

**SCHOOL OF PLANNING AND PUBLIC AFFAIRS
UNIVERSITY OF IOWA**

**APPLIED GIS FOR PLANNING AND POLICY MAKING
FINAL PROJECT**

**TOPIC: CONNECTING THE DOTS: MAPPING THE DETERMINANTS OF THE USE OF
SUSTAINABLE MODES OF TRANSPORTATION IN THE SACRAMENTO REGION**

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Abstract

The crucial role of transportation in cities' growth cannot be undermined, and it is in the same vein that its negative repercussions cannot be underestimated. With growing concerns about high automobile use, citing its grave impact on greenhouse gas emissions, communities and governments are working tirelessly to reduce its usage. Even in the face of such policies, using automobiles and/ or personal cars still persists in many jurisdictions. This makes it imperative for more empirical studies to understand why people behave the way they do with respect to transportation. This study, therefore, contributes to this by using ArcGIS Pro to spatially analyze the relationship between household size and income on modes of transportation. Using data from the American Community Survey 2023 and the Sacramento Regional Transportation Study 2018, the study reveals a positive correlation between household size and income on the number of cars in a household and the primary mode of transportation people use in the six counties in the Sacramento region. The study, therefore, concluded with some policy recommendations that could help meet the targets of using more sustainable modes of transportation and what should guide future studies to ensure a more comprehensive understanding of the phenomenon.

1.0 Introduction

Transportation is an inevitable activity in our lives. Transportation refers to the movement of people and commodities within urban centers by various modes such as private vehicles, public transport, and non-motorized transportation systems. It also includes services, infrastructure, and regulations that make movement inside urban centers easy and comfortable. Arguably, it is widely accorded as the prime factor that breathes life into cities. However, since the inception of sustainability as a concept and a development agenda, transportation has been viewed as a cancer in the body politic of cities. The intensity of discussions grows as climate change, with its spreading effects on almost all aspects of cities' economic growth, becomes critical. Nevertheless, individuals have preferences as to which mode of transport they want to use to reach their activity areas, such as the workplace, school, health, entertainment, etc. Notwithstanding, certain factors trigger people to rely on specific modes of transportation over others, such as personal cars, public transit, walking, and biking, among others.

Nevertheless, empirical evidence has shown that the high usage of certain modes of transportation, such as automobiles, is considered unsustainable as it endangers the natural environment.

However, other modes of transportation, such as active transportation (biking & walking), mass transit, and ridesharing, are highly affirmed as more sustainable, albeit they generally record low patronage (Abduljabbar et al., 2021; Eren & Uz, 2020). This has posed a clarion call for transportation planners to ascertain this phenomenon and formulate informed policies ensuring modal shift to more sustainable modes. Notwithstanding, achieving this target heavily relies on ascertaining what informs people's modal choice. Arguably, this fact still hangs in the balance and remains dangling in global sustainability discourse, although some factors have been spotted as having impacts on people's modal choices, for instance, income, household size, and frequency of travel (Bak et al., 2022; Jing et al., 2020; Tirachini, 2020). This study, therefore, seeks to contribute to this ongoing discourse by using ArcGIS Pro to map the usage of various modes of transportation in the Sacramento Region against the above-mentioned potential influencers. The findings from this study will be analyzed in comparison to empirical evidence from other replica cities to make informed policy recommendations.

2.0 Literature Review

2.1 Relationship between income and mode of transportation

Income is a critical factor in understanding socioeconomic position and travel habits. Lower-income individuals are more likely to use non-motorized modes or public transportation (Buehler et al., 2020). Results of a survey by Harsha & Ashish, (2022) in India revealed that low-income groups of both sexes mainly use public transit. In contrast, high-income groups use personal vehicles as they perceive them to be affordable. Again, a study in the Jakarta Metropolitan Area in Indonesia unraveled that there is a negative correlation between income and the use of public transit; thus, the patronage of public transit services declines as income increases (Maulana & Yudhistira, 2020). According to Hansa & Susilowati, (2020) also, most people in low-income groups predominantly use modes such as mass transportation (bus) services, motorbikes, and walking to work. However, distance from the workplace influences their findings, though it is minor. For low-income individuals, accessibility has a more pronounced and non-linear effect on public transportation mode share, particularly in the largest cities, where public transportation mode share will decline if accessibility rises above a certain ideal level (Cui et al., 2020). It is again reaffirmed that income levels influence people's use of public transportation for work trips in Ontario, Quebec (Mercado et al., 2012). A study in the USA also suggests that lower-income

inhabitants are more likely to use public transportation and tend to use it more for longer distances (Alexandra K. et al., 2022; Bemanian & Mosser, 2023).

