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The Transportation Burden in Seattle Neighborhoods

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Abstract: Transportation burden has long existed in Seattle; yet few research has looked into the burden on different neighborhoods. This research therefore constructed a linear regression model for estimating transportation burden to explore the geographical disparities. In addition, the significant influence of racial distribution was also analyzed. Future policies may utilize the findings of this research.

1. Introduction

The City of Seattle, along with King County, has developed a sophisticated public transportation system that includes a light-rail link, BRT, streetcars, and buses. Yet, as problems of transportation burden exist given the unbalanced regional development of Seattle neighborhoods, the city is addressing the issue of transportation affordability.

As Litman (2013) defines, transportation affordability is “all households, including those with low incomes” being able to “afford to access basic services and activities”, which suggests each household spend less than 20% of household expense in transportation. According to Roshidi, Baharun, and Masrom (2021), transportation expenditure is one of the major aspects of housing affordability that decide the quality of life. Some researchers therefore identify the combined housing and transportation (CHT) affordability as an important reference, for instance, MR (2019) examines the peripheral region of the Surabaya Metropolitan Area and studies the relationship between the CHT affordability, the housing location and travel behavior. Some also utilize the interval data envelopment analysis (DEA) method that measures, as Dewita, Burke, & Yen (2020) describe, “each housing location’s performance in terms of support, housing, and overall affordability”. Aljoufie and Tiwari (2020) explore the spatial clustering of combined affordability of housing and transportation based on the local indicator of spatial association (LISA). Despite the different approaches, researchers all recognize the value of analyzing the transportation costs.

Regarding the US nationwide circumstance, Jahan and Hamidi (2020) estimate that 44% of residents in metropolitan areas are not affordable in terms of transportation. The low-income households are especially vulnerable to high transportation costs. According to Makarewicz, Dantzler, and Adkins (2020), although households in “location-efficient places” may save enough budget to offset the higher housing costs in these areas, households with very low income are still unable to save enough for their life; such a situation is even more serious in Latin America and

Caribbean countries, where household income is significantly lower (Gandelman, Serebrisky, & Suárez-Alemán, 2019). As to the details of transportation burden in US, Vaidyanathan, Huether, and Jennings (2021) pay attention to the expenses on gasoline across different ethnicities, concluding that the gasoline expense burden of black and Hispanic are higher than the other races. Moreover, Zhou, Aeschliman, and Gohlke (2021) discovered that the average burden of vehicle fuel may reach as high as 8%; whereas the ownership of multiple vehicles may further contribute to the economic vulnerability of households (Hartell, 2018). At the same time, the low-income populations have less access to public transportation than higher-income households, though many of them are relying on it (Fleming, 2018).

In the City of Seattle, some areas also have limited access to public transit, bearing higher transportation cost than others. The City of Seattle thus took the initiative of changing racial disparity and promoting equity in 2005 and launched the Transportation Equity Program, which comprises Low-income Transit Access (ORCA LIFT), Youth ORCA Program, Vehicle License Rebate Program (Car Tab Rebate Program), Low-Income Car Share, and Community Conversations & Ambassador Program (Seattle Channel, 2016). In 2015, former Mayor Ed Murray also started a 10-year strategic vision for Seattle's transportation system that gives "all people high-quality and low-cost transportation options that allow them to spend their money on things other than transportation" (SDOT, 2015). However, before further improvement on transportation affordability, some questions remain unanswered. How is the transportation burden distributed across neighborhoods? How heavy is their burden? What are some factors that contribute to this burden? These are the most fundamental issues that relate to the future of transportation in Seattle. Therefore, as part of a larger transportation affordability research program, this paper focuses on the above three questions and aims at depicting a comprehensive picture for the city planners.

2. Research Design

2.1 The Transportation Cost Model

To understand how transportation cost in Seattle varies from neighborhood to neighborhood, an estimating model should be constructed. Litman (2021) introduces a Housing and Transportation Affordability Index that calculates the housing and transportation costs over income for households, based on real estate market and census data. Similarly, using the available 2016 ACS data and additional data from the Census and Puget Sound Regional Council's Transportation Survey, we constructed a transportation cost model. The variables in the ACS data used include 9 categories: Geo ID, Population, Race, Means of Transportation, Travel Time from Home to Work, Employment, Household, Income, and Rent. The input variables from other sources include National Average Car Cost, National Work Days, Average Transit Fare, Average Taxi Cost, National Average Motorcycle Cost, and National Average Bicycle Cost. The linear regression model produces six final outputs: Average Transportation Cost; Average Transportation Cost as Percentage of Income; Average Household Transportation Cost; Average Household Transportation Cost as Percentage of Income; Transportation Burden Index.

Each of these variables are essentially helpful for evaluating Seattle's neighborhood-level situations. Based on the first five variables, a Transportation Burden Index was created that concludes the transportation burden distribution with a single number for each neighborhood. With this index we are able to tell which neighborhood has the highest transportation burden. Using the Transportation Cost Model, several maps were created, showing the areas that are most impacted.

2.2 Modeling

The ACS data provides the number of commuters of each transportation type – Car Alone, Carpool, Transit, Taxi, Motorcycle, Bike, Walk, Home, and Other. As shown in *Figure 1*, Car Alone, Transit, and Carpool are the three most frequent types of transportation. A certain portion of residents choose Walk, Bicycle, and Home. Nevertheless, since Walk and Home do not involve any transportation cost, and very few people choose Other, these types were ignored in our model.

