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## Travel Behavior, Responses To Fuel Prices, And Barriers To Change In Small And Rural Communities

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TRAVEL BEHAVIOR, RESPONSES TO FUEL PRICES, AND BARRIERS TO CHANGE IN SMALL  
AND RURAL COMMUNITIES

A Thesis Presented

By

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## ABSTRACT

Travel behavior and the factors which drive it in small and rural communities has been historically understudied in transportation research. By understanding these factors and behaviors, a clearer picture of these regions can be drawn so that meaningful change towards greenhouse gas reductions can be realized. My research aims to examine barriers to making sustainable travel behavior changes such as using multi-modal transportation, reducing overall amounts of travel, or moving to locations closer to necessary services. I do this by first evaluating what “rural” means in terms of existing definitions of the term. The assessment of rural definitions analyzes vehicle miles traveled (VMT) calculated from statewide inspection and registration data under multiple definitions of urban and rural. Large discrepancies were found to occur in VMT depending on the definition used, and common presuppositions, such as rural areas being those that experience the highest VMT, are directly questioned. The results presented here suggest that multiple ways of defining rurality can conclude differing results, and that what we think to be true about rural areas’ travel behavior is directly tied to which definition of rural is used. I then analyze interviews conducted with Vermonters to get first-hand accounts of what types of change people think are possible as well as the barriers to achieving this change. The interviews employed questions on day-to-day challenges of traveling, suggestions for reducing greenhouse gas emissions in their communities, responses to fuel prices, and opinions on electric vehicles. These two components of my research highlight that rural travel behavior stereotypes may not accurately reflect reality and that while there are barriers, opportunities exist to bring about greenhouse gas emissions reductions from transportation in small and rural communities. Finally, a revealed and stated preference survey was deployed statewide to assess how individuals have responded to increasing fuel prices between February and April 2022. This survey indicates that Vermonters are taking notice of increasing fuel prices and have begun to shift their behavior in response. While shifts are minimal currently, this presents an opportunity to further the stages of change and move towards meaningful emissions reductions through behavioral changes.

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## CHAPTER 1: INTRODUCTION

The time to act on reducing the impacts of climate change and mitigating the damage already done began a long time ago, yet many places around the US and the world have not made substantial changes in terms of lessening their impact. In 2018, the United States emitted a total of 5,281 million metric tons of CO<sub>2</sub>, and nearly 30% of those emissions came from the transportation sector. Transportation greenhouse gas (GHG) emissions are particularly significant in small and rural (S&R) communities since transportation makes up the largest share of emissions and 30% of U.S. auto-travel occurs in these communities. The average resident of S&R communities travels 40% further than their urban counterparts according to data tabulated in the Transportation Energy Data Book (Davis & Boundy, 2020). In the state of Vermont, approximately 40% of GHG emissions come from the transportation sector. Strategies that have been found to reduce GHGs in urban areas are likely not the same as those required in S&R communities due to differences in transportation options, the built environment, socioeconomics, values, and norms. Through the research proposed here, we seek to better understand what it means to be defined as rural, values and beliefs in these communities, as well as examine responses to fuel prices changes.

The foundational work for this thesis and for much work to come is to first understand what a “rural” community is and how it can be defined in a way that is clear and useful (Quallen & Rowangould, 2022). Underlying previous research on S&R communities is that we can define what a “rural” community is, but a review of existing definitions of rural found at least 17 different ways of defining or classifying communities on the urban-rural continuum. Simplistic definitions of urban and rural are commonly used because they can rely on easily accessible data but often, these basic data contain differing levels of correlation between variables and concepts under study, and can perpetuate myths regarding stereotyped communities (Goodall et al., 1998; Satterthwaite, 2010; Wineman et al., 2020). For example, rural communities have typically been associated with agricultural land and employment, but there has been a gradual shift away from an agricultural focus in favor of movement towards a more diversified economy (Wineman et al., 2020). Other potential, more data intensive, measures may be used in place of the typical categorical definitions involving population. By using new or combined means of identifying rural areas, a clearer picture of the types of communities may emerge. One such example was used in a study of transportation safety outcomes by McAndrews et al (McAndrews et al., 2016). This study included the use

of three different urban-rural continua, rather than the traditional urban-rural dichotomy, to examine differences in transportation safety outcomes. The continua presented were based on regional economics, population density, and intensity of commuter flows to core urbanized area. These types of definitions, while more complex in their data requirements, may serve to more accurately portray the nature of a region. Many definitions focus heavily on urban and suburban areas, however there are those which relate directly to rural areas.

The USDOT defines three types of rural in the US: (1) Basic rural which has geographically dispersed counties or regions with few or no population centers of 5,000 or more, primarily agricultural and natural resource-based economics, “farm-to-market” localized transportation patterns, and stable or declining populations; (2) Developed rural which has sprawling development but includes one or more population centers of 5,000 or more, mixed industrial, agricultural, and natural resource economies, and stable or growing populations; and (3) Urban boundary rural which is bordering metropolitan areas and are highly developed, promoted economic and population growth from the nearby urban center, transportation is tied to that urban center, and has experienced high population growth in recent years (FHWA, 2016). These typologies are helpful in identifying different areas but do not necessarily incorporate many other relevant factors, particularly in an area like Vermont which has low overall population density but includes dense villages reliant upon recreation tourism economies or the presence of colleges and universities. Carole Voulgaris et al. established seven neighborhood types, only one of which was rural, described as “new development rural”. The variables in this study were wider ranging than the USDOT’s definitions, including job access within a 45-minute drive, housing density, network density (including roadways, sidewalks, intersections, etc.), and employment share of office and retail jobs. Applying these variables to 30,000 census blocks across the US, 20% were identified as “new development rural” and the rest were categorized as some type of urban or suburban (Voulgaris et al., 2017).

In our study, we sought to understand if using different definitions results in varying outcomes in terms of one of the most widely used travel behavior metrics, VMT. This research found that there are significant differences in outcomes when these designations are applied to the same dataset. Using the Vermont Department of Motor Vehicles (DMV) registration and inspection records, VMT per vehicle and

per person was aggregated at census tract and county levels according to each geographic area's classification. This was completed for six rural definition schemes and showed that the myth of rural individuals always traveling more than their urban counterparts may not necessarily be the case. The more detailed definitions that took into account more than population density (e.g., Rural Urban Commute Area (RUCA) codes) found that communities deemed rural do not travel, on average, any more than those communities which lie on the outskirts of urban areas where longer commutes are typical. These myths surround rural travel behavior may persist because these areas are often overlooked in research. Being overlooked and understudied may be a result of an unclear definition but also because they can be harder to reach through traditional survey methods. There is clearly no unified definition of rural and it is unclear if this is helpful or harmful. One thing that is clear, however, is that rural populations are often left as the "other" category which provides a label for those areas which could not fit into one of the urban or suburban designations. This lack of knowledge and the generally more isolated nature of rural communities often keeps them from being studied, including in travel behavior research.

As with any understudied population, barriers exist in reaching rural dwelling individuals. In an earlier phase of this study conducted in 2021, we sought to overcome many of the traditional barriers to accessing these communities by going to them and conducting in-person interviews, rather than hoping for them to come to us. By using this style of data collection, we intended to eliminate some of the bias inherent in telephone or internet surveys relating to access to internet or a smartphone, income, and/or age (Aultman-Hall & Dowds, 2019). In Vermont, we face rural transportation issues which need to be addressed using solutions tailored to rural communities.

I focus on Vermont as I have local knowledge and access to communities as well as it being a rural state where there is deep dependence on vehicles. Many residents of Vermont, particularly in the communities deemed rural, struggle with affordability of transportation costs and distance to services for meeting their needs. This makes these individuals a valuable asset to more deeply understanding travel behavior in marginalized or isolated populations. Vermont is a helpful case study when studying transportation emissions reductions as they have undertaken numerous efforts to set forth plans and policies to reduce GHG emissions, yet no noticeable change has been realized. This raises the question of how

effective policy can be made in this region and how to elicit meaningful change and GHG reductions. Some of these plans and policies aimed at tackling climate change include the 2008 Climate Change Action Plan, the 2014 Zero Emission Vehicle Action Plan, and the 2020 Global Warming Solutions Act (GWSA). Through the GWSA, Vermont is required to reduce its GHG emissions by 50% below 1990 levels by 2028 and 75% by 2050 (10 V.S.A. § 578) yet the state's level of emissions has been increasing since 2011 (Hafstead et al., 2019).

Evidence that travel behavior in S&R communities differs from behavior in more urbanized areas is starting to emerge from research on gasoline price responsiveness (elasticity). Hundreds of fuel price elasticity studies have been conducted (Labandeira et al., 2017), but only a few have attempted to also understand price responses in S&R communities (Gillingham, 2014; Gillingham et al., 2015; Spiller et al., 2017). Perhaps counterintuitively, some of these studies suggest that rural households may be more responsive to changing fuel prices than their urban counterparts, challenging the findings of earlier studies that use more aggregate data (Delbosc & Currie, 2011; Gillingham, 2014). While more spatially refined gasoline price elasticities would be useful for estimating the impacts of market-based GHG mitigation policies on S&R communities they are essentially a black box – they reveal how much a traveler changes their consumption of transportation-related goods, but they do not reveal how and why they do so. Insights about how and why travelers change their behavior is necessary to understand the role contextual factors such as transportation infrastructure and the attributes of households and individuals play in supporting or limiting travel behavior change. This thesis will explore the fuel price responses of individuals in communities self-identified as urban, suburban, and rural areas. Through the exploration of rural individuals' responses to rising fuel prices, this research will add to the body of literature facilitating meaningful policy agendas addressing rural populations and understanding elasticities of these understudied communities. An increase in gas prices may be controversial to some, but it provides an opportunity for consistent funding for the sake of counteracting transportation emissions and generating revenue to advance high-efficiency technologies

This thesis includes three major components which include: (1) an assessment of the existing definitions of rural in terms of travel behavior metrics, (2) a qualitative examination of Vermonters'

opinions on the transportation system, and (3) preliminary analyses of a statewide survey about responses to fuel prices. The next chapter on rural definitions aims to answer the question of how and to what extent travel behavior varies across community types under different urban-rural classifications? Then, the third chapter examines responses from interviews with Vermont residents and looks for challenges to and opportunities for transportation GHG reductions. Finally, the fourth chapter will discuss an ongoing survey effort which has built upon the two previous studies.

## CHAPTER 2: ASSESSING RURAL DEFINITIONS

As of 2018, 45% of the world's population lived in non-urban areas, yet the word "rural" does not appear once in the 2019 revision of the United Nations' World Population Prospects (United Nations et al., 2019). Urban systems are seen as centers of economic growth, significant sources of resource and energy consumption, and environmental pollution, so these are more frequently studied, but there is an increasing interest in assessing development progress and transportation systems in rural areas (Satterthwaite, 2010). Understanding transportation systems in rural communities is paramount to developing effective, efficient, and equitable policies which are tailored to meet the needs of each targeted community. In the United States, state and federal agencies attempt to do this by classifying cities and towns as accurately as possible along the urban-rural continuum, but numerous definitions appear across various areas of study. Being defined as urban or rural can decide if a region is eligible for certain funding opportunities and policy applications including those coming from the United States Department of Agriculture (USDA) Rural Development Program which funds transportation projects across the country but require a local designation of rural. There are also many US Department of Transportation (USDOT) rural funding programs that require this same designation, including the Rural Transit Assistance Program and others under the Rural Opportunities to Use Transportation for Economic Success Initiative. When definitions of urban and rural are assumed to give the whole picture of distinctions between these types of communities, it can lead to the misdirection of federal programs and funds (Isserman, 2005). Without a clear understanding of which communities are rural and what that means in terms of explaining the heterogeneity of travel behavior in these areas, transportation planners and policymakers are left to follow department-specific standards when choosing which of the various classification schemes to use. This leaves communities to be impacted in ways which were decided by the policy maker and their department or jurisdiction rather than from an objective analysis of the behavior and needs of the area. Without filling this gap of how rural definitions represent travel behavior, this pattern of simplistic definitions determining the allocation of funds will persist. In this study, we use a dataset of Vermont registration and inspection records to assess vehicle miles traveled (VMT) under different definition schemes to understand the variance of distributions across these definitions and discuss policy implications of inaccurate representations of travel behavior, particularly in rural areas.

## 2.1. Defining Rural

Rural areas are often understood as neither urban nor metropolitan, but with 83% of the United States' geographic area classified as "rural", such communities require a wider body of scholarship and their own robust definition that accounts for the diversity present. Rural communities are inconsistently, and often vaguely defined due to varying definition techniques and a lack of available data (Satterthwaite, 2010; Wineman et al., 2020). When various definitions exist for a single term such as "rural" or "urban", levels of urbanization and demographic characteristics can be analyzed in ways that suit the researcher or the needs of the policy, rather than by what is objectively observed. Identifying areas with low population is a typical approach to designating rural areas, although the population threshold is unclear, with the United States Department of Transportation Federal Highway Administration (USDOT FHWA) using proximity to areas with 5,000 people or areas outside of metropolitan areas of 50,000 people (FHWA, 2001) and many other organizations using different thresholds or entirely different categorizations. Using the USDOT's values, the entire state of Vermont and the majority of New Hampshire and Maine fall generally under the heading of rural.