2.2 Relationship between Household size and mode of transportation

One critical issue that drives people's choice of mode of transportation is household size. According to Sovacool et al., (2018) In the Nordic region, larger households are more likely to acquire more private vehicles. Changes in household population have a significant impact on car usage. According to Feng et al., (2011), the aggregate demand for car use over the past few decades has been significantly impacted by changes in American households. The further posited socioeconomic status is intrinsically linked to vehicle ownership and usage by establishing that the size, income, and type of the household, as well as the race, sex, and age of the head of the household, have a significant impact on the acquisition of vehicles by the family. However, when urban and rural households' car ownership patterns are compared by Choudhary & Vasudevan, (2017), they found that in India, rural households are more likely to own a private vehicle than urban households with comparable incomes.

The changing preferences and size of the household over time give rise to dynamic concerns in the vehicle ownership dilemma. Many factors influence changes in taste. Households can create habits that serve as the foundation for changes in taste by becoming accustomed to a particular car or model of vehicle based on past decisions (Mannering & Winston, 1985; Ma & Ye, 2019). Meanwhile, Feng et al., (2011) forecasted that there would be 235 million household vehicles overall in 2025, a 31% increase over the previous 25 years. The consumption of vehicles accounts for around half of the increase, although household consumption of vans will rise more quickly than that of cars and trucks.

2.3 Effects of Automobile Usage

According to the Environmental Protection Agency (1993), the average American family spent \$1,161 on fuel for their cars in 1991. Family automobiles were responsible for 13% of the nation's overall energy use and 31% of its petroleum usage. Even though the average fuel economy grew by 44% between 1966 and 1991, vehicle and light truck fuel consumption rose by 60% during the same time (Schmalensee & Stoker, 1999). In recent years, transportation accounts for a significant portion of both energy consumption and emissions. According to Li et al.,(2019) in the US, the

transportation sector used 29% of energy in 2017 and released 28% of greenhouse gas emissions in 2016. In the US, over the past few decades, laws pertaining to car emissions and fuel economy have become stricter due to worries about global warming, pollution, and rising fuel prices.

Due to this ongoing phenomenon, communities and governments around the United States (US) have been on a fervent mission to encourage people to switch from driving to more environmentally friendly modes of transportation, in order to decrease vehicle ownership and single-occupant travel and increase the sustainability and efficiency of transportation systems (Liu & Cirillo, 2015; Zhang & Zhang, 2018). Relatedly, several other emerging factors, such as carsharing and public transit, have been noted as a key factor that can minimize household car ownership by removing the requirement for a separate vehicle for non-work-related travel (Martin & Shaheen, 2011). In this sense, car sharing gives users access to a vehicle just when they need it. Usually, multiple people use a shared car during the day.