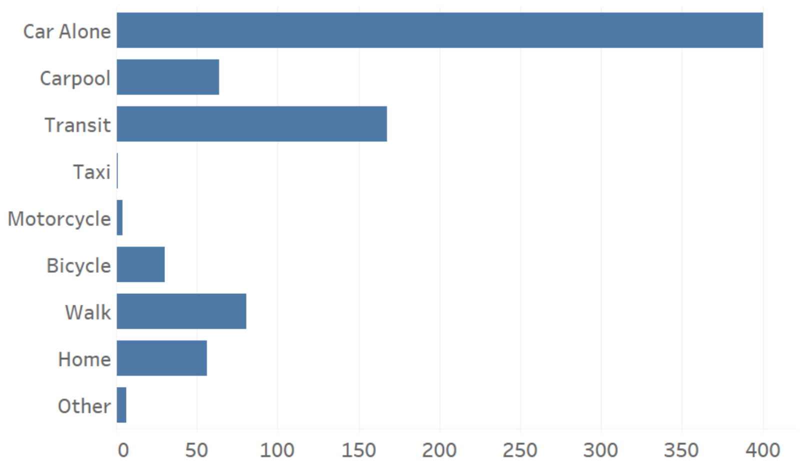


Figure 1: The Average Number of Commuters of Each Transportation Type

The fundamental idea of this model is to use these numbers multiplied by the average cost of each type to get the total transportation cost for each neighborhood. The entire modeling process involves the following 4 steps.

2.2.1 Step 1: Determine the Average Cost of Each Type

For vehicles, such as car, motorcycle, and bicycle, the national/ King County average costs (constant numbers from other sources) were used as the basis, adjusted by the Per Capita Income and Travel Time from Home to Work of each neighborhood. That is:

- If a neighborhood has higher income, the average cost would be higher.
- If a neighborhood has more residents who spend more time on commuting, the average cost would also be higher.

The basic equation for the Average Cat Cost (ACC) is as follows:

$$ACC = NACC + a * PCI + WTT$$

Where:

- a = The Weighting for Per Capita Income
- ACC = Average Car Cost of a Given Census Block Group
- NACC = National Average Car Cost
- PCI = Per Capita Income of a Given Census Block Group
- WTT = Weighted Travel Time from Home to Work

For transit and taxi, constant numbers were used as average costs. As in *Figure 2*, most commuters take bus; few choose subway; barely anyone use other transits. This suggests that the average cost of other transit methods would not significantly affect the total transit cost. Therefore, the average cost of all kinds of transit is set at a constant rate of $2.75 per trip[1].

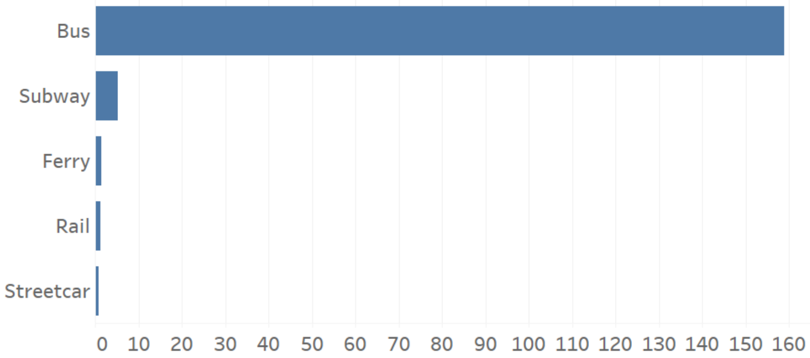


Figure 2: The Average Number of Commuters of Each Transit Types

2.2.2 Step 2: Calculate the Total Cost of Each Type

The number of commuters of each type of transportation was used to calculate the total cost. However, as *Figure 3* demonstrates, the population of means of transportation only covers the working population, which is significantly less than the total population.

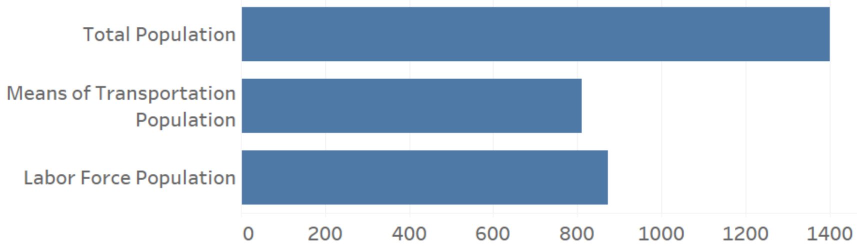


Figure 3: Population, Labor Force, & Transportation

Considering that the nonworking population, such as students, senior residents, etc., also has certain transportation demands, in the current step, the model assumes they have similar transportation consumption behavior as the working population. In other words, to include the transportation consumption of the nonworking population, the model proportionally expanded the number of each transportation type to cover the entire population. For example, the calculation of Total Car Alone Cost is as follows[2]:

$$TCAC = ACC * CA * (TP / MTP)$$

Where:

- ACC = Average Car Cost of a Given Census Block Group
- CA = Population of Driving Car Alone in a Given Census Block Group
- TCAC = Total Car-Alone Cost of a Given Census Block Group
- TP = Total Population of a Given Census Block Group
- MTP = Means of Transportation Population of a Given Census Block Group

2.2.3 Step 3: Calculate the Total Cost and Adjust It by Employment Status

[1] the single trip fare within King County

[2] The calculation for bicycle and motorcycle follows the same algorithm.