Urban and rural are usually taken to be distinct types of communities, with high density and mixed-use land use patterns defining urban areas and sprawling farmland and villages defining rural areas. This fails to take into account the integration of these areas and the interplay between their forms and functions. Particularly at the county level, researchers, planners, and policymakers can fall into a "county trap" and does not consider the presence of rural people and places in urban counties and vice versa (Isserman, 2005). By doing this, planners in particular, look at the counties for which they are responsible and see only the urban areas, neglecting the planning needs of rural communities (Miller, 2013).

Federal level definitions the Office of Management and Budget (OMB), National Center for Health Statistics (NCHS), and National Center for Education Statistics (NCES), and five coming from the USDA Economic Research Service (ERS). The definitions coming from the USDA ERS are typically used for social science research, policy development, and program administration (*Rationalizing Rural Area Classifications for the Economic Research Service*, 2015). The adoption of these USDA ERS definitions as decision making tools has come after they were developed originally for research purposes. The NCHS and

NCES definitions, however, were designed with more practical applications in mind. The NCHS definition is primarily used for analysis of associations between community types and public health outcomes, while the NCES definition is used to define which schools are eligible for rural specific educational and professional development programs and funding. When looking globally, a 2018 pilot test was conducted to develop an international definition and in 2020, the “Degree of Urbanization” standard was endorsed by the UN Statistical Commission as the recommended method for comparing urban and rural definitions across international boundaries (European Commissions - Eurostat et al., 2020; Food and Agriculture Organization of the United Nations, 2018). The newly recommended Degree of Urbanization standard involves three classes which extend to: (1) cities, dense and semi-dense towns, suburban or per-urban areas, villages, dispersed rural areas, and mostly uninhabited areas; and (2) a commuting zone around each city to create a functional urban or metropolitan area.

While some definitions take into account specific attributes of an area, simplistic definitions of urban and rural are commonly used because they can rely on easily accessible data but often, these basic data contain differing levels of correlation between variables, and can perpetuate myths regarding stereotyped communities (Goodall et al., 1998; Satterthwaite, 2010; Wineman et al., 2020). For example, rural communities have typically been associated with agricultural land and employment, but there has been a gradual shift away from an agricultural focus in favor of movement towards a more diversified economy (Wineman et al., 2020). Other potential, more data intensive, measures may be used in place of the typical categorical definitions involving population. One study conducted in the US suggests using “(1) population of the largest place in the county; (2) root sum of squared populations of the three largest places; and (3) root sum of squared population of all places” (Goodall et al., 1998). By using new or combined means of identifying rural areas, a clearer picture of the types of communities may emerge.

Some studies look to bring more detail into the continua developed by defining multiple urban and suburban types, but classify the rest generally as rural, if rural is even a category (Ralph et al., 2016; Voulgaris et al., 2017). Voulgaris et al. established seven neighborhood types across the country, only one of which was rural, described as “new development rural”, thereby leaving out rural areas that have an older history or lack much development. The variables in this study were wider ranging than the USDOT or

US Census definitions, including job access within a 45-minute drive, housing density, network density (including roadways, sidewalks, intersections, etc.), and employment share of office and retail jobs. Applying these variables to 30,000 census blocks across the US, 20% were identified as “new development rural” and the rest were categorized as some type of urban or suburban (Voulgaris et al., 2017). The 2010 census, as previously mentioned, identified 83% of the country’s geographic area and approximately 20% of the population as rural. There is clearly more than one way of defining what is constituted as a rural community.

Wineman et al. found different levels of urbanization in Tanzania when using administrative categorizations, population data, nighttime lights, or economic characteristics to classify areas (Wineman et al., 2020). They illustrate this well by showing that the share of urban populations varies between 12 and 38% depending on which rural identification technique is used. In the same study, household income from the same source varies between 37% and 42%. When income or levels of urbanization are misrepresented, resources and funding may not be allocated in an equitable manner. Proper designations could also affect the quality of data, as current inconsistent or excessively broad data create issues when comparing rural vs. urban areas (Johnson-Webb et al., 1997). This requires that locations be accurately designated to ensure proper planning and resource allocation. Hart and their colleagues identify the need for the definition of rural to measure something “explicit and meaningful, be replicable, be derived from available, high-quality data, be quantifiable and objective, and have on-the-ground validity” (Hart et al., 2005). Taking this approach in Vermont may lead to data skewed by the few metropolitan areas which may still be considered rural using many of the current criteria as they have low populations, despite being urban compared to the rest of the state.

Research on the connection between travel behavior, land use, and rurality exists in numerous forms including the development of typologies which consider these factors in determining urbanicity and rurality as previously mentioned (Ralph et al., 2016; Voulgaris et al., 2017). These studies seek to characterize the built environment and assess the relationship between this and travel behavior for various land use schemes and therefore, creating definitional schemes that more accurately represent transportation networks and their use. Other studies focus on existing definitions and how they have a direct impact on

statistical analysis that will subsequently influence policy (European Commissions - Eurostat et al., 2020). This study by the European Commission shows the disjointed nature of global definitions of urbanicity and proposes a unified framework that will capture more of the continuum that exists within and across communities. The current classification scheme is used to capture local, national, and international statistics which are used for research and policy development in nearly all fields of study, including the study of transportation infrastructure and mobility. These definitions extend beyond statistics, performance measures, and policies and into the realm of sustainability, livability, and equity. Transportation data, categorized by their urbanicity and rurality, are used to assess access to goods and services needed for members of society to be included socially and physically (Gray, 2004). The ability to accurately assess mobility needs and opportunities based on rurality can allow for effective and efficient planning and policies which will facilitate stronger communities, but this cannot happen if we do not understand how these communities travel.

With the rising interest in better understanding rural communities, we seek to add to the body of literature on rural communities and their travel behavior. This paper presents numerous classification schemes for identifying varying levels of urbanicity and rurality and then compares six of them using vehicle miles traveled (VMT) per person and per vehicle. These definitions are applied at different geographic scales and the subsequent discrepancies and potential implications are discussed at the conclusion of the paper. Using this analysis, we seek to explore if there are varying outcomes when applying the same dataset to different definitions. If there are differences, what are the implications of this when looking to understand travel behavior in communities across Vermont and the US? To do this, we will apply a dataset from the Vermont Department of Motor Vehicles (DMV) registration records and statewide inspection records which include yearly odometer readings. VMT per person and per vehicle was calculated and aggregated to the scales used by six of the definitions to identify any discrepancies and discuss how this may impact policy decisions regarding travel behavior. Through this process, more light can be shed on the true travel behavior observed in various community types, not simply relying on overarching assumptions (often based only on population or population density) about how rural individuals interact with the transportation system. By aggregating data to define community types, there is

a loss of observed variance which may lead to conclusions which cannot be trusted and relied upon. The impact of this is unclear in terms of allocated funding and proposed policies in rural communities.

Table 1 describes 18 different definitional schemes for urban and rural areas from international organizations, federal agencies, and academic sources. These definitions range from highly simplistic (i.e. urban, suburban, and rural) to very detailed (i.e. 12 levels of urbanicity and rurality). It is not clear if one of these styles is better than the other; all may have their proper time for use and this paper does not propose a preferred approach. Some of these definitions, such as the US Census, National Household Travel Survey (NHTS), FHWA, or Rural Urban Commute Area (RUCA) definitions are used for the purpose of transportation research, planning, and funding allocation. They all use slightly different metrics and have differing level of detail in terms of their spectrum of urbanicity. Of these four definitions, only one of them (RUCA) uses travel behavior as an indicator of urban or rural travel behavior. By applying only population thresholds, as the other three definitions do, the heterogeneity of travel behavior across communities is likely not captured. The purpose of this research is an examination of the current literature and an analysis of these definitions when applied to the same travel behavior dataset. By studying the wide-ranging definitions of rurality, we are looking to examine if any or all of these definitions align with the current understanding of travel behavior.

**Table 1 Rural Definitions from Federal and Research Sources**

Source	Definition	Geographic Unit	Usage
<p>United Nations (European Commissions - Eurostat et al., 2020)</p>	<p><i>Cities</i> – Local unites that have at least 50% of their population in urban centers  <i>Dense Towns</i> – have a larger share of their population in dense urban clusters than in semi-dense urban clusters (i.e. it is dense) and a larger share in dense plus semi-dense urban clusters than in suburban or peri-urban cells (i.e. it is a town).  <i>Semi-Dense Towns</i> – have a larger population share in semi-dense urban clusters than in dense urban clusters (i.e. it is semi-dense) and a larger share in dense plus semi-dense urban clusters than in suburban or peri-urban cells (i.e. it is a town)  <i>Suburban/Peri-Urban</i> – have a larger population share in suburban or peri-urban cells than in dense plus semi-dense urban clusters  <i>Villages</i> – Have the largest share of their rural grid cell population living in a rural cluster  <i>Dispersed Rural</i> – have the largest share of their rural grid cell population living in low density rural grid cells  <i>Mostly Uninhabited</i> – have the largest share of their rural grid cell population living in very low-density rural grid cells.</p>	<p>1 km<sup>2</sup> grid cell</p>	<p>International unified definition for analysis of national metrics</p>
<p>US Census (Ratcliffe et al., 2016)</p>	<p><i>Urban Area</i> – Area with population of 50,000 or more  <i>Urban Cluster</i> – Area with population between 2,500 and 50,000  <i>Rural</i> – Any area not in an urban area or cluster</p>	<p>Combination of census blocks and tracts</p>	<p>Federal funding allocations; grant award eligibility</p>
<p>Federal Highway Administration (FHWA, 2001)</p>	<p><i>Urban</i> – Counties or regions with population of 50,000 or more  <i>Urban Boundary Rural</i> – Counties or regions bordering metropolitan centers and are highly developed  <i>Developed Rural</i> – Fundamentally dispersed counties or regions with one or more population center(s) of 5,000 or more  <i>Basic Rural</i> – Dispersed counties or regions with few or no major population centers of 5,000 or more</p>	<p>County</p>	<p>Highway functional classification; transportation planning; outdoor advertising regulations</p>

Table continued on net page.

**Table 1 continued**

Source	Definition	Geographic Unit	Usage
<p>National Household Travel Survey (NHTS)</p>	<p><i>Urban</i> - Downtown areas of major cities  <i>Suburban</i> – Areas surrounding urban areas  <i>Second City</i> – Satellite cities surround major metropolitan areas  <i>Town/Rural</i> – Exurban towns with slightly denser populations than rural areas</p>	<p>Block group</p>	<p>Transportation research</p>
<p>Office of Management and Budget (OMB) (Mar, 2010)</p>	<p><i>Metropolitan</i> – Area containing urban core with population of 50,000 or more  <i>Metropolitan</i> – Area containing an urban core with population between 10,000 and 50,000  <i>Neither</i> – An area which is neither metropolitan nor micropolitan</p>	<p>Core-based statistical area</p>	<p>Research and statistics</p>
<p>National Center for Health Statistics (<i>Data Access - Urban Rural Classification Scheme for Counties</i>, 2019)</p>	<p><i>Metropolitan</i> – Large central counties in OMB metropolitan statistical area (MSA) of 1 million population that 1) contain the entire population of the largest principal city of the MSA, or 2) are completely contained within the largest principal city of the MSA, or 3) contain at least 250,000 residents of any principal city in the MSA.  <i>Large Fringe Metropolitan</i> – Counties in MSA of 1 million or more population that do not qualify as large central  <i>Medium Metropolitan</i> – Counties in MSA of 250,000-999,999 population.  <i>Small Metropolitan</i> – Counties are counties in MSAs of less than 250,000 population.  <i>Nonmetropolitan</i> - Micropolitan counties in OMB micropolitan statistical area; Noncore counties not in micropolitan statistical area</p>	<p>County</p>	<p>Public Health research</p>