3.0 Methods and Materials

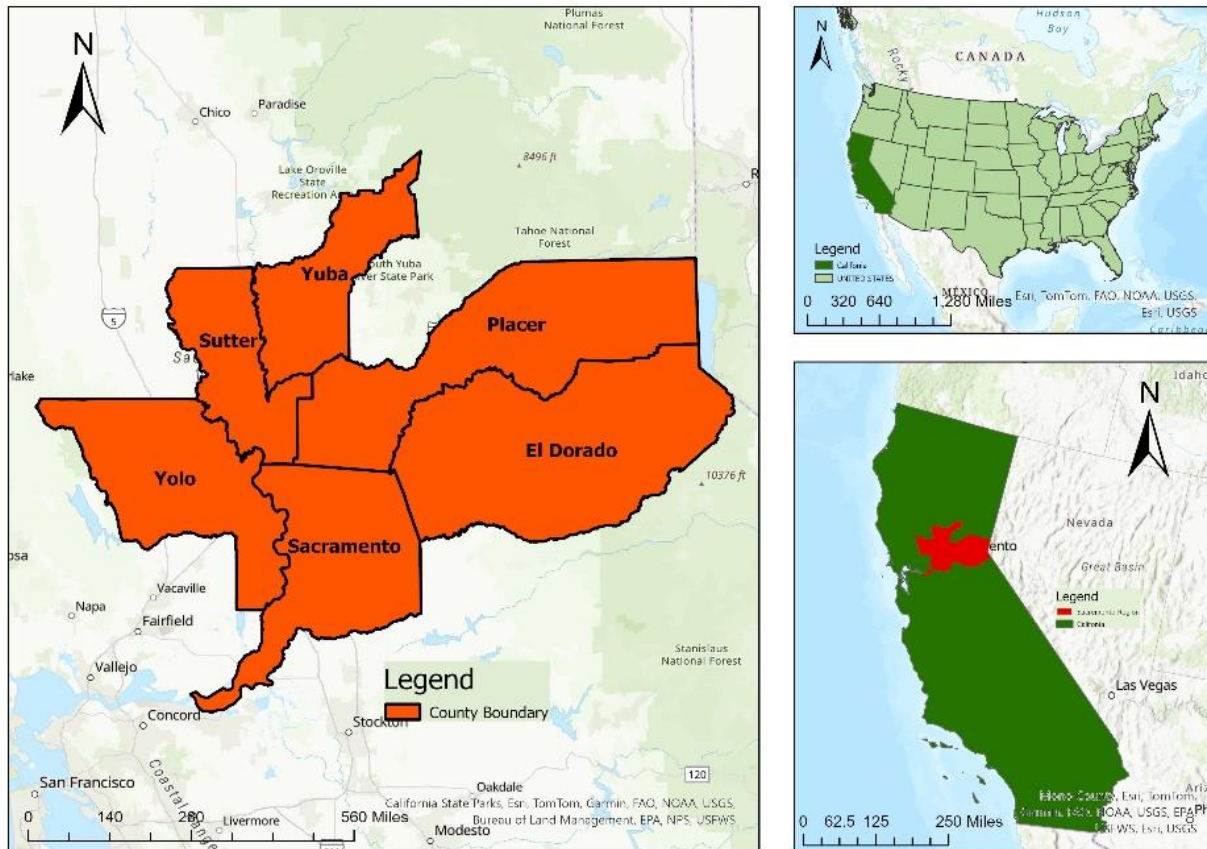
Having identified the topic of interest for the study, a literature review was conducted to help understand the topic and what already exists. The purpose was to give a glimpse into the state of the identified variables in the literature. As the foregoing sections have established, the study maps income, household size, number of vehicles in households, and fuel type used in the region. Data for this study were mainly sourced through secondary sources, i.e., the American Community Survey 2023 and the Sacramento Regional Transportation Study 2018 collected from April 10 to May 21, 2018, with a sample size of 4,010 according to (Rosenson, 2018). The data used primarily includes the modes of transportation by residents of Sacramento Regional, income, household size, number of vehicles per household, number of trips, and fuel type. The data was then cleaned upon sourcing using Microsoft Excel and Python. Spatially, the plotting was done by the Traffic Analysis Zone since that was the primary reference for geographic coordinates. However, the analysis was done based on counties using generalization. Correlation tests were also run using Python to further ascertain the result quantitatively. Choropleth and dot density mapping techniques were used to for the spatial visualization of the study variables.

The study was conducted in the Sacramento Region, which, according to the ACS-23, has over 2.5 million people as of 2023. The region comprises six counties, with Sacramento County headlining it as the major city, with the other 20% of the region's population. The counties in the region are

Placer, El Dorado, Yuba, Yolo, Sutter, and Sacramento. It is worthwhile to note that the majority of residents in the region are people of color (*SACOG 2024 Progress Report, 2024*). The region is situated in the northeastern part of California.

Figure 1

CONTEXTUAL MAP OF THE SACREMENTO REGION



Source: Author's construct

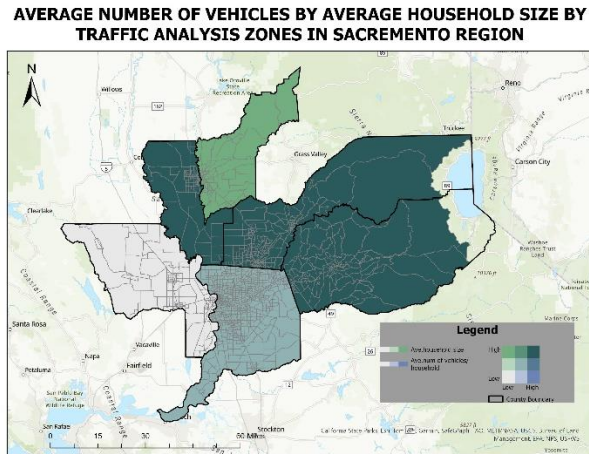
4.0 Results

This section of the report presents the key results of the study. It reports on how the household size influences the number of vehicles a household owns. It also spells out the income distribution pattern using the median household income for the respective counties in the region. A map visualizing the modes of transportation is also shown to determine key patterns. Last but not least, the vehicle fuel type is also visualized.