Since the nonworking population might not have as much demand as the working population, the model adjusted the total cost by the percentage of unemployed/ not labor force population, which means:

- If a neighborhood has a larger percent not working, the transportation cost would be lower down, and vice versa.

The fundamental equations of this step are:

$$TTC = TCAC + TCCC + TTSC + TTXC + TTMC + TTBC$$

$$ATTC = TTC + i * (LFU + NLF)$$

Where:

- ATTC = Adjusted Total Transportation Cost of a Given Census Block Group
- i = The Weighting for the Not Employed Population
- LFU = Unemployed Labor Force Population of a Given Census Block Group
- NLF = Not Labor Force Population of a Given Census Block Group
- TCAC = Total Car-Alone Cost of a Given Census Block Group
- TCCC = Total Car-Carpooled Cost of a Given Census Block Group
- TTC = Total Transportation Cost of a Given Census Block Group
- TTBC = Total Bicycle Cost of a Given Census Block Group
- TTMC = Total Motorcycle Cost of a Given Census Block Group
- TTSC = Total Transit Cost of a Given Census Block Group
- TTXC = Total Taxi Cost of a Given Census Block Group

2.2.4 Step 4: Determine the Weighting Coefficients by Linear Model Fitness

The above steps involve 3 constant coefficients: a coefficient to weight income (step 1); a coefficient to weight travel time (step 2); a coefficient to weight the nonworking population (step 3). To choose the most appropriate numbers, the model:

a) defined a reasonable range for each coefficient;
b) constructed a linear model that regresses the transportation cost on the basic input variables and other related variables;
c) tested the fitness under each combination of numbers and found the best numbers.

2.3 Key Assumptions

Following these four steps, the transportation costs were calculated for each neighborhood. A validation test for the results was conducted and the data was proven to be robust. But there are several important assumptions under this model that should be notified:

- National/ King County Average Costs represents the average cost level of Seattle neighborhoods. With no available average vehicle cost, the model assumes this statement is true for the calculation of Average Bike Cost, Car Cost, and Motorcycle Cost.
- Individuals with higher income may purchase higher-value vehicles. This is important for differentiating the average vehicle cost of each neighborhood.
- Individuals with longer Travel Time from Home to Work may spend more on gas, hence having higher car cost. This is another key aspect to adjust the average vehicle cost of each neighborhood.
- Total Population in a given census block group has similar behavior as Means of Transportation. Since there is no direct data on the transportation behaviors of the non-working residents, we need to assume they behave similarly to (but consume less than) the working population.

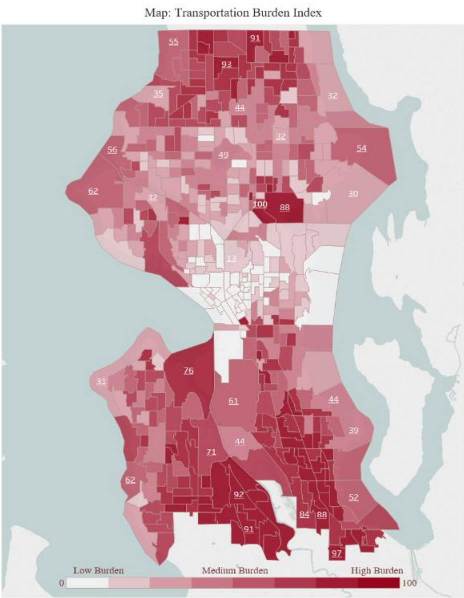
- All Seattle residents work within the area of King County. This is the prerequisite for fixing the Average Transit Cost and Average Taxi Cost.
- All commuters travel twice a weekday (from home to work/ from work to home) during peak hours.

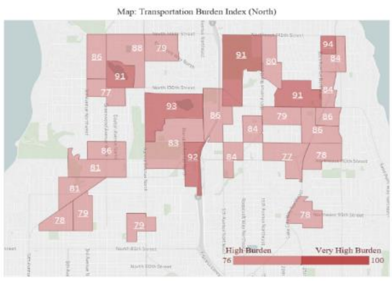
3. The Transportation Burden

3.1 The Overall Situation

The Transportation Burden Index (TBI) was calculated based on the census block groups' rankings of transportation costs (including individual & household levels) as percentages of income. By design, the TBI score ranges from 0 to 100. As shown in *Figure 4*, Transportation Burden varies from area to area. South Seattle and University District have many burdened neighborhoods, while some neighborhoods in North Seattle also bear high transportation costs.

The situations of the cost burdened areas (TBI >= 75) are displayed in the three specific maps. In the north, many neighborhoods have high burdens, such as Haller Lake (93), Bitter Lake (91), Liction Springs (92), and Olympic Hill (91), which are usually near parks or highways/ major streets. In University District (mid-north), Portage Bay (91), NE Campus Parkway (100), the neighborhood to the north of Burke Museum (98), and the neighborhood next to I-5 (92) are particularly cost-burdened. They mostly consist of student accommodations. The north area of North Queen Anne (92) also has very high burden. In South Seattle, most heavily-cost-burdened neighborhoods are located on both sides of the Boeing Airport, such as Dunlap (99) and White Center (99). Beyond these areas, North Beacon Hill (90), the neighborhood to the northwest of International District (99), and two neighborhoods to the south of High Point (97 and 96) also have very high burdens.





