0.1):

	x	x*x	y	y*y	xy	x-(x- \bar{x})	y-(y- \bar{y})	[x-(x- \bar{x})]^2	[y-(y- \bar{y})]^2	[x-(x- \bar{x})]*[y-(y- \bar{y})]
2005 to 2006	1.30	1.69	0.70	0.49	0.91	-0.16	0.41	0.02	0.17	-0.07
2006 to 2007	1.70	2.89	0.70	0.49	1.19	0.24	0.41	0.06	0.17	0.10
2007 to 2008	1.80	3.24	0.60	0.36	1.08	0.34	0.31	0.12	0.10	0.11
2008 to 2009	2.50	6.25	1.40	1.96	3.50	1.04	1.11	1.09	1.24	1.16
2009 to 2010	-1.30	1.69	-2.80	7.84	3.64	-2.76	-3.09	7.60	9.52	8.51
2010 to 2011	2.00	4.00	0.30	0.09	0.60	0.54	0.01	0.29	0.00	0.01
2011 to 2012	2.20	4.84	1.10	1.21	2.42	0.74	0.81	0.55	0.66	0.60
Σ	10.20	24.60	2.00	12.44	13.34	0.00	0.00	9.74	11.87	10.43
Mean	1.46		0.29							1.49
r	0.96982									

VI. Summary

Overall, the light rail and commuter rail allow any metropolitan city the option for expansion, without overcrowding the individual area. Livable and workable spaces are finite resources in the United States. Understanding of the climate effects overcrowding areas with private vehicle usage, which increases our global footprint by increasing carbon emissions and the rate of fossil fuel usage, the globe will experience negative effects at an accelerated pace. By no means does this study suggest that Light Rail

Transit and Commuter Rail expansion will be a solution to all the world global problems. What this report has done is highlight a viable addition to other future sustainability projects (green spaces, no drive zones, etc.).

Expanded LRT could also be explored as a solution to low income, poverty, and homelessness throughout the nation. Areas across the country have overpopulation issues in need of a solution. In exploring the expansion of LRT policies across the nation could potentially allow for more opportunities decreased urban area population and civilian betterment by giving more options to expand quality of life. The possibility of offering higher waged employment within metro areas, providing affordable living, and can be expanded on by developers outside of the metro area could transform the makeup of areas plagued by overcrowding. In return, creating more employment opportunity and decreasing poverty and homelessness rates. This could also provide low-income families to be more economically stable.

Be that as it may, the essential data does not prove a deeper correlation between Seattle decongestion and population increase in Edmonds, nor does it effectively indicate the economic benefits of the targeted surrounding city. Through the failure of the original assertion, the does allow for alternatives for decongestion. Employment opportunities would be an interesting focus as to the driving factor for population reduction in Metro-Seattle area. That could be added to the proposed (currently under construction) expansion of the Light Rail Transit Line to the Puget Sound Eastside corridor (servicing the Bellevue, Redmond, and Renton areas by 2023-2024). These measures indicate that the Greater Seattle Area transportation policy has an investment into providing expanded LRT options, for the possible benefits.

The search for suburb Seattle area economic data is infrequent and scarce. More research is required for deeper investigation of information regarding economic relationship between those areas and public transit. Public funds are used to construct rail lines, and the people have a right to know what those funds are used for. Along with the knowledge of what is going on, citizens should be able to have reports details and prepared for them, within a reasonable timeframe, with all the parameters requested by the citizen laid out for them in laymen. Further research could possibly explore and report the economic benefits of Light Rail Transit expansion for the outer areas of Seattle's urban boundary. Thus, providing evidence towards overall connectivity could break ground on American High-Speed Rail advancement. Which, hypothetically, will allow for a massive decongestion movement with the United States.

VII. Appendices

Demographic Breakdown Tables

Education (2016)⁴²:

	UNITED STATES		EDMONDS, WA		SEATTLE, WA	
	Value	Error	Value	Error	Value	Error
TOTAL:	100.00%	0.01%	100.00%	1.71%	100.00%	0.41%
MALE:	48.26%	0.00%	46.11%	1.81%	50.13%	0.37%
NO SCHOOLING COMPLETED	0.69%	0.01%	0.12%	0.13%	0.50%	0.07%
NURSERY TO 4TH GRADE	0.38%	0.00%	0.00%	0.08%	0.17%	0.06%
5TH AND 6TH GRADE	0.80%	0.01%	0.02%	0.03%	0.35%	0.07%
7TH AND 8TH GRADE	0.91%	0.01%	0.39%	0.28%	0.35%	0.07%
9TH GRADE	0.84%	0.01%	0.19%	0.19%	0.30%	0.07%
10TH GRADE	0.97%	0.01%	0.29%	0.24%	0.31%	0.06%
11TH GRADE	1.10%	0.01%	0.11%	0.13%	0.40%	0.06%
12TH GRADE, NO DIPLOMA	0.95%	0.01%	0.81%	0.27%	0.56%	0.07%
HIGH SCHOOL GRADUATE (INCLUDES EQUIVALENCY)	13.63%	0.05%	7.80%	1.33%	5.41%	0.26%
SOME COLLEGE, LESS THAN 1 YEAR	2.90%	0.02%	2.03%	0.48%	1.98%	0.14%
SOME COLLEGE, 1 OR MORE YEARS, NO DEGREE	7.07%	0.02%	7.56%	1.33%	6.59%	0.20%
ASSOCIATE DEGREE	3.51%	0.01%	3.32%	0.68%	3.37%	0.21%
BACHELOR'S DEGREE	8.97%	0.03%	14.66%	1.38%	17.57%	0.33%
MASTER'S DEGREE	3.61%	0.02%	5.50%	1.00%	7.49%	0.27%
PROFESSIONAL SCHOOL DEGREE	1.16%	0.01%	1.89%	0.55%	2.67%	0.15%
DOCTORATE DEGREE	0.80%	0.01%	1.42%	0.46%	2.11%	0.15%
FEMALE:	51.74%	0.00%	53.89%	1.62%	49.87%	0.33%
NO SCHOOLING COMPLETED	0.74%	0.01%	0.22%	0.16%	0.65%	0.09%
NURSERY TO 4TH GRADE	0.39%	0.00%	0.00%	0.08%	0.34%	0.07%
5TH AND 6TH GRADE	0.78%	0.01%	0.28%	0.24%	0.42%	0.07%
7TH AND 8TH GRADE	0.90%	0.01%	0.17%	0.15%	0.27%	0.05%
9TH GRADE	0.77%	0.01%	0.17%	0.16%	0.32%	0.06%
10TH GRADE	0.92%	0.01%	0.20%	0.18%	0.30%	0.06%
11TH GRADE	1.05%	0.01%	0.44%	0.32%	0.31%	0.08%
12TH GRADE, NO DIPLOMA	0.85%	0.01%	0.53%	0.25%	0.52%	0.07%
HIGH SCHOOL GRADUATE (INCLUDES EQUIVALENCY)	13.90%	0.04%	9.03%	1.23%	5.12%	0.24%
SOME COLLEGE, LESS THAN 1 YEAR	3.35%	0.02%	4.53%	0.88%	1.99%	0.13%
SOME COLLEGE, 1 OR MORE YEARS, NO DEGREE	7.64%	0.03%	7.75%	1.08%	5.62%	0.25%
ASSOCIATE DEGREE	4.67%	0.01%	5.21%	0.90%	3.42%	0.18%
BACHELOR'S DEGREE	9.84%	0.04%	17.21%	1.57%	17.98%	0.42%
MASTER'S DEGREE	4.56%	0.03%	6.31%	0.95%	8.71%	0.23%
PROFESSIONAL SCHOOL DEGREE	0.84%	0.01%	0.98%	0.37%	2.32%	0.16%
DOCTORATE DEGREE	0.54%	0.00%	0.86%	0.34%	1.58%	0.11%

⁴² U.S. Census Bureau (2012-2016). Sex by Educational Attainment for the Population 25 Years and Over American Community Survey 5-year estimates. Retrieved from https://censusreporter.org/data/table/?table=B15002&geo_ids=16000US5363000,01000US,16000US5320750&primary_geo_id=16000US5363000

Race (2016)⁴³:

	UNITED STATES		EDMONDS, WA		SEATTLE, WA	
	Value	Error	Value	Error	Value	Error
TOTAL:	100.00%	0.00%	100.00%	0.20%	100.00%	0.01%
NOT HISPANIC OR LATINO:	82.67%	0.00%	95.05%	1.43%	93.44%	0.29%
WHITE ALONE	61.95%	0.00%	78.64%	2.06%	65.71%	0.42%
BLACK OR AFRICAN AMERICAN ALONE	12.27%	0.01%	1.12%	0.51%	6.96%	0.32%
AMERICAN INDIAN AND ALASKA NATIVE ALONE	0.65%	0.00%	0.67%	0.30%	0.51%	0.07%
ASIAN ALONE	5.16%	0.01%	9.06%	1.35%	14.05%	0.38%
NATIVE HAWAIIAN AND OTHER PACIFIC ISLANDER ALONE	0.16%	0.00%	0.48%	0.30%	0.39%	0.10%
SOME OTHER RACE ALONE	0.21%	0.00%	0.17%	0.12%	0.23%	0.06%
TWO OR MORE RACES:	2.26%	0.02%	4.91%	1.15%	5.60%	0.26%
TWO RACES INCLUDING SOME OTHER RACE	0.09%	0.00%	0.00%	0.06%	0.06%	0.03%
TWO RACES EXCLUDING SOME OTHER RACE, AND THREE OR MORE RACES	2.17%	0.01%	4.91%	1.15%	5.54%	0.26%
HISPANIC OR LATINO:	17.33%	0.00%	4.95%	1.40%	6.56%	0.28%
WHITE ALONE	11.39%	0.02%	2.54%	0.84%	3.47%	0.22%
BLACK OR AFRICAN AMERICAN ALONE	0.36%	0.01%	0.00%	0.06%	0.14%	0.05%
AMERICAN INDIAN AND ALASKA NATIVE ALONE	0.16%	0.00%	0.00%	0.06%	0.10%	0.04%
ASIAN ALONE	0.06%	0.00%	0.01%	0.03%	0.10%	0.04%
NATIVE HAWAIIAN AND OTHER PACIFIC ISLANDER ALONE	0.02%	0.00%	0.00%	0.06%	0.01%	0.01%
SOME OTHER RACE ALONE	4.54%	0.03%	2.02%	1.14%	1.87%	0.19%
TWO OR MORE RACES:	0.80%	0.01%	0.38%	0.23%	0.87%	0.17%
TWO RACES INCLUDING SOME OTHER RACE	0.39%	0.01%	0.35%	0.22%	0.30%	0.07%

⁴³ U.S. Census Bureau (2012-2016). Hispanic or Latino Origin by Race American Community Survey 5-year estimates. Retrieved from https://censusreporter.org/data/table/?table=B03002&geo_ids=16000US5363000,01000US,16000US5320750&primary_geo_id=16000US5363000

Sound Transit Commuter Map (With 2012-2024 expansion projections)⁴⁴



⁴⁴ "Sound Transit." Sound Transit, soundtransit.org/

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