4.1 Household size and vehicle ownership

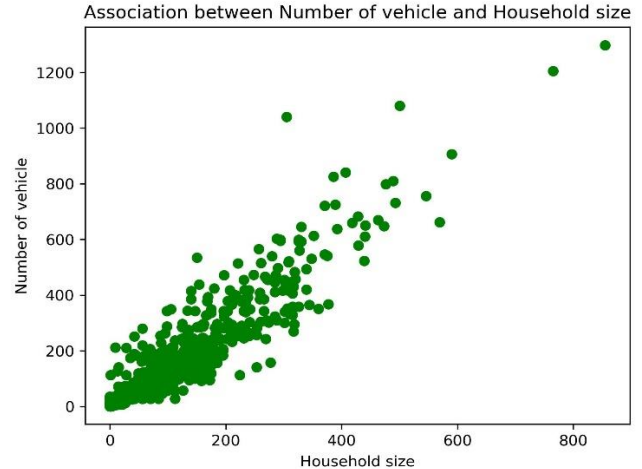
As is outrightly established in literature, the number of people in a household considerably influences how many vehicles or cars they have. Meanwhile, there has been massive policy attention aimed at reducing the use of personal cars. However, higher personal car ownership is tantamount to high usage. Figure 2 shows that in the Sacramento Region, household size actually has some appreciable influence on how many cars a household owns. Using the household population and number of cars in a county, Figure 3 shows that a household size correlates positively with the number of vehicles in a household: the higher the household size, the higher the number of vehicles. A Spearman correlation coefficient of 0.9 with a p-value of 0.001 shows a strong correlation between the household population and the number of vehicles. The Yolo County shows a low household size and a low number of vehicles a household owns. Also, the Placer and El Dorado counties exhibit high household size and a high number of vehicles per household.

Figure 2



Source: Author's construct

Figure 3

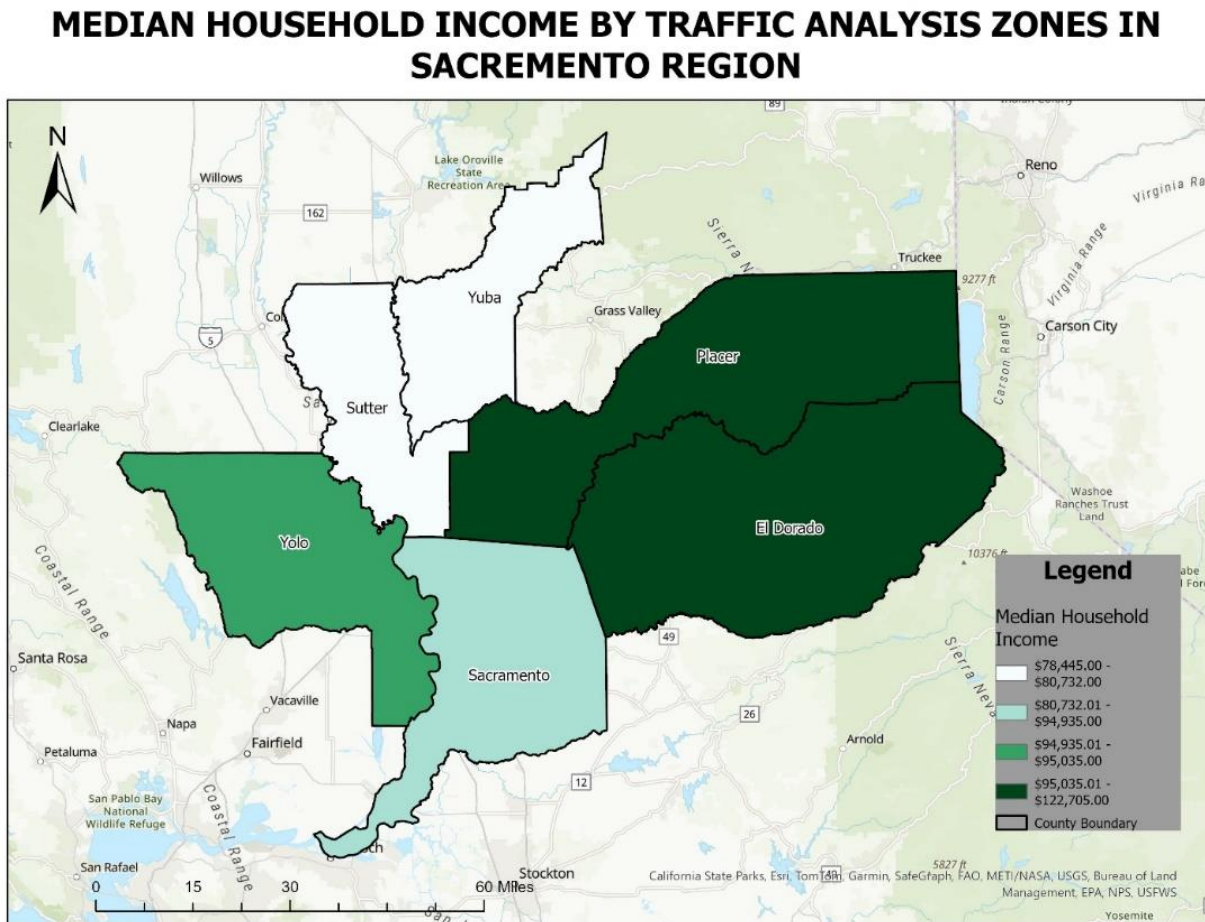


4.2 Income distribution pattern

Income has been captured as a major determinant of the primary mode of transportation used by individuals and households. Figure 4 shows the income distribution pattern in the Sacramento Region. The map shows that Placer and El Dorado counties have the highest median household

income. Yolo and Sacramento counties follow, even though Yolo has a higher median income than Sacramento. The counties with the lowest median household income are Sutter and Yuba.