*Table continued on next page.*

**Table 1 continued**

Source	Definition	Geographic Unit	Usage
<p>US Department of Agriculture – Economic Research Service (USDA ERS - <i>Documentation</i>, n.d.-a)</p> <p>US Health Resources and Service Administration</p>	<p><i>Rural-Urban Commute Area (RUCA) 1</i> – Metropolitan area core: primarily flow within urbanized area (UA)</p> <p><i>RUCA 2</i> – Metropolitan area high commuting: primary flow with 30% or more to UA</p> <p><i>RUCA 3</i> – Metropolitan area low commuting: primary flow 10-30% to UA</p> <p><i>RUCA 4</i> – Metropolitan area core: primary flow within a large urban cluster (UC)</p> <p><i>RUCA 5</i> – Metropolitan area high commuting: primary flow with 30% or more to a large UC</p> <p><i>RUCA 6</i> – Metropolitan low commuting: primary flow 10-30% to a large UC</p> <p><i>RUCA 7</i> – Small town core: primary flow within a small UC</p> <p><i>RUCA 8</i> – Small town high commuting: primary flow 30% or more to small UC</p> <p><i>RUCA 9</i> – Small town low commuting: primary flow 10-30% to a small UC</p> <p><i>RUCA 10</i> – Rural areas: primary flow to a tract outside UA or UC</p>	<p>Census tract</p>	<p>Research</p>
<p>USDA – Economic Research Service (USDA ERS - <i>Frontier and Remote Area Codes</i>, n.d.)</p>	<p><i>Frontier and Remote (FAR) Level 1</i> – Zip code area remote (15 minutes or more) from urban areas of more than 50,000 people</p> <p><i>FAR Level 2</i> – Zip code area remote from urban areas of 25,000 or more people</p> <p><i>FAR Level 3</i> – Zip Code area remote from urban areas of 10,000 or more people</p> <p><i>FAR Level 4</i> – Zip code area remote from urban areas of 2,500 or more people</p>	<p>Zip Code Area</p>	<p>Research</p>

*Table continued on next page.*

**Table 1 continued**

Source	Definition	Geographic Unit	Usage
<p>USDA – Economic Research Service (<i>USDA ERS - Documentation</i>, n.d.-b)</p>	<p><i>Rural-Urban Continuum Codes (RUCC) 1</i> – Counties in metro areas of 1 million people or more  <i>RUCC 2</i> – Counties in metro areas of 250,000 – 1 million people  <i>RUCC 3</i> – Counties in metro areas fewer than 250,000 people  <i>RUCC 4</i> – Urban population of 20,000 or more, adjacent to metro area  <i>RUCC 5</i> – Urban population of 20,000 or more, not adjacent to metro area  <i>RUCC 6</i> – Urban population of 2,500 – 19,999, adjacent to metro area  <i>RUCC 7</i> – Urban population of 2,500 – 19,999, not adjacent to metro area  <i>RUCC 8</i> – Completely rural or less than 2,500 urban population, adjacent to a metro area  <i>RUCC 9</i> – Completely rural or less than 2,500 urban population, not adjacent to metro area</p>	<p>County</p>	<p>Research</p>
<p>USDA – Economic Research Service (<i>USDA ERS - Natural Amenities Scale</i>, n.d.)</p>	<p><i>Natural Amenities Scale Levels 1-7</i> – Based on scoring of six measures of climate, topography, and water area that reflect environmental qualities most people prefer with 1 being low amenities and 7 being high amenities</p>	<p>County</p>	<p>Research</p>

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**Table 1 continued**

Source	Definition	Geographic Unit	Usage
<p>USDA – Economic Research Service (<i>USDA ERS - Documentation, n.d.-c</i>)</p>	<p><i>Urban Influence Code (UIC)</i> 1 – In large metro area of 1+ million residents  <i>UIC</i> 2 – In small metro area of less than 1 million residents  <i>UIC</i> 3 – Metropolitan area adjacent to large metro area  <i>UIC</i> 4 – Noncore adjacent to large metro area  <i>UIC</i> 5 – Metropolitan area adjacent to small metro area  <i>UIC</i> 6 – Noncore adjacent to small metro area and contains a town of at least 2,500 residents  <i>UIC</i> 7 – Noncore adjacent to small metro area and does not contain a town of at least 2,500 residents  <i>UIC</i> 8 – Metropolitan area not adjacent to a metro area  <i>UIC</i> 9 – Noncore adjacent to micro area and contains a town of at least 2,500 residents  <i>UIC</i> 10 – Noncore adjacent to micro area and does not contain a town of at least 2,500 residents  <i>UIC</i> 11 – Noncore not adjacent to metro or micro area and contains a town of at least 2,500 residents  <i>UIC</i> 12 – Noncore not adjacent to metro or micro area and does not contain a town of at least 2,500 residents</p>	<p>County</p>	<p>Research</p>
<p>National Center for Education Statistics (<i>Rural Education in America - Definitions, n.d.</i>)</p>	<p><i>City</i> – Categorized Small, Midsize, or Large; Territories inside an UA and inside a principal city (PC)  <i>Suburb</i> – Categorized Small, Midsize, or Large; Territories outside PC and inside UA  <i>Town</i> – Categorized Remote, Distant, or Fringe; Territories inside UC  <i>Rural</i> – Categorized Remote, Distant, or Fringe; Census-defined rural-territory outside UA and UC</p>	<p>Location of school</p>	<p>School Funding, Grant and loan award eligibility</p>

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**Table 1 continued**

Source	Definition	Geographic Unit	Usage
Gray (Gray, 2004)	<p><i>A1</i> – Rural areas close to a major conurbation (Up to 80% of households within 13 minutes of hourly bus service; 65-75% of journeys made by car)</p> <p><i>A2</i> – Rural locality surrounding a freestanding city (Up to 80% of households within 13 minutes of hourly bus service; 65-75% of journeys made by car)</p> <p><i>B1</i> – Retail and service provision of a smaller market town (Up to 60% of households within 13 minutes of hourly bus service; 65-75% of journeys made by car)</p> <p><i>B2</i> – Market town(s) servicing a dispersed rural population (Up to 50% of households within 13 minutes of hourly bus service; 70-75% of journeys made by car)</p> <p><i>B3</i> – Market town(s) servicing a rural population dispersed in a linear fashion along main routes (Up to 50% of households within 13 minutes of hourly bus service; 70-75% of journeys made by car)</p> <p><i>C1</i> – A remote “ honey-pot” or “ tourist” location (Less than 35% of households within 13 minutes of hourly bus service; 70-80% of journeys made by car)</p> <p><i>C2</i> – An isolated village or villages (Less than 25% of households within 13 minutes of hourly bus service; 75-85% of journeys made by car)</p> <p><i>C3</i> – Extremely isolated settlement or households well removed from main roads and/or buses 0% of households within 13 minutes of hourly bus service; 80-90% of journeys made by car)</p>		<p>Rural Transport Research</p>

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**Table 1 continued**

Source	Definition	Geographic Unit	Usage
<p>Ralph et al. (Ralph et al., 2016)</p> <p>Voulgaris et al. (Voulgaris et al., 2017)</p>	<p><i>Rural</i> – Least dense, few jobs nearby, little or no public transit service (19% of US population; 20% of census tracts)</p> <p><i>New Development</i> – New areas with low-density single-family homes and very few jobs (27% of US population; 22% of census tracts)</p> <p><i>Patchwork</i> – Mostly mixed-use areas with relatively low-density housing and suburban retail and office developments (18% of US population, 18% of census tracts)</p> <p><i>Established Suburbs</i> – Older suburban developments with higher density, greater access to jobs, and better transit service (13% of US population, 15% of census tracts)</p> <p><i>Urban Residential</i> – Urban version of Established Suburbs with higher density, better transit service, and higher share of rental housing (14% of US population, 14% of census tracts)</p> <p><i>Old Urban</i> – Highest density neighborhoods with good transit service and high number of jobs within a 45-minute drive (4% of US population, 5% of census tracts)</p> <p><i>Mixed-Use</i> – Primarily job centers with some housing (5% of US population, 6% of census tracts)</p>	<p>Cluster and latent based statistical area; census tract</p>	<p>Transportation Research</p>
<p>Hamilton et al. (Hamilton et al., 2008)</p>	<p><i>Amenity-Rich Rural</i> – Growing population of higher income individuals and retirees drawn by natural landscape</p> <p><i>Declining Resource-Dependent Rural</i> – Declining population which previously depended on a single economy which supported a blue-collar middle class</p> <p><i>Chronically Poor Rural</i> – Historically low-income with limited services, jobs, and infrastructure</p> <p><i>Amenity/Decline Rural</i> – A transitional area characterized by both Amenity-Rich and Declining Resource-Dependent attributes</p>	<p>Community, Town, or City</p>	<p>Public Policy Research</p>

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**Table 1 continued**

Source	Definition	Geographic Unit	Usage
Miller (Miller, 2013)	<p><i>Productive</i> – Location dependent definition of productive based on land-use, population, and/or potential use, and reliant on productive uses</p> <p><i>Destination</i> – Location defined by seasonally-occupied housing, high property values, and known tourist destinations</p> <p><i>Edge</i> – “Rounded up” areas often classified as urban, locations with spillover urban development, and low-density areas with infill or a return to agriculture</p>	Census block or Community	Planning Research
<p>National Cooperative Highway Research Program (Report 582) (National Cooperative Highway Research Program et al., 2007)</p>	<p><i>Exurban</i> – Communities on the fringe of must urban areas with dependence on jobs outside of the community</p> <p><i>Destination</i> – Communities featuring natural amenities which rely on a service-based economy</p> <p><i>Production</i> – Communities found in remote areas which depend on a single industry such as agriculture, manufacturing, or mining</p>	Community, Town, or City	Local and regional transportation and land-use planning
<p>Oregon Office of Rural Policy Classification (Crandall &amp; Weber, n.d.)</p>	<p><i>Urban</i> – Community of 50,000 or more and the surrounding area within 10 miles of these communities</p> <p><i>Urban Rural</i> – Geographic area that is at least 10 miles by road from an urban community</p> <p><i>Rural</i> – Geographic area that is at least 30 miles by road from and urban community</p> <p><i>Isolated Rural</i> – A rural area that is at least 100 miles by road from a community of 3,000 or more</p> <p><i>Frontier Rural</i> – A rural area that is at least 75 miles by road from a community of less than 2,000</p>	Community or Census block group	Planning and Policy

## 2.2. Policy Applications

The designation as rural is required by policies across the country to be eligible for funding assistance for various types of transportation projects, including those related to public transportation, infrastructure, and vehicle electrification support. As the future of sustainable transportation grows closer, there have been policy recommendations for funding the electrification of vehicles throughout the US's rural communities. The USDOT's 2022 Electric Mobility Infrastructure Guide defines rural using census data and notes that 20% of Americans and 70% of America's road miles are in these rural-defined areas (*Charging Forward - A Toolkit for Planning and Funding Rural Electric Mobility Infrastructure*, 2022). This document was developed in response to a supposed need for electrifying areas where individuals drive the most. The USDOT cites the NHTS LATCH survey data which says rural-dwelling people drive more than their urban counterparts. The *Charging Forward* document identifies 48 different funding programs specifically tailored to communities designated rural by the census or other departments' definitions. Since definitions vary from one agency to another, a community may be eligible for one of these programs but not another. This leaves room for confusion amongst local planners and town officials who are seeking funding for a project in their area. In addition to potential misunderstanding of eligibility, none of these definitions, aside from the RUCA codes, account for travel behavior, despite being used for funding vehicle electrification projects which is an issue deeply tied to current behavior. One example where a rural designation that does not account for behavior would be misleading is the case of compact development in a low population area. If the assumption is that rural areas are sparsely populated and have high VMT, there may be a case made for electrification causing lifecycle cost reductions. However, if VMT is lower because of this compact development, the cost savings may be overpromised, and the efficiency of a funding program is less than optimal.

Also at the national level, there has been a piece of legislature brought to Congress which is known as the Rural Transportation Equity Act of 2021 (S.2137) (Rural Transportation Equity Act of 2021, 2021). This Act proposes establishing an Office of Rural Investment within the US DOT and appropriating

\$7,000,000 per fiscal year to this office from 2022 to 2026. This shows an interest in deepening the understanding rural transportation and how it relates to equity and behavior. The key goals and objectives of this Act and the Office of Rural Investment are to address and prioritize the “unique needs and attributes of rural transportation”, encourage better coordination between federal programs, policies, and activities, expand federal investment in rural transportation, promote innovative solutions for rural transportation challenges, and improve access to resources for outreach, education, and technical assistance in the relevant communities. This Act does not specify which communities would be included in the work carried out by the proposed office, but it can be assumed that they will be designated as rural by the Census or FHWA, as they are the mostly closely aligned departments. These definitions rely on population as the defining feature of a community as to their labelling as rural or not.

Plans and policies moving towards electrification exist locally in Vermont as well, where the VMT analysis in this study takes place. Pursuant to the State’s 2020 Global Warming Solutions Act (Act 153), a Climate Action Plan has been developed and outlines objectives and strategies for reducing emissions from transportation in this overwhelmingly rural state. The Climate Action Plan was developed by the Vermont Climate Council which includes a subcommittee on Rural Resilience and Adaptation. The plan includes two objectives related to this subcommittee:

- (1) Minimize negative impacts on marginalized and rural communities and individuals with low and moderate incomes;*
- (2) Support economic sectors and regions of the state that face the greatest barriers to emissions reductions, especially rural and economically distressed regions and industries (Vermont Climate Council, 2021)*

This plan cites a study which was performed in collaboration with the Union of Concerned Scientists (UCS) which, like the example previously mentioned, that claims rural-dwelling individuals could save more money than urban-dwelling individuals could by switching to an electric vehicle (Lowell et al., 2020). The study uses census definitions which were aggregated to the county level, whereby hiding

variability across communities even further than the census tract scale already does. The policy recommendations made using this process for classifying urban and rural areas then may not reflect the needs across the wide range of communities that fall into either category. For example, if rural areas are seen as driving a much higher amount per year, they may be seen as having an even larger price burden for transportation, which may or may not be the case.