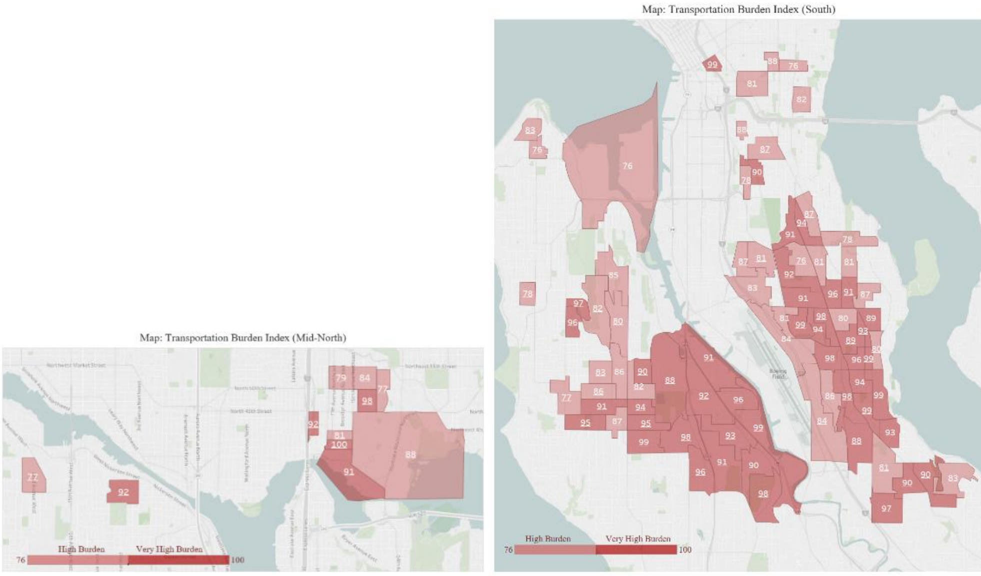


Figure 4: Maps of Transportation Burden Index

The key takeaways from these maps are:

1) South Seattle neighborhoods usually have very high transportation burden.
2) Downtown Seattle has the lowest transportation burden in comparison with other areas.
3) University District has particularly high transportation burden.
4) Some neighborhoods in West Seattle and some near the north boundary of Seattle also endure high transportation burden.

3.2 The Burdened Neighborhoods

In this section we'll analyze the neighborhoods under high transportation burdens. There is a total of 125 cost-burdened neighborhoods (TBI >= 75).

3.2.1 Average Transportation Cost (ATC)

Figure 5 suggests that the mean of the ATC of these neighborhoods is $7,986 while the median is $8,174. Most neighborhoods have an ATC between $6,000 and $10,000; very few neighborhoods fall beyond this interval. In terms of percentage, as in *Figure 6*, on average these neighborhoods' ATC is as much as 33.6% of their per capita Income. The median is lower: 29.9%. The figure above shows that most neighborhoods are below 40%, but several outliers significantly raise the mean.

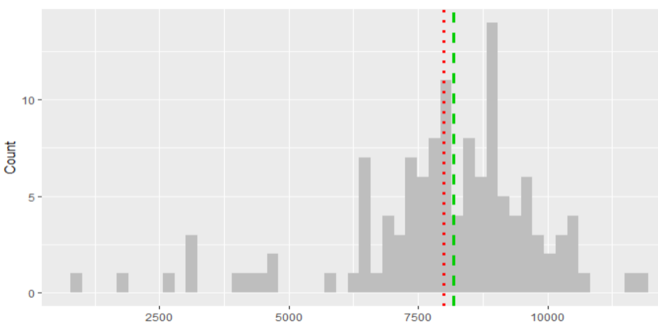


Figure 5: Average Transportation Cost (Burdened Neighborhoods)

Cost (Red = Mean; Green = Median)

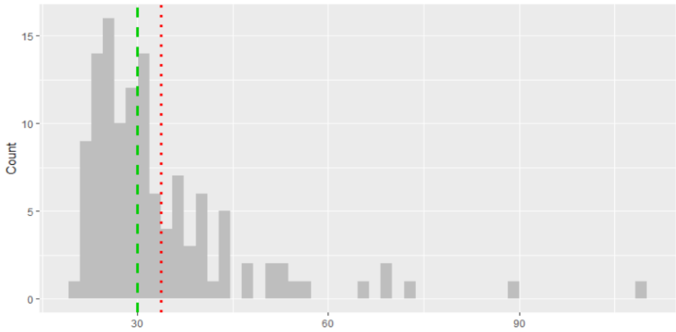


Figure 6: Average Transportation Cost Percentage (Burdened Neighborhoods)

Cost Percentage (Red = Mean; Green = Median)

In the North, most burdened neighborhoods have a percentage between 20% and 30%, while several exceptions are higher, e.g., Haller Lake (36%), Bitter Lake (31%), Liction Springs (34%), Olympic Hill (38%), etc. In University District (Mid-North), there are three neighborhoods having a percentage greater than 30%. As mentioned, the fact that these areas are mostly student residents may account for the unusually high percentage. In South Seattle, many neighborhoods have a percentage higher than 30%. Some neighborhoods like East Dunlap even reached 88%. Such high percentages may occur as a result of the fact that some of them consist of many non-working populations.