Figure 4



Source: Author's construct

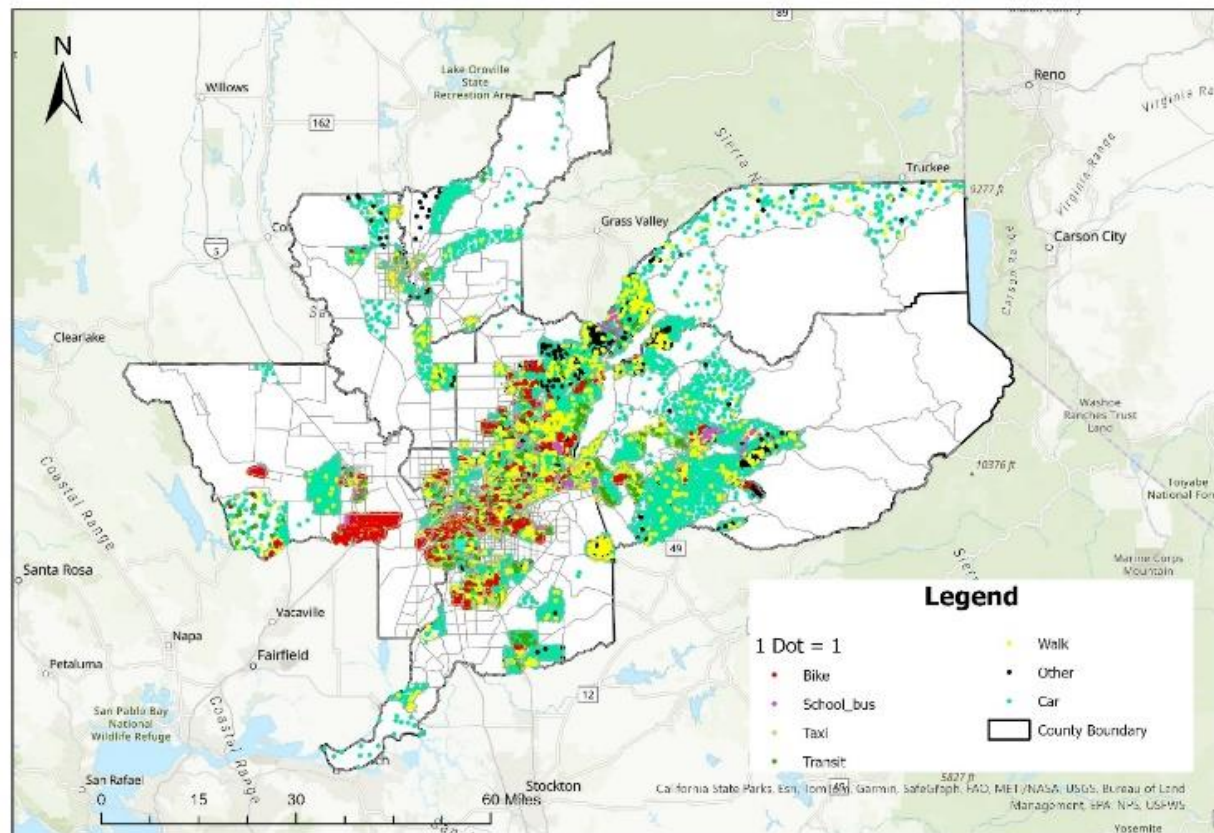
4.3 Modes of transportation by county

This is the central point of the study. Figure 4 shows at a glance that, the primary mode of transportation is personal cars, shown with the light green color. However, this is highly concentrated in El Dorado County and along the Yuba, Placer, and Sutter counties. The second most dominant mode used is walking, shown with the yellow color. This is largely concentrated in the Sacramento region. Notwithstanding, the county also shows high traits of biking. However, biking is generally the third most-used mode of transportation, which is concentrated in Sacramento and Yolo counties. Sutter, Yuba, and Placer counties have very low bike usage.

Nevertheless, the second most dominant mode of transportation used in the Sutter and Yuba counties is walking, with a little bit of public transit. Generally, the results show a very low transit usage.