An additional statewide policy, this occurring in Massachusetts, is the 2018 Rural Policy Plan (Rural Policy Advisory Commission, 2019). This plan identifies three communities of interest which fall under their general heading of “rural” (in this case, meaning a population density of less than 500 people per square mile): (1) bedroom communities, (2) areas of economic distress, and (3) concentrations of second homes. At the outset of the plan’s section on transportation infrastructure challenges it is noted that rural communities are identified as struggling to pay for design and engineering to get projects included in the state’s Transportation Improvement Program (TIP) or to apply for other grants. The related goal for addressing this is to “develop and fund sustainable, efficient, and convenient transportation options in rural areas to provide optimal mobility and accessibility to goods, services, and employment”. The plan proceeds with recommendations for meeting this goal through public transportation, passenger rail, and increased active transportation. These recommendations have been laid out without any identified travel behavior statistics. If rural travel were to be better understood and applied to the definition used in this plan, these types of recommendations could be more well-informed and be better suited to match the existing behavior. This highlights a need for a more nuanced definition that can represent travel behavior when making planning and policy decisions, rather than relying on population alone.

### **2.3. Methods**

To assess travel behavior metrics under different definitions of urban and rural, six measurable or publicly available definitions were applied to Vermont and then VMT per vehicle was calculated for each definition.

VMT is used as the metric of choice for this study because it has been shown to be an indicator for travel behavior, land use patterns, the presence and availability of alternative modes, and other externalities related to the transportation system (Ewing et al., 2014). The selected definitions were the US Census, RUCA, RUCC, UIC, NAM and NHTS LATCH classification schemes, details of which can be found in Table 1. The Census, RUCA, and NHTS LATCH classifications are available at the census tract level and were compared to each other. The RUCC, UIC, and NAM classifications are provided at the county level and compared against each other. This method was used to identify any discrepancies in outcomes when the same data were applied to different definitions. The NHTS LATCH and RUCA definitions were selected as they are directly related to travel behavior and are developed (NHTS LATCH) and used by transportation sectors for evaluating data. The US Census, RUCC, and UIC definitions were included as they are commonly used metrics for both research and practical applications across numerous sectors, including transportation, and are frequently referenced in policy documents. Finally, the NAM definition was selected as Vermont is known for its natural amenities throughout the State and may be an indicator of VMT if those in areas with fewer amenities frequently travel longer distances to reach the natural amenities. The opposite may also be true if the more remote and naturally amenable areas have less services and residences are therefore required to travel to other areas to meet their needs. The following sections outline in more detail the methods for calculating VMT from Vermont's inspection data and the subsequent assignment of these metrics to each definition.

### **2.3.1. Vehicle Miles Traveled Calculation**

The unit of comparison for urban-rural definitions in this study are median yearly VMT for the geographic unit (either census tract or county). VMT values were calculated using vehicle inspection and registration datasets acquired from the Vermont Department of Motor Vehicles (DMV) in June 2019. These datasets contain the Vehicle Identification Number (VIN), date of inspection, odometer reading at time of inspection, registration address, vehicle fuel type, vehicle make and model, and other attributes of the vehicle. In the inspection dataset, each entry equates to one vehicle inspection. Many inspection records

shared the same date which occurs when someone fails their inspection and goes for additional inspections on the same day. To avoid using these types of occurrences, VINs were searched to identify those that had at least two entries with unique inspection dates. These were used for VMT per day and per year calculations. Using the two different dates, the number of days between each inspection was calculated. The difference in the two odometer readings from each inspection was divided the by the number of days between inspection to get the VMT per day for the vehicle. This was then multiplied by 365 to calculate VMT per year for each vehicle.

Registration records were acquired in June 2019 and cleaned to keep only records that were up to date and any registrations that would expire after August 2019 (allowing for a two-month grace period for renewal) were removed. This left 608,127 unique registration records. Registration records were merged with inspection records based on VIN, keeping all registration records, and removing any unused inspection records. For any duplicate VINs, the record with the most recent inspection date was kept for use. This resulted in a total of 511,334 records. After the initial VMT calculation, many records had unreasonably low or high yearly VMT values after calculation which were likely a result of errors when odometer readings were manually entered into the system. To remove these values, only the central 95<sup>th</sup> percentile of data was used for analysis. Taking this percentile of the data removed any negative VMT values or unreasonably large outliers and resulted in a spread of yearly vehicle VMT of 72 to 35,387 miles. An additional cleanup step of removing out of state vehicles which are registered in Vermont, only records associated with a valid Vermont zip code were kept for analysis. After taking only the Vermont records within the central 95<sup>th</sup> percentile, there were 462,047 records.

### **2.3.1. VMT Aggregation**

From these records, which included the previously calculated registration address, VMT per day per vehicle, and VMT per year per vehicle, mean yearly VMT per vehicle was aggregated at the census tract and county levels, using the mean value for each tract or county. Average household vehicle availability by household size and average household size were acquired from the five-year averages of the

2019 American Community Survey (ACS) at the census tract level. To obtain an average number of vehicles available to households for every census tract, the mean was taken of an expanded frequency table of all numbers of vehicles available for each tract. The census tract level data were used at this geographic scale and were also aggregated to the county level. After calculating average vehicles per household and yearly VMT per vehicle, yearly VMT per person could be calculated using the formula presented below.

$$VMT_{person} = \frac{VMT_{veh} * V_{HH}}{P} \quad \text{Equation 1}$$

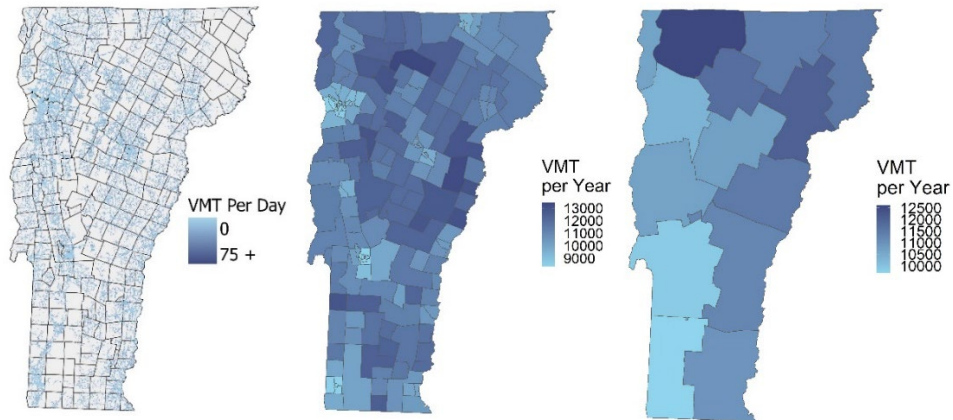
Where:

$VMT_{veh}$  = vehicle miles traveled per vehicle (from inspection records);

$V_{HH}$  = average rate of vehicle per household of the census tract or county;

$P$  = average rate of persons per household of the census tract or county

The raw and aggregated VMT values are presented in Figure 1. These graphics show the loss of variation that occurs during the aggregation process, with the overall spread of values decreasing.



**Figure 1 (From left to right) Statewide VMT Per Day, Census Tract Average VMT per Year, County Average VMT per Year**

After aggregating VMT to census tract and county levels, the six classification schemes could then be applied to these data. Classification of each tract and county was collected from publicly available databases from the Census, NHTS, and USDA ERS. These databases were merged with the tract and county VMT data and could then be further assessed. The range, variance, mean, and median VMT were calculated for each classification across the six definitions.

## **2.4. Results**

Results are presented in the following two sections based on the two geographic scales at which the VMT comparisons were conducted. The first is a census tract level comparison which assesses the US Census, RUCA, and NHTS LATCH definitions. The second comparison is presented at the county level to assess the RUCC, NAM, and UIC classification schemes. The two comparisons resulted in varying outcomes and did not present a consistent pattern of VMT related to level of rurality or urbanicity. The number of vehicles available to each household does not vary widely across classifications, whereas VMT per person varied by nearly 1,000 miles depending on the definitional scheme applied.

### **2.4.1. Census Tract Level Comparison**

The VMT comparison conducted was at the census tract level included the US Census, RUCA, and NHTS LATCH definitions. When looking at the US Census and NHTS LATCH classification schemes, there is a general pattern of increasing VMT and vehicle availability as level of rurality increases, however this not the case when the RUCA codes are applied. The Census and LATCH definitions include only urban, suburban, and rural classifications based on population, whereas the RUCA classification is dependent on the primary commute flow into urban areas or clusters. Under the RUCA definitions, the highest VMT per person is associated with the metropolitan area low commuting classification where 10 to 30% of commuter travel to an urbanized area, which in the case of Vermont, is Burlington. These areas also have the highest rate of vehicle availability per household at 2.62 vehicles per household. When using the

RUCA codes, the interquartile range (IQR) of yearly VMT per vehicle in the rural classification varies from 11,060 (25<sup>th</sup> percentile) to 12,109 (75<sup>th</sup> percentile). A very similar result for the IQR is obtained for tracts classified as rural by the Census. The standard deviations of the distributions, however, show that the variance is minimized under the RUCA definitions whereas there is a greater level of variation under the other two classification schemes. When variance is minimized within groups, this points to more precision in the categorization and more accurately reflects the true behavior being exhibited in each community types. The standard deviations for the rural category for the Census, NHTS, and RUCA schemes are 781.8, 1,130.0, and 743.2, respectively.

When addressing the stereotype that rural areas travel more than their urban counterparts, this is shown to be true under the Census and NHTS LATCH definitions. However, using the RUCA definitions, the “Metro Low Commuting” and “Small Town Low Commuting” categories exhibit a higher median VMT than the “Rural” category.

The maps shown in Figure 2 show the classification of each tract according to the three definitions. The boxplots then show the interquartile ranges and median VMT for each of the definitions.