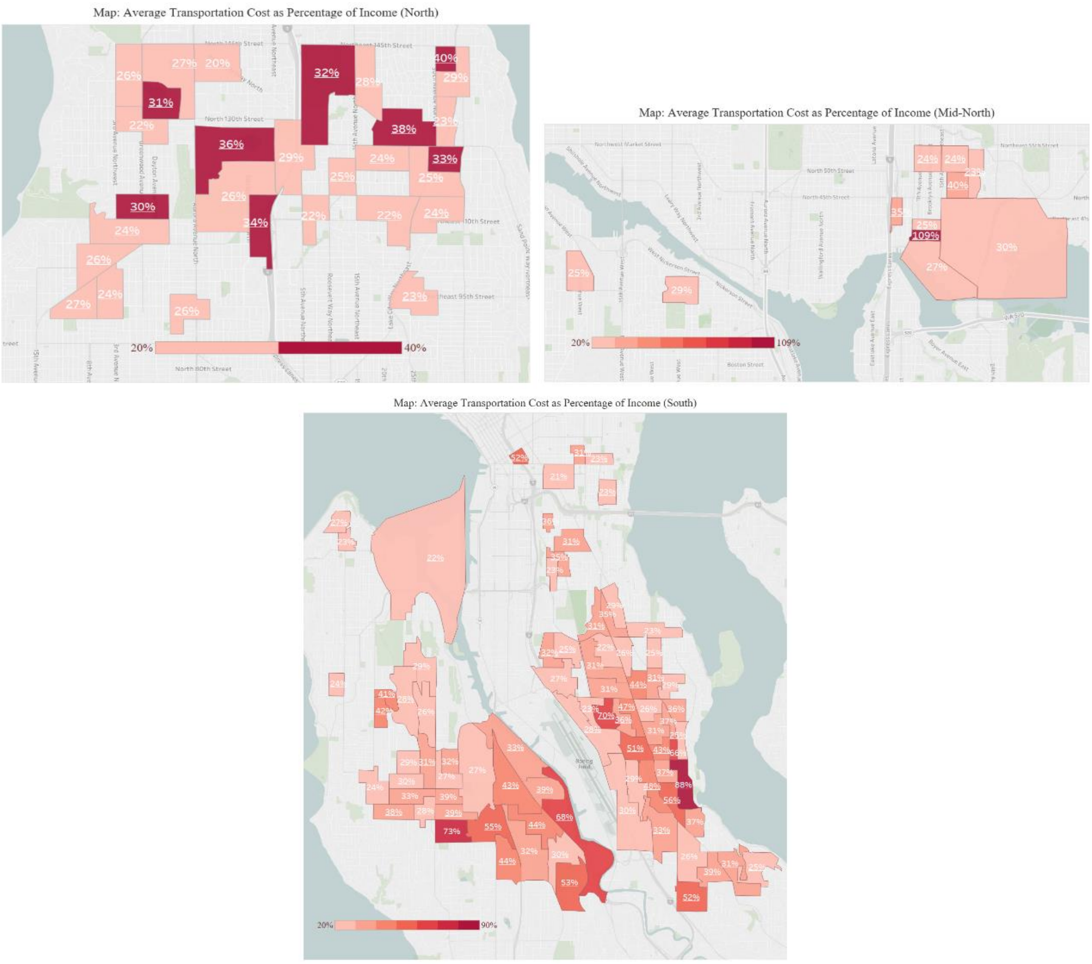


Figure 7: Maps of Average Transportation Cost Percentage

3.2.2 Average Household Transportation Cost (AHTC)

On average, each household in the burdened neighborhoods spend $21,339 on transportation. The median is almost the same ($21,289). *Figure 8* indicates how AHTC distributes across these areas. Most neighborhoods center around $21,000, from $15,000 to $30,000. Very few neighborhoods have extremely high AHTC. *Figure 9* shows how the AHTC as percentage of Median Household Income looks like. Similar to the individual percentage, the several outliers (greater than 50%) significantly drag the average (red line) to the right side. In other words, most neighborhoods are below 50%; only few passed 50%.

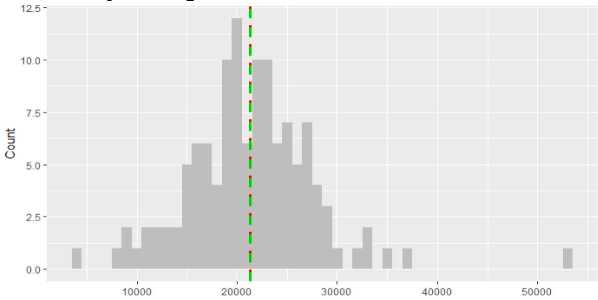


Figure 8: Average Household Transportation Cost (Burdened Neighborhoods)

Cost (Red = Mean; Green = Median)