Figure 4

MODES OF TRANSPORTATION USAGE BY TRAFFIC ANALYSIS ZONES IN SACRAMENTO



Source: Author's construct

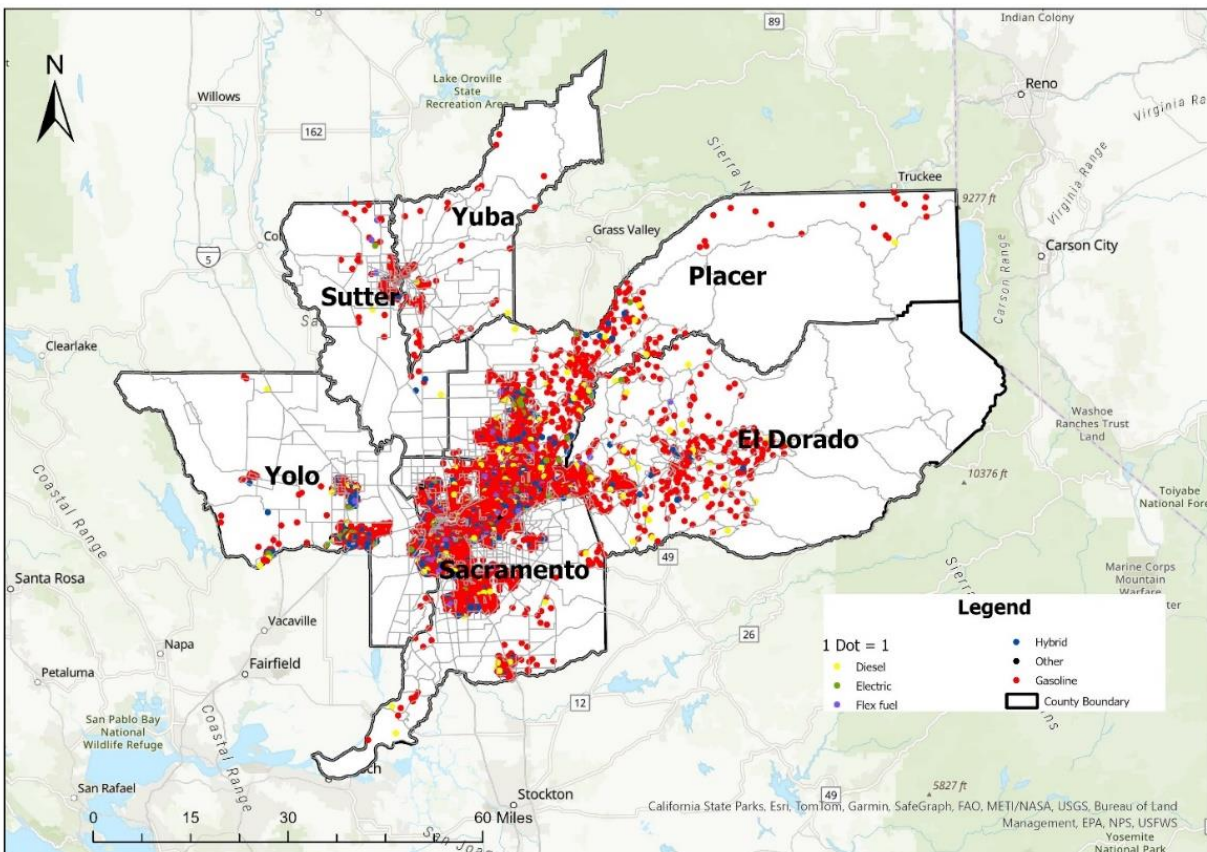
4.4 Vehicle fuel type

Fuel type makes this study critical and relevant because it shows whether the primary mode of transportation used in the region is against the Sustainable Development Agenda or not. This is due to the fact that the impetus behind this sustainable transportation agenda is to reduce carbon emissions. Evidently, from Figure 5, the major fuel type used in the region is gasoline, with about 80% usage. Relatedly, diesel is the predominant fuel used in the region. There are also a few hybrid

and electric vehicles in use in the region. However, the hybrid cars are concentrated in Sacramento County.

Figure 5

VEHICLE FUEL TYPE USAGE IN SACRAMENTO REGION



5.0 Findings and Discussion

Section 4.2 suggests that Placer and El Dorado counties have the highest median household income range in the Sacramento region. Meanwhile, it has been established in the literature in section 2.0 that income is a major determinant of the mode of transportation (see. Buehler et al., 2020). First, relating this to the findings in section 4.1, which suggests that the higher the household size, the higher the number of cars in the household, the high median household income also relates appreciably because the highest median household income range is reported in Placer and El Dorado counties, as is the case with the number of cars. Secondly, section 4.3 puts forward that Placer and El Dorado counties highly rely on personal cars as their primary mode of transportation,

with just a few walking. However, places like Yolo County, which have a lower median household income, exhibit some considerable taste for biking.