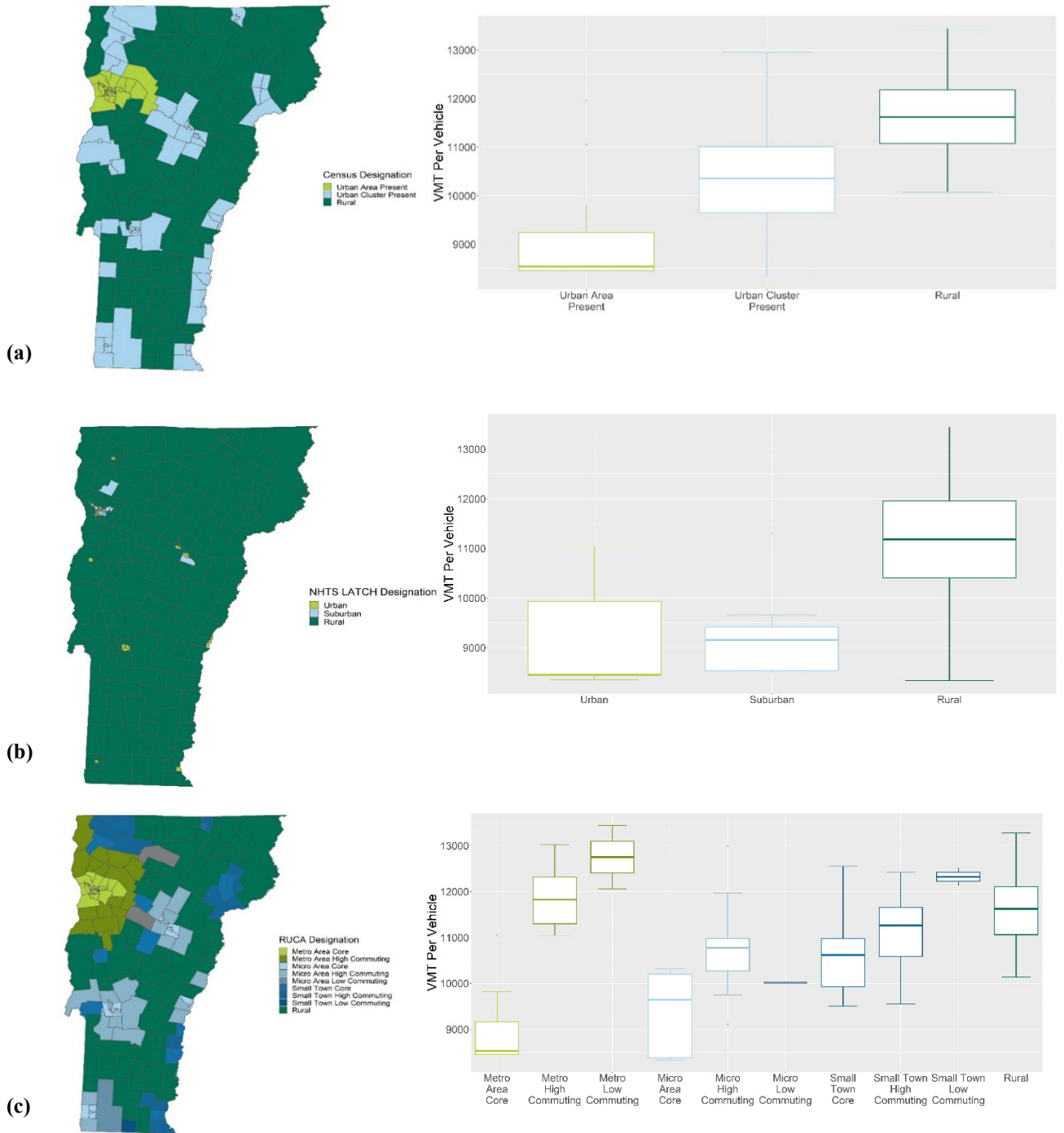
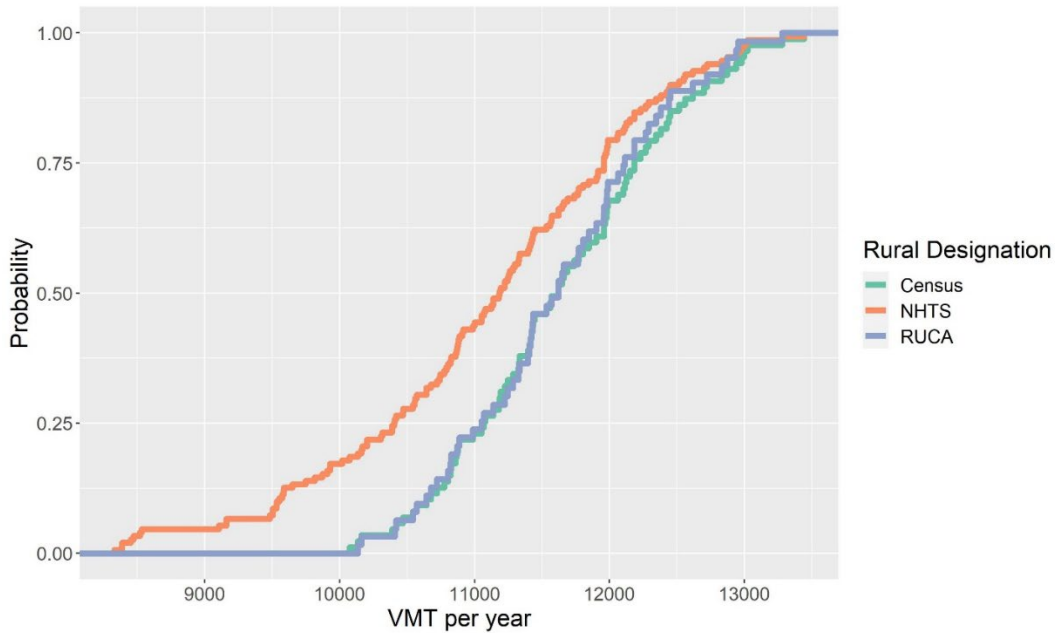


Figure 2 (a) Census, (b) NHTS LATCH, (c) RUCA Census Tract Designations (Left) and VMT Boxplots (Right)

To test if the distributions of VMT within each rural designation, a Kolmogorov-Smirnov (K-S) test was conducted. The K-S test looks to see if the values within each designation could be drawn from the same distribution. If the p-value calculated is statistically significant, it can be concluded that the distributions are significantly different. The Census, NHTS, and RUCA distributions of VMT for the rural-designated tracts were compared and it was found that the Census and RUCA rural VMT values are significantly different from both the NHTS rural tracts' VMT values ( $p = 0.009$  and  $p = 0.02$ ). The cumulative distributive functions from which the K-S test is based are provided in Figure 4.



**Figure 3 Cumulative Density Functions of Tract Level VMT Distributions for Rural Designations**

#### 2.4.2. County Level Comparison

The second VMT comparison conducted was between the RUCC, NAM, and UIC classification schemes, all of which occur at the county level. At the county level, there was much less variation in VMT values within categories compared to the census tract level. This is not surprising as this is a higher level of analysis with coarser aggregation. None of the county level classification schemes display a clear pattern of

increasing or decreasing VMT as the level of rurality increases. As aggregation occurs at a larger geographic scale, the median will grow closer to that of the state and be less sensitive to the variations which occur at a block, block group, or census tract level.

The maps shown in Figure 4 show the classification of each tract according to the three definitions. The boxplots then show the interquartile ranges and median VMT for each of the definitions.

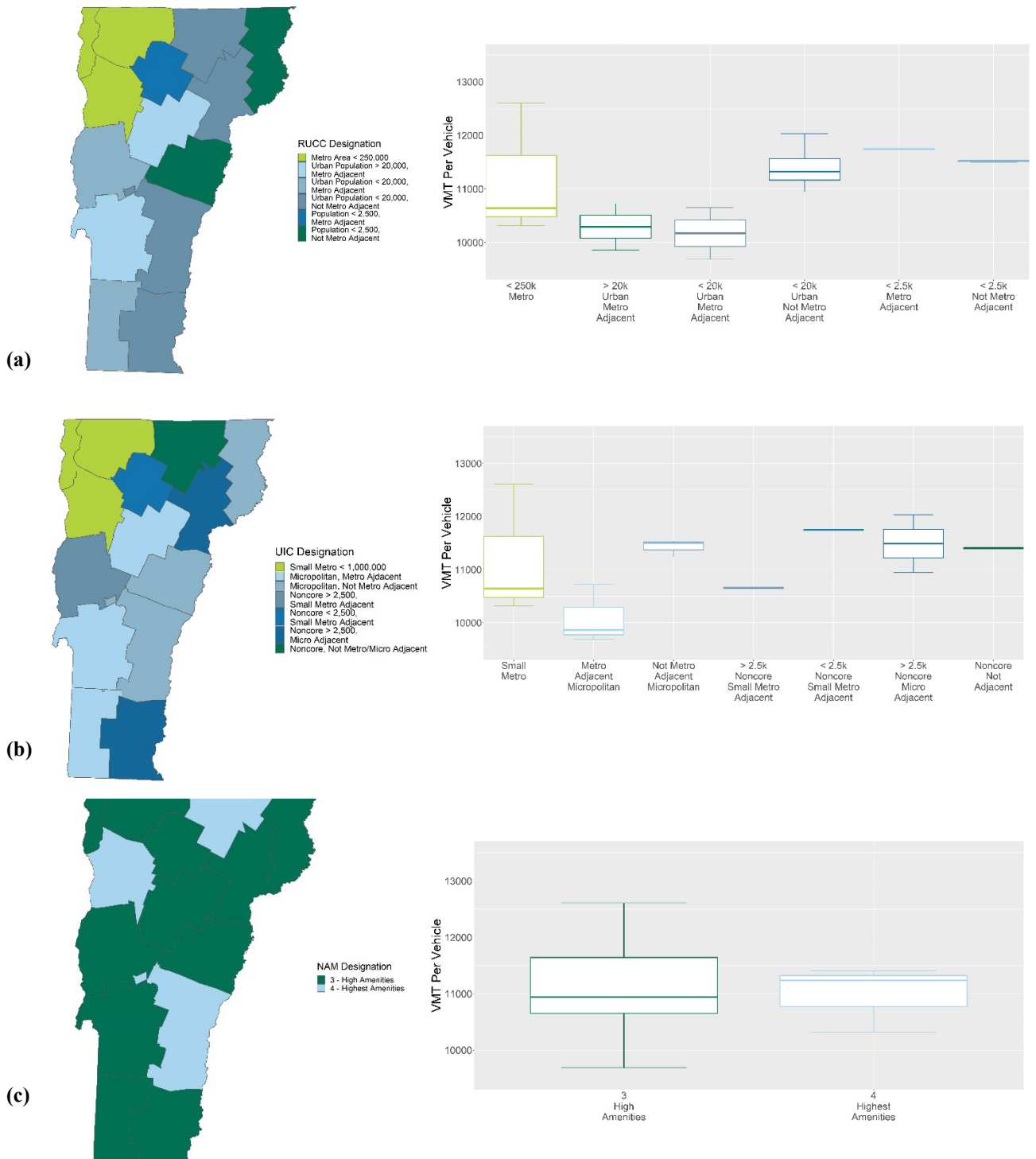
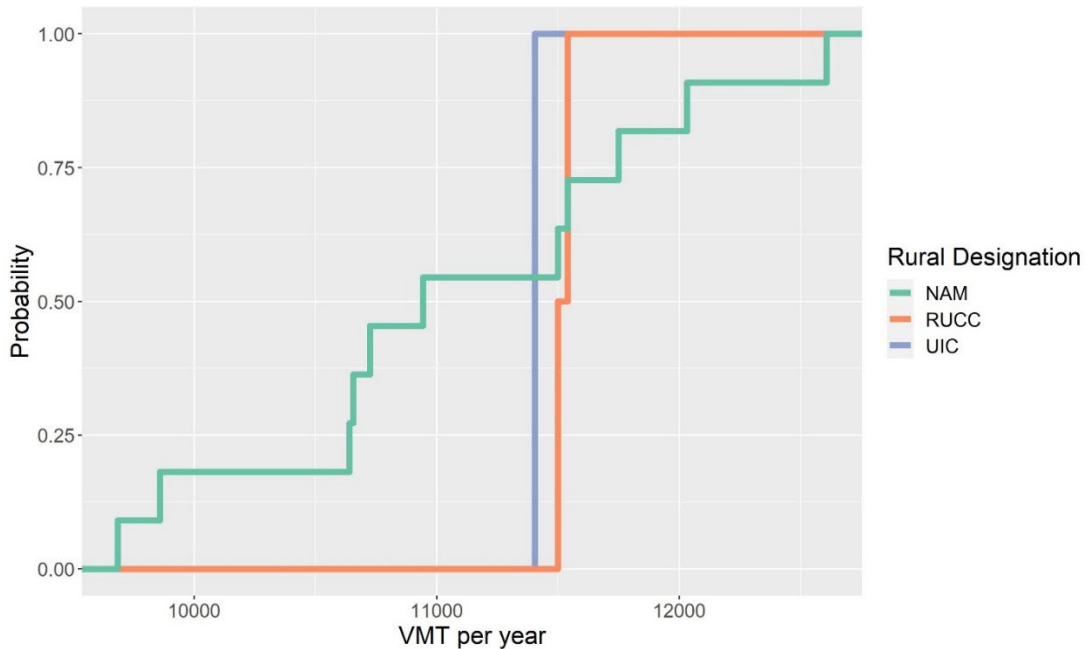


Figure 4 (a) RUCC, (b) UIC, (c) NAM County Designations (Left) and VMT Boxplots (Right)

To test if the distributions of VMT within each rural designation at the county, a Kolmogorov-Smirnov (K-S) test was conducted. The RUCC, UIC, and NAM distributions of VMT for the rural-designated tracts were compared and it was found that none of the distributions were significantly different. The cumulative distributive functions from which the K-S test is based are provided in Figure 5.



**Figure 5 Cumulative Density Functions of County Level VMT Distributions for Rural Designations**

## 2.5. Conclusions

When looking at various definitions of urban and rural areas, the question must be asked, why are there so many varying definitions and what purpose do they each serve? A unified definition which is used for funding allocations and policy research and implementation may be helpful but with the previously noted heterogeneity of rural areas, applying these definitions may even be harmful. By assuming that all rural areas, whether defined by population, land use, or any other characteristic, a level of homogeneity is

assumed which could be detrimental when developing policies aimed at these communities. The level of homogeneity assumed is also based on the definition used for any given analysis, meaning that behavior in rural communities can look one way in one study and be shown to be completely different in another. The research presented here shows that not all definitions are made equal and that our understanding of rural travel behavior at any given time is based upon the definition, level of detail, and spatial scale applied for each individual analysis.

Many definitions are applied at high geographic scales such as the census tract or county level and this allows for even less accuracy in capturing the true identity of a community. The research presented here shows that as geographic scale increase, the level of variation decreases and therefore, does not adequately represent many smaller communities. Those definitions that use a large geographic scale likely result in skewed data and inaccurately portray attributes such as average yearly vehicle miles traveled (VMT), income, or any other social or demographic statistic. This then raises the question of how different definitions may provide opportunities for policymakers or researchers to draw varying conclusions about an area. If the goal of a study is to show that urban and rural areas present similar behaviors, a county level classification scheme may be used to prove this, and if variation between communities is the goal, using census tracts or a smaller scale can be used.