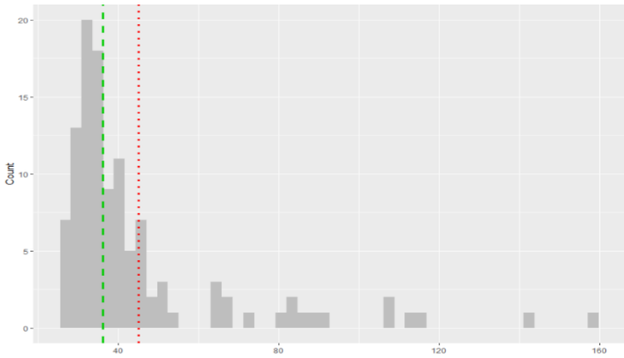


Figure 9: Average Household Transportation Cost Percentage (Burdened Neighborhoods)

Cost (Red = Mean; Green = Median)

Looking at the geographic distribution illustrated in *Figure 10*, nearly half of the burdened neighborhoods in the North have a percentage greater than 35%. Most neighborhoods are at least 30%. This is much higher than the individual level situation, where only about 1/3 neighborhoods are above 30%. In University District (Mid-North), unsurprisingly, some neighborhoods have extremely high percentages. However, what's alarming on this map is that the north part of North Queen Anne also reached 64%. In the South, most neighborhoods exceed 30%. The areas around Dunlap and South Beacon Hill have very high percentages. The Southwest also have many neighborhoods higher than 40%.

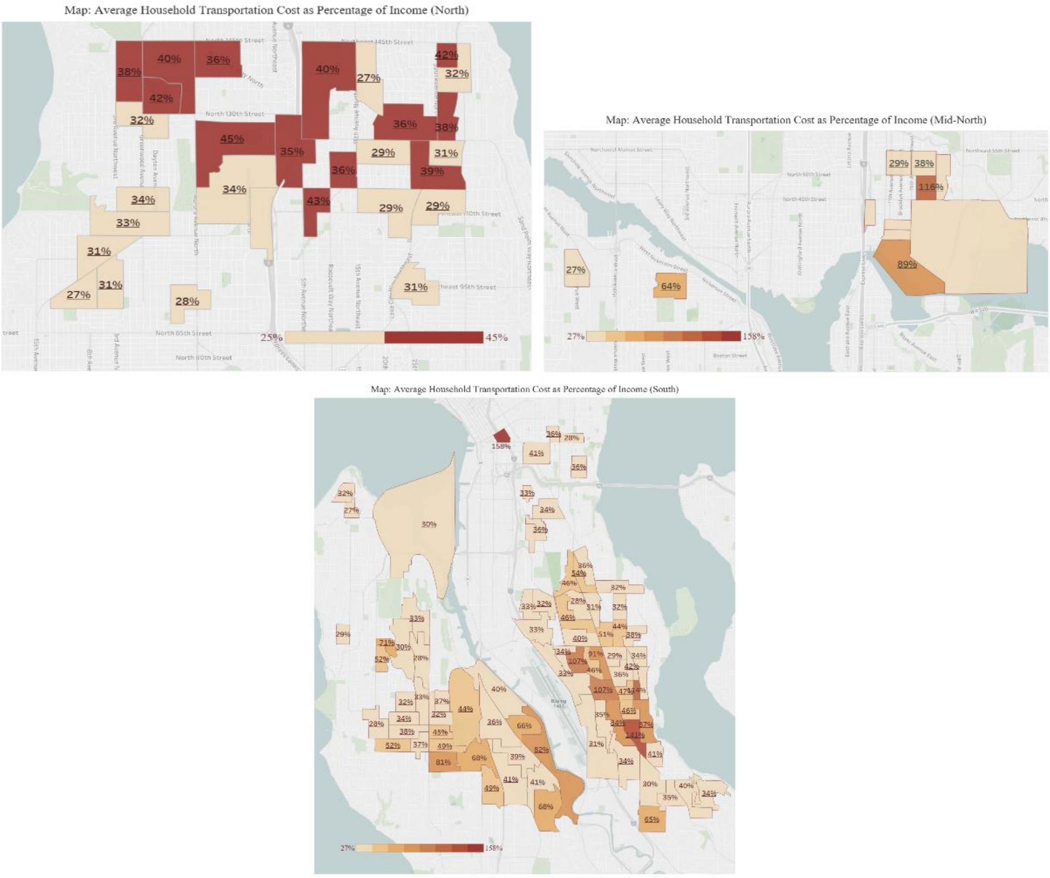


Figure 10: Maps of Average Household Transportation Cost Percentage

3.3 Transportation Burden and Race

In terms of why there is regional difference on transportation burden, Race is an important factor. The three major races are White (68.7%), Black (7.3%), and Asian (14.1%). We can find strong correlations between TBI and these races.

3.3.1 The White Population

In *Figure 11*, we can clearly see the tendency of decrease in TBI as White population increases. Neighborhoods having higher White population usually have lower TBI. If we break down TBI into details (individual/ household cost percentages), the figures indicates that higher White population neighborhoods tend to spend less percentage of income on transportation cost on both individual and household levels.