Furthermore, the Yuba and Sutter counties use mainly cars and walking. This is not entirely surprising because this region has the lowest median household income range. They also show some appreciable use of other modes of transportation, including micro mobility modes and ridesharing. The Sacramento County, even though it is the capital of the region, is ranked third on the median household income scale. However, it is the counties with high diversity with respect to the mode of transportation used. Perhaps that is due to the fact that it is the central city, and it is typical of central cities to have a diversified socio-economic structure. The predominant modes of transportation in the county are walking and biking, with some considerable personal car usage. This blends well with the income rank of the county, suggesting that income really has some impact on the modes of transportation use, compared to counties such as Placer and El Dorado.

Moreover, it is also worth noting that the correlation between income and personal car use may be weak, due to some other factors such as car sale policies and cultural taste. However, the densities and distribution of biking and walking indicate that income has a strong relationship with their usage. Because Yuba, Sutter, Sacramento, and Yolo counties, which have record-low median incomes, have fair use of biking and walking. Another critical factor that informs the mode of transportation use is the number of people in a household. This shows why counties such as Yuba and Sutter, even with low incomes, use more personal cars, because they have a higher average number of people per household, hence they own more cars.

Finally, the most critical issue about transportation is its impact on the natural environment. In essence, the ramifications of transportation have been cited as a major contributor to high carbon emissions, with a share of 28% in the US as of 2022 (Li et al.,2019;US EPA, 2022); exacerbating issues of climate change. This comes from fossil burning, mainly gasoline and diesel. This suggests that the high personal car usage in the Sacramento region is not a concern in itself, but the energy or fuel type that those cars use. For instance, electric cars have been one of the emerging strategies to salvage the situation, but regrettably, they are less used in the Sacramento region.

6.0 Recommendation and Conclusion

Generally, the study reveals a positive correlation between household size and the number of cars in a household. This relationship is statistically significant. Also, the spatial distribution pattern of income and modes of transportation used is relatively proportional, with high-income counties recording more personal car usage than low-income counties. Counties such as Sutter and Yuba, with low income, report some appreciable taste for walking and micro mobility modes of transportation. Sacramento, as the central county, exhibits traits of a typical central city as it records very diverse modes of transportation usage.

The findings show that, even though there is a strong correlation between household size, number of vehicles per household, and household income, some other factors influence people's modes of transportation, for instance, car sale policies that make it easier to own a vehicle. More critically, the wide use of gasoline in the region greatly threatens the sustainability agenda. It is therefore imperative for policymakers to put in place more realistic strategies to encourage car sharing among households. Moreover, more investment should go into public transit, biking, and walking infrastructure. More conscious efforts and policies, such as congestion pricing and strict taxes on vehicle production, should be put in place to control vehicle ownership. Cities should also consider making electric vehicles more attractive to people. Notwithstanding, effective public sensitization on the grave effects of using personal cars most especially gasoline fueled cars, on food security and public health should be prioritized. However, future research could delve deep into this topic by using more quantitative methods by adding more related variables such as employment type and location, the spatial structure of cities, gender, and availability of alternative modes of transportation, such as reliability of transit services and ridesharing.