Following this research, questions remain on whether these classification schemes along the urban-rural continuum should exist, and if they do, how can they most accurately convey the diverse communities across the country. The first suggestion is to apply these definitions at a finer scale, such as census block or block group level. This will minimize homogeneity within groups and maximize heterogeneity across groups. The second suggestion is to take into account many characteristics of a community including demographic, social, land use, and travel behavior variables. When these two components are combined, the more subtle differences in areas may be noticed. These subtle differences may be the difference between choosing to implement one policy or another. For example, an area may

seem like public transportation will never be a viable option when looking at the county level, but a smaller scale analysis may reveal that bolstering public transportation would be worthwhile endeavor.

For example, within Vermont, when looking at the block group level, the 2019 ACS shows a 13.7% mode share of commuting by public transportation in downtown Burlington. When zoomed out to the county level, this drops to 2.8%. Clearly the travel behavior varies across the county and what may be considered urban at the block or block group level does not appear that way at the county level. This renders the RUCC and UIC classification schemes essentially useless when analyzing travel behavior in downtown Burlington. Vermont is not unique in this phenomenon and this likely occurs across the country in many small cities that are densely populated and heavily mixed use but surrounded by sparsely populated areas with limited access. As definitions of rurality and urbanicity currently exist, there is no accurate way of classifying these cities and towns which exhibit behavior drastically different than those with which they share a census tract or county.

### CHAPTER 3: INTERVIEWING VERMONTERS

The need to better understand rural travel behavior has never been greater or more urgent. Transportation is the largest source of greenhouse gas (GHG) emissions in the US, and transportation GHGs are particularly significant in small and rural (S&R) communities where 30% of U.S. auto-travel occurs, according to highway statistics collected by the US Department of Transportation and the average person travels 40% farther than their urban counterparts according to data tabulated in the Transportation Energy Data Book (Davis & Boundy, 2020). A significant body of travel behavior research seeks to predict how infrastructure investments, technology and policies can reduce GHG emissions from transportation, however the vast majority of this research has been conducted in urban areas. As a result, very little is known about how people and households in S&R communities make travel decisions and how they respond to changes in transportation infrastructure, technology, and policies. Strategies that have been found to reduce GHGs in urban areas are likely to be ineffective in S&R communities due to differences in transportation options, the built environment, socioeconomics, values and norms, attitudes, and beliefs. This research aims to begin addressing the need for a deeper understanding of travel behavior in S&R communities by conducting exploratory qualitative research in a wide range of small and rural communities in Vermont. Our objective is to develop an initial understanding of potential barriers to travel behavior change in S&R communities that would support more sustainable transportation.

An important concern for Vermont where 61% of the population resides in a rural area according to the 2010 US Census, and other states with large rural populations, is that market-based climate policies like the previously studied Transportation Climate Initiative may disproportionately impact the welfare of low income and rural households because they may be more automobile dependent, less able to afford alternatives, and transportation costs may be a higher share of their household expenditures (Frost et al., 2018; Hanson & Hildebrand, 2011; McNamara & Caulfield, 2011; Millward & Spinney, 2011; Perrels, 2010; Vermont Climate Council, 2021; Voulgaris et al., 2017). While the proceeds from GHG emission allowance auctions can be used to increase the effectiveness and equity impacts of policies like TCI and

offset inequities (Boyce, 2018; Hafstead et al., 2019), data to understand welfare impacts and investments decisions is lacking for rural communities (Beck et al., 2015; Hanson & Hildebrand, 2011). Similar gaps exist with respect to the effectiveness of programs and policies to encourage the use of electric vehicles (EV), such as rebate programs. While research on EV incentive programs generally find that they are associated with higher EV adoption rates, there is little evidence on their effectiveness in rural communities as prior research evaluates national and state-level data (Jenn et al., 2018). Even in states with high EV adoption rates, adoption and incentive effectiveness may be lower in rural areas where range anxiety could be greater given longer trip distances, people may have preferences for different types of vehicles (e.g., trucks and four-wheel drive vehicles), and where incomes are often lower.

While travel behavior research and the knowledge it has produced is extensive, this field of scholarship has its roots in trying to solve urban transportation problems with little attention given to rural areas. The lack of rural transportation GHG mitigation research is perhaps best summarized in the concluding remarks of a TRB 2<sup>nd</sup> Strategic Highway Research Program (SHRP 2) study on GHG mitigation decision making that states “By far, and not surprisingly, most of the research on GHG emissions reduction strategies has focused on metropolitan areas or at the national and state levels.” and that “...very little attention has been given to nonurban areas.” (TRB, 2013). Most of what we currently know about travel behavior, including theories of travel demand, mode and destination choice, vehicle and housing location choice, price elasticities, and technology adoption has come from research collecting data in urban areas to address urban transportation problems such as traffic congestion and regional air quality concerns, and more recently urban GHG mitigation strategies. However, climate change and GHG mitigation policies will also affect, and require robust participation from, small and rural communities. New data and knowledge are required to understand the interactions between individual and household attributes, contextual factors and travel behavior in S&R communities and ultimately identify effective, efficient and equitable transportation GHG mitigation strategies.

Our research begins to address the lack of travel behavior research in S&R communities by conducting exploratory qualitative research through interviews in a wide range of S&R community types. Gathering data on the travel behavior and attitudes of a diverse cohort of people in rural places can be challenging. We address this challenge by going out to these communities and interviewing people in public places in a wide range of settings. Our recruitment approach of intercepting research subjects in public places and conducting our interviews on the spot, eliminates some of the bias inherent in telephone or internet surveys relating to access to internet or a smartphone, income, and/or age (Aultman-Hall & Dowds, 2019). The data we collect through these interviews are evaluated to identify factors, including attitudes and beliefs, that may create barriers to more sustainable travel behavior and choices and how they vary across different types of communities. The remainder of this paper discusses our interview and qualitative research methods in more detail, discusses what we learned about travel behavior and potential barriers to change in different types of Vermont communities and concludes with how the findings from this phase of our work can inform policy decisions and further research needs.

### **3.1. Methods**

We collected information on travel behavior, fuel price response, attitudes towards EVs, and opportunities and barriers to reduce GHG emissions from transportation from 173 in-person interviews conducted during the spring and summer of 2021 with individuals from 43 Vermont municipalities. Interviews were transcribed and coded to identify differences in the responses of individuals from different types of communities.

#### **3.1.1. On-the-Street Interviews**

To reach a diverse group of people in a variety of small and rural places, we choose to interview people in person in a range of frequently used public places. The semi-structured interviews included 20 questions with additional follow up questions depending on the respondents' answers (e.g. asking if they use public transportation after the respondent states that they have access). Topics of questioning included

general travel questions about primary mode in a typical week, overall challenges and likes about travel in their community, travel changes related to the Covid-19 pandemic, responses to fuel price changes, predictions for fuel prices, opportunities and challenges to meeting statewide GHG emission reduction goals, and one question comparing their personal travel to others in their community. The full range of questions we asked and their themes are shown in Table 2. The audio of the interviews was recorded and a transcript was generated to be coded qualitatively. At the conclusion of the interview, an optional demographic questionnaire capturing town of residence, age, household size, number of household vehicles, gender, income, employment status, race, and ethnicity.

Over the course of the study, interviews were conducted in 16 towns at 26 locations. The towns and cities selected represented a range of population densities and distance to more metropolitan areas. Locations included public parks, beaches, recreation facilities, downtowns and village centers, boat launches, farmers markets, state parks, and general stores or supermarkets. These places were selected as they attract a wide variety of people and are open to the general public. Researchers conducted interviews between 10am and 1pm and again between 3pm and 7pm on both weekdays and weekends. In a given city or town, between 2 and 20 people were interviewed during a single session with each interview lasting approximately five minutes.

Interview participants were selected at random with a few considerations. To qualify as a research participant, the individual must be at least 18 years old and be a resident of Vermont. In sparsely populated parks and beaches, all individuals who were not actively preoccupied (i.e. on the phone, taking care of a child, etc.) were approached for an interview. In more populated public spaces, the area was subdivided and each person within a randomly selected subdivision was approached. When interviews were conducted outside of stores or on a downtown sidewalk, every third person to pass by was asked to participate in the study. We had an 74.6% acceptance rate for inclusion in the study with 173 completed interviews out of 232 attempted interviews.

**Table 2 Interview Questions by Theme**

Theme	Interview Questions
Opening Questions	<ol style="list-style-type: none"> <li>1. Do you live in an urban, suburban, or rural area?</li> <li>2. How long have you lived in Vermont?</li> </ol>
Covid-19 Effects on Travel	<ol style="list-style-type: none"> <li>1. How has your travel changed since Covid-19?</li> <li>2. During the initial stages of the pandemic quarantines, were you walking or biking more or less than usual?</li> <li>3. Do you walk or bike more or less since the pandemic conditions have improved?</li> </ol>
Responses to Fuel Prices	<ol style="list-style-type: none"> <li>1. Has the increasing cost of gas has changed how you travel?</li> <li>2. Has the increasing cost of gasoline changed the type of vehicle you now own or would consider purchasing in the future?</li> <li>3. Do you think gas prices will stay about the same, increase, or decrease in the next 5 – 10 years?</li> <li>4. If gas prices were expected to increase by 50% in the next year, how do you think this would impact how you travel?</li> </ol>
Actual and Perceived Barriers to Change	<ol style="list-style-type: none"> <li>1. What do you think could be done to reduce greenhouse gas emissions from transportation in your community so the State can meet its goals?</li> <li>2. What are some of the largest challenges you see to reducing the amount of gas that people in your community use for transportation?</li> <li>3. Are you aware of the rebates and incentive programs offered by the state and federal governments?</li> <li>4. Do you feel that electric vehicles would work for you?</li> <li>5. Do you think these incentives are helping people purchase electric vehicles?</li> </ol>
Alternative Modes of Transportation	<ol style="list-style-type: none"> <li>1. Do you have access to public transportation where you live and/or work?               <ol style="list-style-type: none"> <li>A. If yes, do you use it?                   <ol style="list-style-type: none"> <li>a. If no, why?</li> <li>b. If yes, how do you use it?</li> </ol> </li> </ol> </li> <li>2. Would you ever consider moving somewhere else to reduce or change the way you travel?</li> </ol>
Range of Travel Behavior	<ol style="list-style-type: none"> <li>1. What are your largest challenges you face while travelling?               <ol style="list-style-type: none"> <li>A. Are there things that you like, or you think work well for people traveling in your community?</li> <li>B. What suggestions or ideas do you have for improving how people travel in your community?</li> </ol> </li> <li>2. In a typical week, what mode of transportation do you usually use?</li> <li>3. How do you feel your travel varies from people in your community? For example, do you feel like you travel more, less, or about the same? What about the different modes of transportation you use?</li> </ol>

**3.1.2. Interview Analysis**

The 173 audio recordings of the interviews were transcribed using computer software which was then manually verified by listening to the recordings and updating transcripts as needed. 19 of these recordings were inaudible due to windy conditions, leaving 151 usable interviews. After removing out of state interviews, 139 interviews remained for analysis. Transcriptions were then coded for attributes of the interviewee, their community, or their travel behavior using NVivo by three members of the research team. The coding scheme used by the coders was developed iteratively after initial attempts at coding a small portion of the interviews. The codes included 21 topics with numerous subcodes to be used in analysis. A brief description of the coding topics is provided in Table 3.