The individual cost percentage of those neighborhoods with a White percentage higher than 60% tend to stay around 15%, as *Figure 12* suggests. The linear tendency is that, ignoring other factors, the Average Transportation Cost Percentage will decrease by 0.31% as White population increases by 1%. The situation on household level cost percentage is similar. As shown in *Figure 13*, When White population is below 60%, Household Cost Percentage drops quickly as White population increases. Above 75%, the percentage stays around 20%. The Household Cost Percentage and White population percentage roughly follows this linear relationship: ignoring other factors, the Average Household Transportation Cost Percentage will decrease by 0.45% as White population increases by 1%.

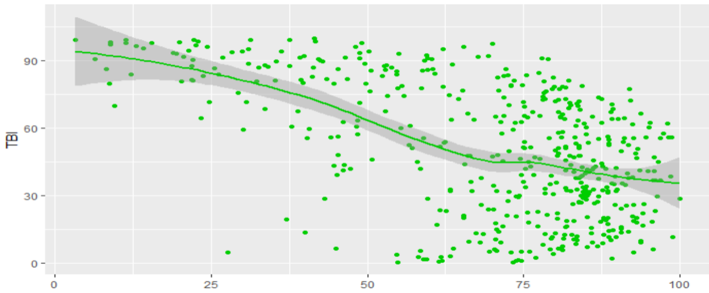


Figure 11: Transportation Burden Index and White Population Percentage

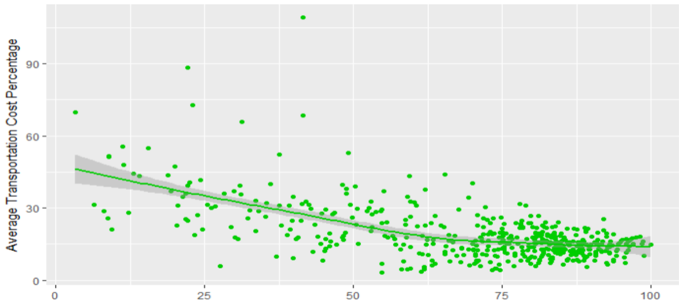


Figure 12: Individual Cost Percentage and White Population Percentage

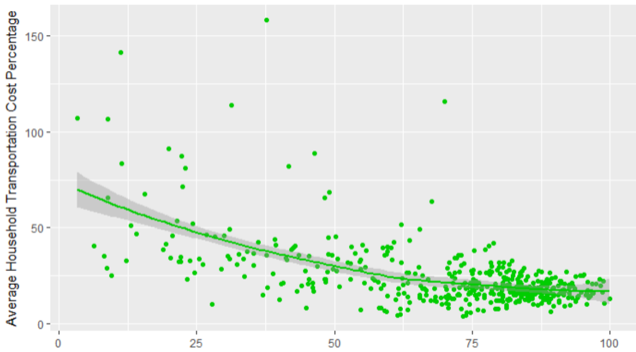


Figure 13: Household Cost Percentage and White Population Percentage

3.3.2 The Black Population

The situation of the Black population is exactly opposite to White population. As shown in *Figure 14*, the Transportation Burden Index would significantly increase as Black population increases. Looking at the details on individual level as revealed in *Figure 15*, the cost percentage will increase by 0.57% as Black population increases by 1%, while other factors are held constant. We can see that regression curve is very close to linear, suggesting the linear correlation that we mentioned is highly evident. *Figure 16* suggests that the household level relationship is also linear-like. The results returned from our linear model regression interpret their relations as: ignoring other factors, the Average Household Transportation Cost Percentage will increase by 0.90% as White population increases by 1%.