References

- Abduljabbar, R. L., Liyanage, S., & Dia, H. (2021). The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transportation Research Part D: Transport and Environment*, 92, 102734. <https://doi.org/10.1016/j.trd.2021.102734>
- Alexandra K., M., Karina, M.-L., Natasha, P., & Alix, G.-W. (2022). *Transportation Insecurity in the United States: A Descriptive Portrait*. <https://doi.org/10.1177/23780231221121060>
- Bak, A., Nawrocka, E., & Jaremen, D. E. (2022). “Sustainability” as a Motive for Choosing Shared-Mobility Services: The Case of Polish Consumers of Uber Services. *Sustainability*, 14(10), Article 10. <https://doi.org/10.3390/su14106352>
- Bemanian, A., & Mosser, J. F. (2023). *Exploring the Relationship Between Household Income and Healthcare Travel Patterns*. <https://doi.org/10.1101/2023.09.05.23295091>
- Buehler, R., Pucher, J., & Bauman, A. (2020). Physical activity from walking and cycling for daily travel in the United States, 2001–2017: Demographic, socioeconomic, and geographic variation. *Journal of Transport & Health*, 16, 100811. <https://doi.org/10.1016/j.jth.2019.100811>
- Choudhary, R., & Vasudevan, V. (2017). Study of vehicle ownership for urban and rural households in India. *Journal of Transport Geography*, 58, 52–58. <https://doi.org/10.1016/j.jtrangeo.2016.11.006>
- Cui, B., Boisjoly, G., Miranda-Moreno, L., & El-Geneidy, A. (2020). Accessibility matters: Exploring the determinants of public transport mode share across income groups in Canadian cities. *Transportation Research Part D: Transport and Environment*, 80, 102276. <https://doi.org/10.1016/j.trd.2020.102276>
- Eren, E., & Uz, V. E. (2020). A review on bike-sharing: The factors affecting bike-sharing demand. *Sustainable Cities and Society*, 54, 101882. <https://doi.org/10.1016/j.scs.2019.101882>
- Fast Facts Facts U.S. Transportation Sector Greenhouse Gas Emissions 1990 –2022*. (n.d.).
- Feng, Q., Wang, Z., Gu, D., & Zeng, Y. (2011). Household Vehicle Consumption Forecasts in the United States, 2000 to 2005. *International Journal of Market Research*, 53(5), 593–618. <https://doi.org/10.2501/IJMR-53-5-593-618>
- Hansa, F., & Susilowati, M. H. D. (2020). Transportation mode choice of workers in Cikupa Village, Cikupa Sub-district, Tangerang Regency, Banten Province. *IOP Conference Series: Earth and Environmental Science*, 561(1), 012017. <https://doi.org/10.1088/1755-1315/561/1/012017>
- Harsha, & Ashish. (2022, June). *Understanding the mitigation potential of sustainable urban transport measures across income and gender groups—ScienceDirect*. https://www.sciencedirect.com/science/article/pii/S0966692322001065?casa_token=AvMmni_pbq0AAAAA:xr1e0sHzanseIkG9SAMBDJufFrZ63MOOeF5Wd1_lddCq_YjIsjE4wqyPgCKn73sCof8J8O0UgBCE
- Jing, P., Xu, G., Chen, Y., Shi, Y., & Zhan, F. (2020). The Determinants behind the Acceptance of Autonomous Vehicles: A Systematic Review. *Sustainability*, 12(5), 1719. <https://doi.org/10.3390/su12051719>

- Li, X., Liu, C., & Jia, J. (2019). Ownership and Usage Analysis of Alternative Fuel Vehicles in the United States with the 2017 National Household Travel Survey Data. *Sustainability*, 11(8), 2262. <https://doi.org/10.3390/su11082262>
- Liu, Y., & Cirillo, C. (2015). Measuring transit service impacts on vehicle ownership and use. *Public Transport*, 7(2), 203–222. <https://doi.org/10.1007/s12469-014-0098-8>
- Ma, J., & Ye, X. (2019). Modeling Household Vehicle Ownership in Emerging Economies. *Journal of the Indian Institute of Science*, 99(4), 647–671. <https://doi.org/10.1007/s41745-019-00133-9>
- Mannering, F., & Winston, C. (1985). A Dynamic Empirical Analysis of Household Vehicle Ownership and Utilization. *The RAND Journal of Economics*, 16(2), 215. <https://doi.org/10.2307/2555411>
- Martin, E., & Shaheen, S. (2011). *The Impact of Carsharing on Household Vehicle Ownership*. 38.
- Maulana, R., & Yudhistira, M. H. (2020). *SOCIO-ECONOMIC FACTORS AFFECTING THE CHOICE OF TRANSPORTATION MODE IN JAKARTA METROPOLITAN AREA*. 16(4).
- Mercado, R. G., Paez, A., Farber, S., Roorda, M. J., & Morency, C. (2012). Explaining transport mode use of low-income persons for journey to work in urban areas: A case study of Ontario and Quebec. *Transportmetrica*, 8(3), 157–179. <https://doi.org/10.1080/18128602.2010.539413>
- Rosenson, A. (2018). *SACRAMENTO REGIONAL TRANSPORTATION Study. SACOG 2024 Progress Report*. (n.d.).
- Schmalensee, R., & Stoker, T. M. (1999). Household Gasoline Demand in the United States. *Econometrica*, 67(3), 645–662. <https://doi.org/10.1111/1468-0262.00041>
- Sovacool, B. K., Kester, J., Noel, L., & De Rubens, G. Z. (2018). The demographics of decarbonizing transport: The influence of gender, education, occupation, age, and household size on electric mobility preferences in the Nordic region. *Global Environmental Change*, 52, 86–100. <https://doi.org/10.1016/j.gloenvcha.2018.06.008>
- Tirachini, A. (2020). Ride-hailing, travel behaviour and sustainable mobility: An international review. *Transportation*, 47(4), 2011–2047. <https://doi.org/10.1007/s11116-019-10070-2>
- Zhang, Y., & Zhang, Y. (2018). Examining the Relationship between Household Vehicle Ownership and Ridesharing Behaviors in the United States. *Sustainability*, 10(8), 2720. <https://doi.org/10.3390/su10082720>