**Table 3 Coding Scheme Description**

<b>Topic</b>	<b>Number of Subcodes</b>	<b>Description</b>
<i>Introductory Questions</i>		
Primary Mode	4	Primary mode of transportation in a typical week
Length of Vermont Residence	5	Length of time the participant has lived in Vermont
<i>Pandemic Travel Behavior</i>		
Overall Travel After Pandemic	4	Overall amount of travel after pandemic conditions improved
Overall Travel During Pandemic	4	Overall amount of travel during pandemic
Walk-Bike Purpose During Quarantine	2	Recreational or essential travel by walking and/or biking during early pandemic quarantine
Travel Improvement Suggestions	15	Suggestions for improving local or regional travel
Walk-Bike-Vehicle Change During Pandemic	16	No change, increase, or decrease of walking, biking, public transportation, and/or vehicular travel during early pandemic quarantine
<i>Responses to Fuel Prices</i>		
Fuel Price Impact	11	Impact of fuel price increases since 2009
Future Fuel Price Impact	10	Anticipated impact from fuel prices if they were to increase by 50% in the next 1 – 2 years
Fuel Price Prediction	5	Prediction for fuel prices over the next decade
<i>Actual and Perceived Barriers to Change</i>		
GHG Reduction Suggestions	16	Strategies recommended for reducing GHG emissions to meet statewide goal

Reducing Gas Challenges	10	Challenges the participant sees to reducing the amount of gas used by members of their community
<i>Electric Vehicles</i>		
Electric Vehicle Rebate Awareness	3	Awareness of existing EV incentive program
Electric Vehicle Incentives	6	Opinion on the effectiveness of Vermont's EV incentive program
Electric Vehicle Ownership	11	Likelihood of owning an electric vehicle at some point
<i>Modes of Transportation</i>		
Public Transit Access	3	Access, or lack thereof, to public transportation and frequency of use
<i>General Travel Behavior</i>		
General Travel Challenges	12	Challenges expressed about general travel in the participants' community
General Travel Likes	8	Components of travel that work well in the participants' community
Travel Improvement Suggestions	15	Suggestions for improving local or regional travel
Travel Improvement Suggestions 15 Suggestions for improving local or regional travel Move to Change Travel	11	Likelihood of participant moving to change or reduce their current travel
Travel Comparison	17	How the participant sees their travel compares to members of their community

Intercoder reliability (ICR) was evaluated to ensure reliability across the three coders coding the interview transcripts (Campbell et al., 2013). Of the 151 usable interviews, 27 (18%) were tested using ICR. It is recommended to test between 15 and 25% of the total sample using ICR (O'Connor & Joffe, 2020). By using the coding comparison query tool in NVivo, the percent agreement and disagreement and Cohen's kappa coefficient are reported. The kappa coefficient is reported in NVivo for each code and file separately. In this report, the average kappa coefficient for each coding theme is reported. Research suggests that percent agreement or disagreement is not a sufficient reporting tool, whereas a kappa coefficient is more widely accepted as they are more likely to account for chance agreements or

disagreements (MacPhail et al., 2016). The range of possible kappa values is from -1 to 1 with a value of 0 meaning agreement by chance, values below 0 meaning agreement less than chance, and values above 0 meaning some level of agreement. A value of 1 indicates perfect agreement that is not related to chance. The formula for calculating kappa is shown below in Equation 2. The kappa coefficients for each coding category across the 27 transcripts tested for ICR are presented in Table 4.

$$\kappa = \frac{A_0 - A_e}{1 - A_e} \quad \text{Equation 2}$$

Where:

$A_0$  = the observed agreement between coders;

$A_e$  = the expected agreement as a result of chance

**Table 4 Coding Scheme Kappa Coefficients**

<b>Code Category</b>	<b>Mean Kappa Coefficient</b>
Electric Vehicle Incentives	0.903
Electric Vehicle Ownership	0.944
Electric Vehicle Rebate Awareness	0.903
Fuel Price Impact	0.929
Fuel Price Prediction	0.937
Future Fuel Price Impact	0.916
General Travel Challenges	0.952
General Travel Likes	0.986
GHG Reduction Suggestions	0.928
Length of Vermont Residence	0.936

Move to Change Travel	0.931
Overall Travel After Pandemic	0.972
Overall Travel During Pandemic	0.919
Primary Mode	0.832
Public Transit Access	0.866
Reducing Gas Challenges	0.958
Travel Comparison	0.961
Travel Improvement Suggestions	0.964
Walk-Bike Purpose During Quarantine	0.961
Walk-Bike-Vehicle Change After Pandemic	0.955
Walk-Bike-Vehicle Change During Pandemic	0.883

The coefficients shown in Table 4 show an overall very high level of agreement, with a minimum value of 0.832 and a mean of 0.926. Research suggests that values of 0.8 are generally accepted by most standards and all standards agree that values over 0.9 are acceptable (O'Connor & Joffe, 2020). One of the most widely cited pieces of literature on measuring agreement between observers or coders states that kappa coefficients between 0.81 and 1 represent almost perfect agreement (Landis & Koch, 1977). Based on these standards, the coding presented in this research is valid and can be used for analysis.

## 3.2. Results

### 3.2.1. Demographic Survey

The optional demographic survey presented to participants was completed by 139 individuals and represented 43 towns in Vermont. The cities and towns sampled are shown in the map provided in Figure 6. This survey was updated to include additional variables as the study progressed, so employment and gender

were completed by fewer respondents than the other variables. The sample demographics are presented in Table 5 and compared to 2019 American Community Survey (ACS) five-year average values for available demographic characteristics. Employment status information was collected from the US Bureau of Labor Statistics 2020 Employment Profile and is only available for employed or unemployed and eligible to be in the workforce. The sample collected in this research is representative of statewide US Census data for race, while our sample underrepresents high income households earning over \$100,000. Employment status is not directly comparable as only those eligible for the workforce are shown for the statewide comparison.

**Figure 6 Sampled Cities and Towns by Proportion of Total Sample**

**Table 5 Sample Demographics Descriptive Statistics**

<b>Variable</b>	<b>Count</b>	<b>Study Sample</b>	<b>2019 ACS</b>
Race			
<i>American Indian or Alaska Native</i>	2	1.4%	0.5%
<i>Asian or Asian American</i>	3	2.1%	1.4%
<i>Black or African American</i>	3	2.1%	1.5%
<i>White</i>	131	93.8%	93.8%

<i>Other</i>	1	0.6%	2.8%
<b>Income</b>			
<i>Less than \$34,999</i>	43	30.7%	26.6%
<i>\$35,000 – \$49,999</i>	16	11.4%	12.3%
<i>\$50,000 – \$74,999</i>	22	15.7%	19.0%
<i>\$75,000 – \$99,999</i>	24	17.1%	13.7%
<i>Over \$100,000</i>	29	20.7%	28.4%
<i>Prefer Not to Answer</i>	6	4.4%	
<b>Employment Status</b>			
<i>Employed (part-time or full-time)</i>	78	63.9%	63.2%
<i>Self-Employed</i>	9	7.4%	7.6%
<i>Retired</i>	20	16.4%	
<i>Student</i>	3	2.5%	
<i>Unable to Work</i>	1	0.8%	
<i>Unemployed</i>	11	9.0%	2.2%
<b>Number of Adults in the Household</b>			
<i>1</i>	28	20.1%	31.6%
<i>2</i>	86	61.9%	39.2%
<i>3</i>	9	6.6%	13.5%
<i>4 or more</i>	16	11.4%	15.5%
<b>Number of Children (under 18 years) in the Household</b>			
<i>0</i>	92	66.2%	71.6%
<i>1</i>	17	12.2%	13.0%
<i>2</i>	19	13.7%	10.9%
<i>3</i>	5	3.6%	3.4%
<i>4 or more</i>	6	4.3%	1.1%
<b>Number of Vehicles Available in the Household</b>			
<i>0</i>	2	1.5%	6.9%
<i>1</i>	37	27.2%	35.9%
<i>2</i>	55	40.4%	39.5%
<i>3</i>	26	19.1%	12.5%
<i>4 or more</i>	16	11.8%	5.2%

### 3.2.2. Interview Responses

The responses provided by the participants have been organized into certain themes which are reflected in the following sections. Of interest to this research are general attitudes towards rural travel behavior, including culture around vehicles and public transportation, attitudes towards EVs, and responses to transportation costs. As part of the interview, participants were asked to self-identify their town or city of residence as urban, suburban, rural or a village center. Due to background noise in some recordings, some interviews have been coded as “unknown” for their residence type. This also resulted in a classification of “Unknown”. The distribution of responses is shown in Table 6.

**Table 6 Distribution of Self-Identification of Rurality**

<b>Classification</b>	<b>Count</b>	<b>Percent of Total Sample</b>
Urban	45	32.4%
Suburban	24	17.3%
Rural	64	46.0%
Village Center	2	1.4%
Unknown	4	2.9%
TOTAL	139	100%

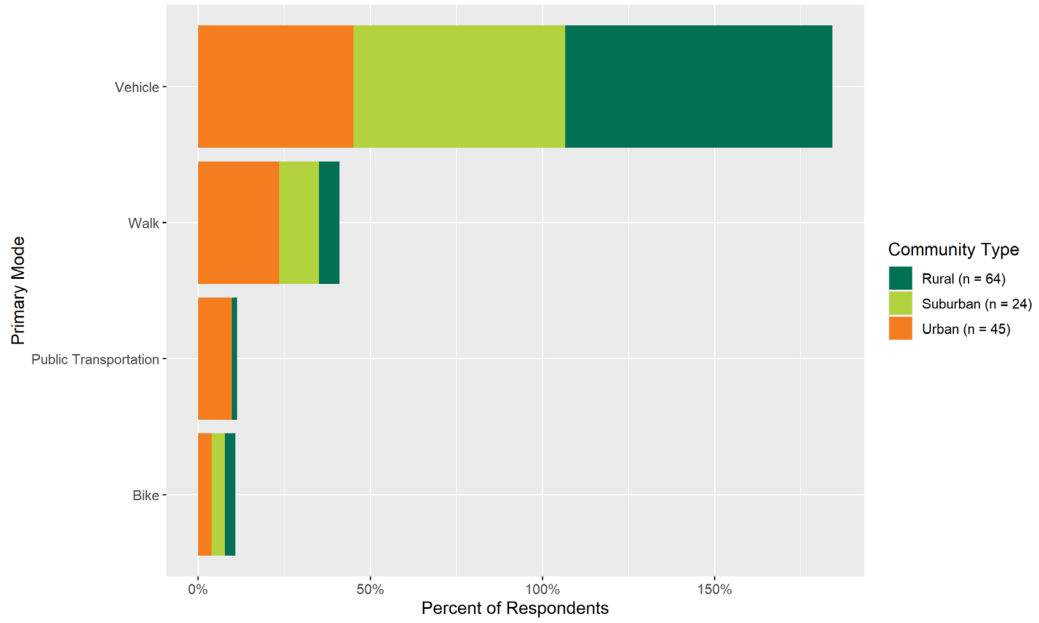
### 3.2.3. General Attitudes on Transportation and Travel Behavior

A participant from a rural area articulated quite clearly the reason for this study and stated, “I think my general messages is pay closer attention to, you know, to rural areas...urban areas; That's where a lot of people, you know, a lot of the population is concentrated, but I think that there's a lot more attention that could be paid to rural communities”. This response sheds light on the fact that some individuals in rural areas feel overlooked when it comes to transportation planning and decision making.

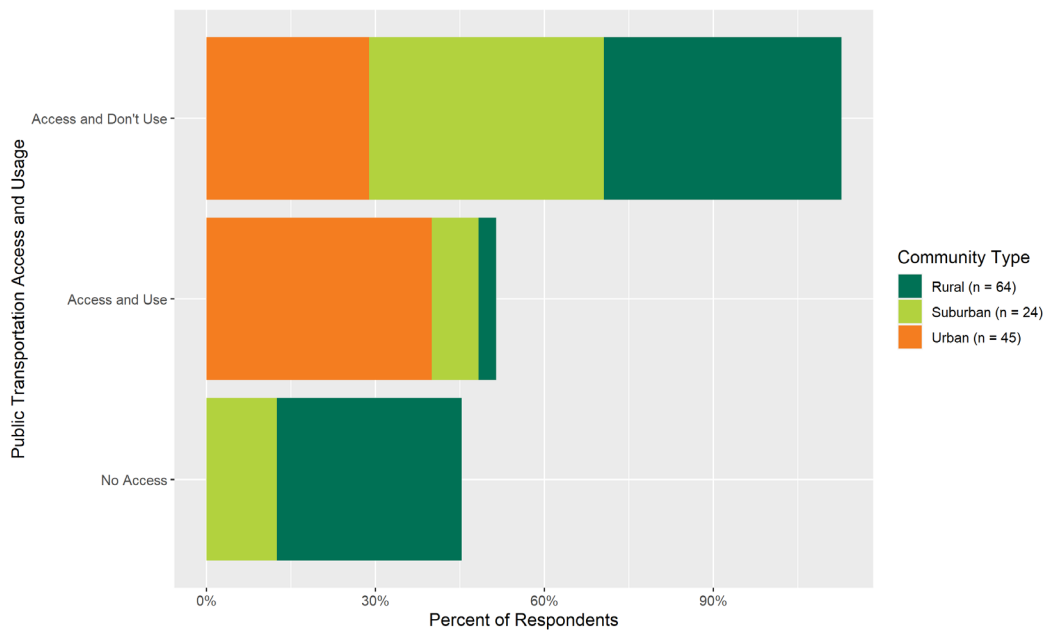
One thing that comes with rural communities is a predominant culture around vehicles and car dependence, often as a result of isolation from necessary services or lack of public transportation. Of the 101 respondents that mentioned a vehicle as their primary mode of transportation, 53 were from rural areas

(over 75% of all rural respondents). In terms of other modes, walking was the next most predominant with 22 responses, 13 of which were from urban areas. While a car is the overwhelmingly majority mode of transportation, walking is shown as a more urban mode of transportation. The distribution of responses regarding primary transportation modes is shown in Figure 7. Only six people mentioned public transportation as their most frequent mode of transportation and five of them were urban areas. Although it is not the primary transportation, all urban area participants had access to some form of public transportation and 40% of them use it on some occasion. By comparison, 33% of rural area individuals had no access to public transportation. For those in rural areas that did have access, the large majority did not use it. Reasons given for not using public transit was easier access to a vehicle or public transportation did not get them where they needed to go. When examining these results using a  $\chi^2$  test, a p-value of 0.0005 was calculated, showing that the differences in responses across urban, suburban, and rural groups were statistically significant. Access and usage of public transportation by rurality is shown in Figure 8.