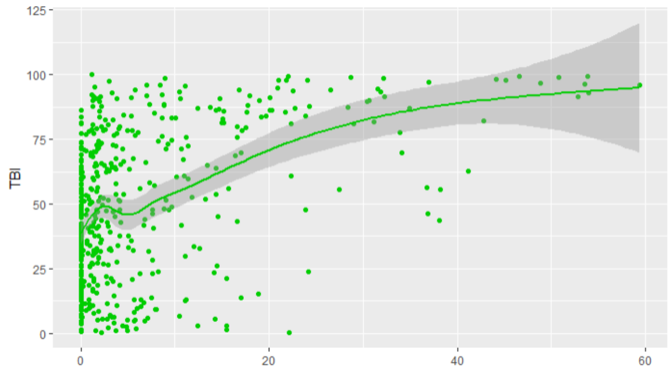


Figure 14: Transportation Burden Index and Black Population Percentage

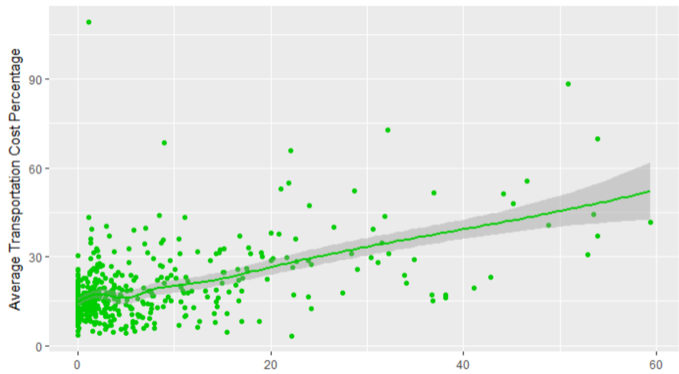


Figure 15: Individual Cost Percentage and Black Population Percentage

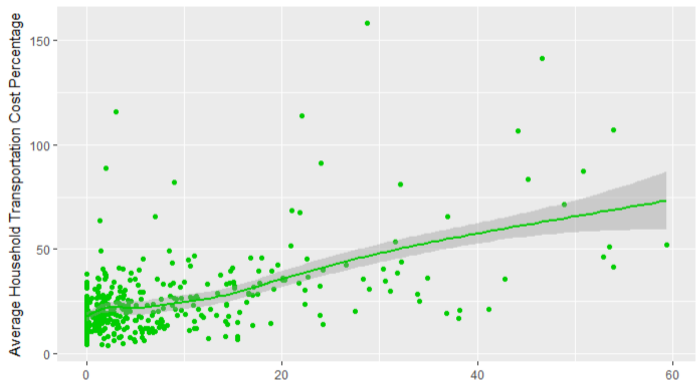


Figure 16: Household Cost Percentage and Black Population Percentage

3.3.3 The Asian Population

The relations between transportation burden and Asian population are not as strong. *Figure 17* demonstrates a curvy regression line with slightly larger shading areas than previous figures. This means the correlation between TBI and Asian population is not as strong. But we can still find an obvious increasing tendency when Asian population is below 50%. The correlation between individual cost percentage and Asian population is evident. If we interpret the *Figure 18* linearly, we can find that the Average Transportation Cost Percentage will increase by 0.27% as Asian population increases by 1%. The household level situation (*Figure 19*) looks identical to the individual level. Our linear regression model reports that the Average Household Transportation Cost Percentage will increase by 0.38% as Asian population increases by 1%.

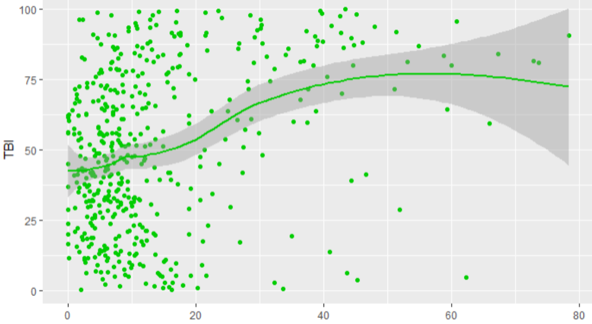


Figure 17: Transportation Burden Index and Asian Population Percentage

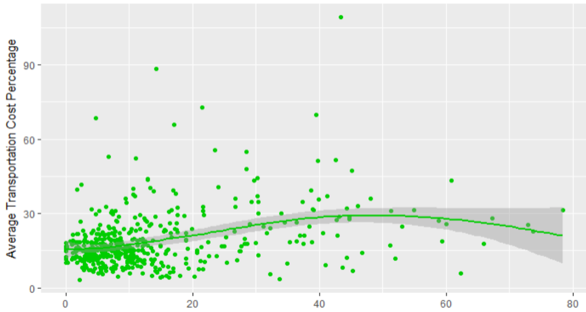


Figure 18: Individual Cost Percentage and Black Population Percentage

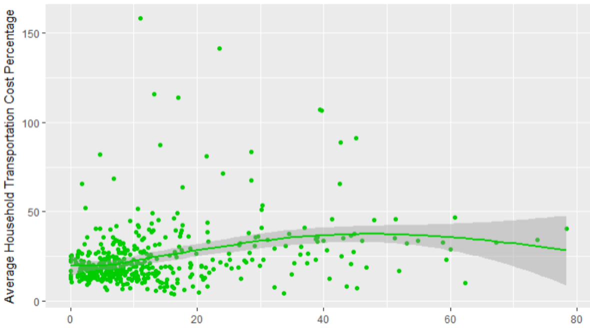


Figure 19: Household Cost Percentage and Black Population Percentage

4. Summary and Conclusion

Despite the advanced public transit system and the continuous effort on equity promotion, transportation burden still exists in many areas of Seattle. Utilizing the Transportation Cost Model and the 2016 ACS data, this research is able to decipher the detailed situations of how the transportation burden distributes across neighborhoods and how heavy their burden is, while also looking into some factors that contribute to this burden. There are some valuable findings:

1) South Seattle neighborhoods typically have very high transportation burden. Many of them have a percentage of average transportation cost over income higher than 30%, both on individual level and household level.

2) In the northern areas, most burdened neighborhoods have a percentage of average transportation cost over income between 20% and 30%, individually speaking. Nevertheless, most of them exceeds 30% on household level, while half of them are even greater than 35%.
3) Transportation burden has a strong correlation with racial distribution. The burden decreases as White population increases. Neighborhoods having higher White population usually have lower burden. With a White population above 75%, the percentage of average household transportation cost over income stays around 20%. In contrast, the same percentage cost increases by 0.90% as Black population increases by 1%.

The three findings present us a clear direction for future research and policy improvement. First, further survey and interviews should be conducted for the highly burdened neighborhoods, especially whose percentage of average household transportation cost over income exceeds 20%. Extensively detailed data of their background should be collected. Second, neighborhoods that have higher black population percentages should be paid attention to. Researchers should explore the reasons why they spent a significant larger proportion of their income in transportation. Third, policies or programs should be introduced for the interests of the burdened neighborhoods, especially those who enjoy less accessibility to public transit. Resources should be allocated primarily for these communities.

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