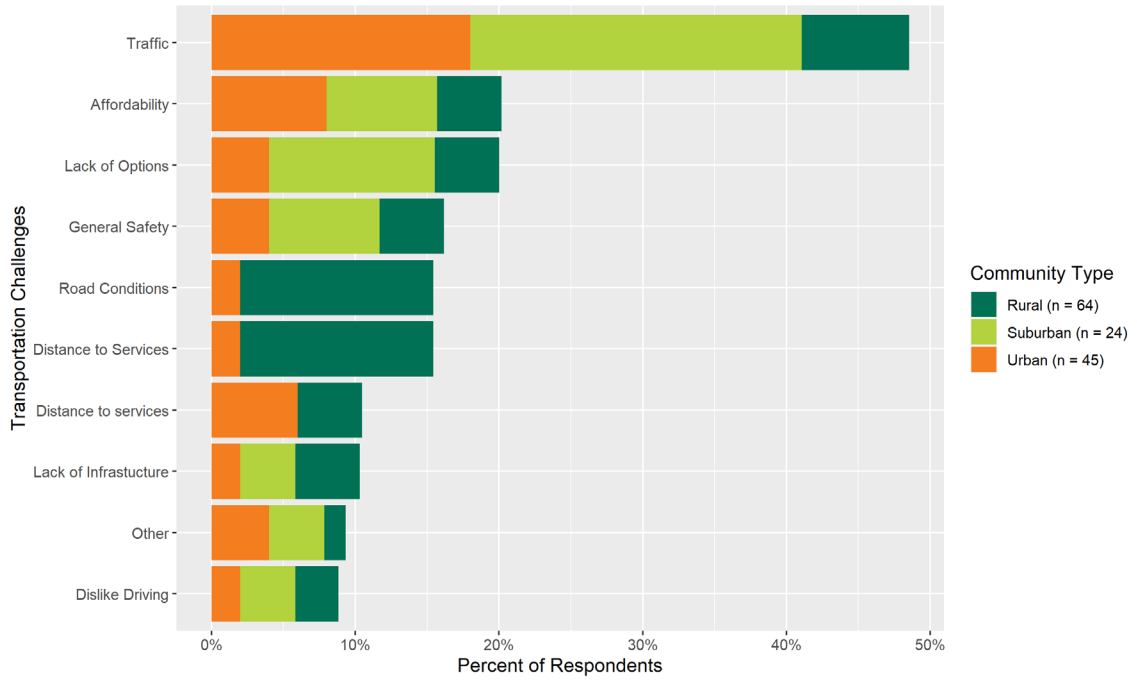
During the interviews, participants were asked generally what they liked or see to be working well in the transportation system and challenges are when traveling day to day. 14% of respondents mentioned traffic as their largest concern, with the majority share being in urban areas. Next highest was distance to services, with 11% of respondents providing this answer. In this case, rural-dwelling individuals were the majority. Figure 9 shows the complete distribution of responses about daily travel challenges. Rural areas may have their challenges, but there was one consistently provided response to what people like about traveling in their area. 12% of all interview participants stated that their most liked aspect of travel in Vermont is the scenery throughout their region and the state. Despite differences shown in the responses of challenges, these were not statistically significant across community types. The responses to what people like most about travelling in their area are shown in Figure 10.



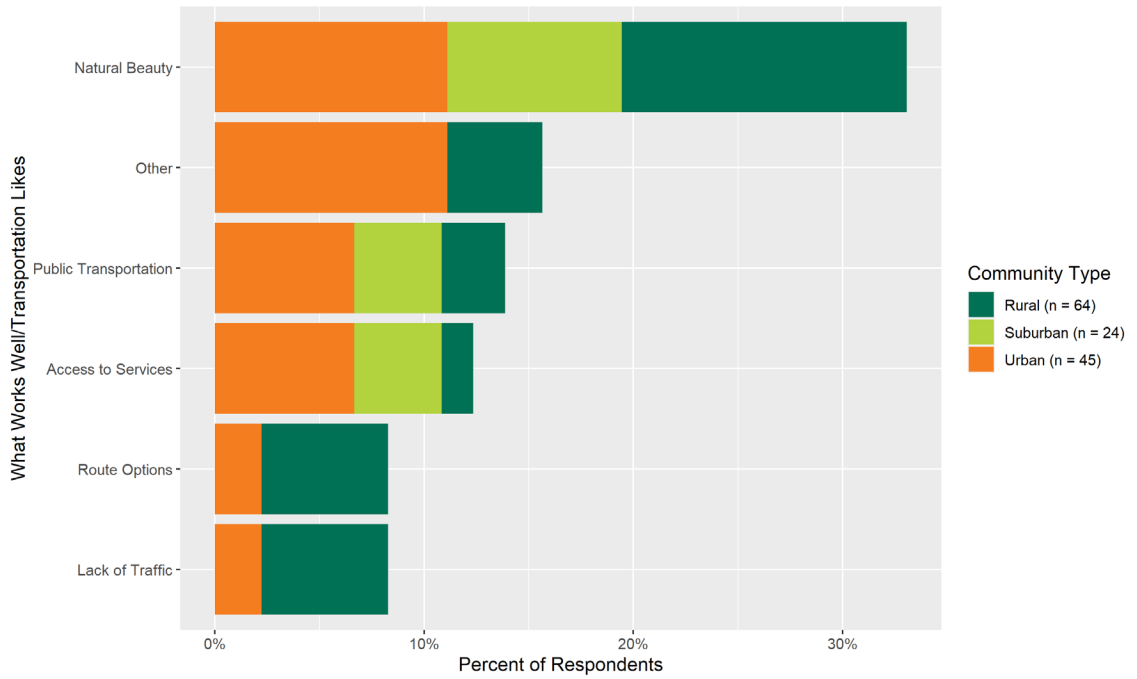
**Figure 7 Primary Mode of Transportation**



**Figure 8 Public Transportation Access and Usage**



**Figure 9 Travel Challenges in Vermont**



**Figure 10 What Works Well or is Liked About Travel in Vermont**

### 3.2.4. Attitudes on Electric Vehicles

Another component of the interview asked about knowledge of EV rebate programs offered by the state, if they think these rebates are effective, and if they would every consider owning an EV. The recurring theme throughout the interviews was that people were not aware of the rebates but there should be more education and outreach efforts to inform Vermonters of the program's existence. Upon hearing about the program, many people said they wished they had known about them, and they would likely tell their friends and family. Across all community types, most people had no awareness of the existing EV rebate and incentive programs offered to Vermonters, with 41% of all respondents answering they were not aware. The complete distribution of responses is shown in Figure 11.

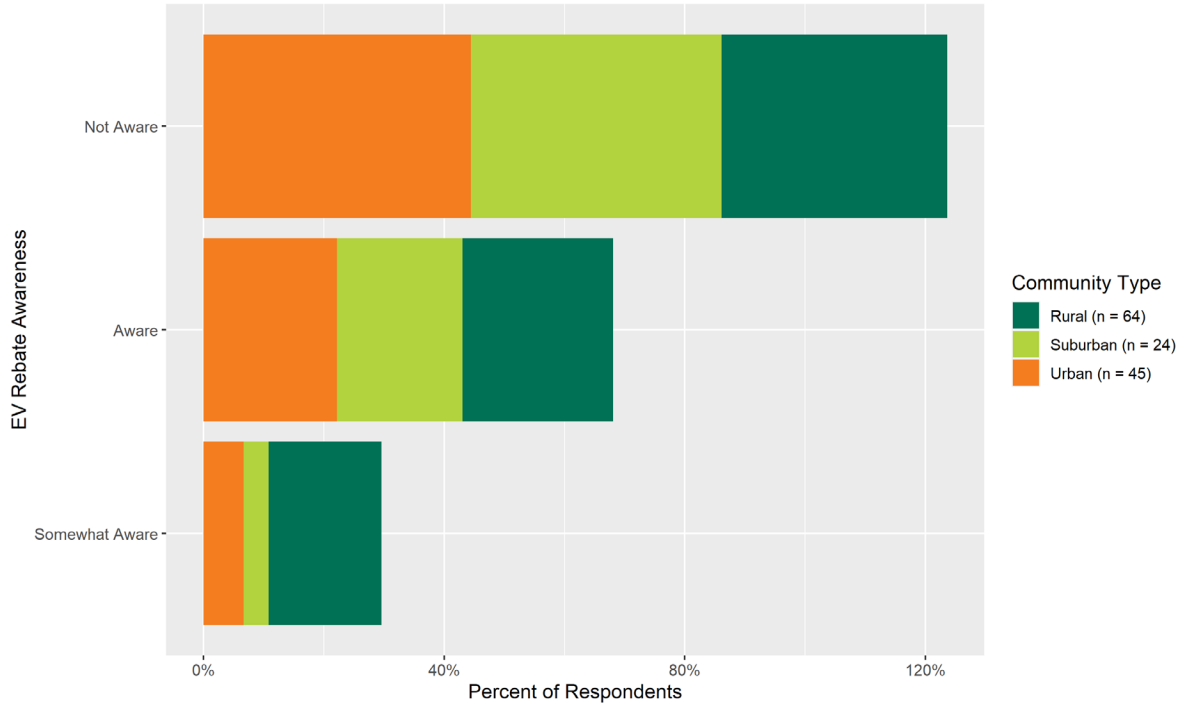
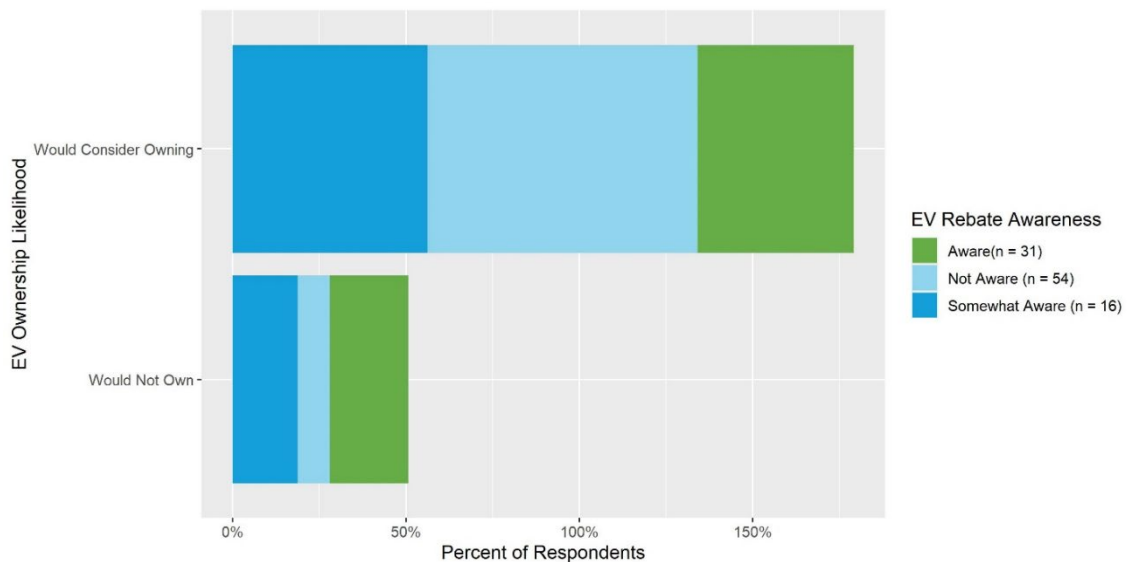


Figure 11 EV Rebate Program Awareness

When looking at ownership likelihood, over 10% of respondents said they would not own an EV. Two quotes from urban and suburban participants summed this up well by saying, “I think because there's

such a culture here. I can't see people switching to tiny little electronic cars” and, “a lot of people will still fight that image of being the Prius driving hippie”. This may be part of the culture, but for some it simply does not fit their lifestyle, or the prices are out of reach. One rural interviewee said, “...my husband was just looking at them and my issue was the smaller ones are too small. I don't feel like they're safe enough for my kids. And then the SUVs are too expensive, so I can't afford them”. Cost was by far the biggest reason for a lack of ownership. In urban, suburban, and rural areas, respondents said they would consider owning an EV at a rate of 29%, 47%, and 19%, respectively, if the vehicles were less expensive. In one interview, the participant said, “I feel like electric vehicles are really targeted to a certain income bracket of people...whereas I would be choosing an electric vehicle over being able to pay the rest of my bills.” To understand if there was a relationship between knowledge about EV rebates and the likelihood of ownership, these two sets of responses were cross-tabulated and organized by rurality. There was no apparent relationship between the two, leaving the question of whether the rebate programs are effective and provide enough incentive to convince people to make the switch to electric. The relationship between EV ownership likelihood and rebate awareness is shown in Figure 12.



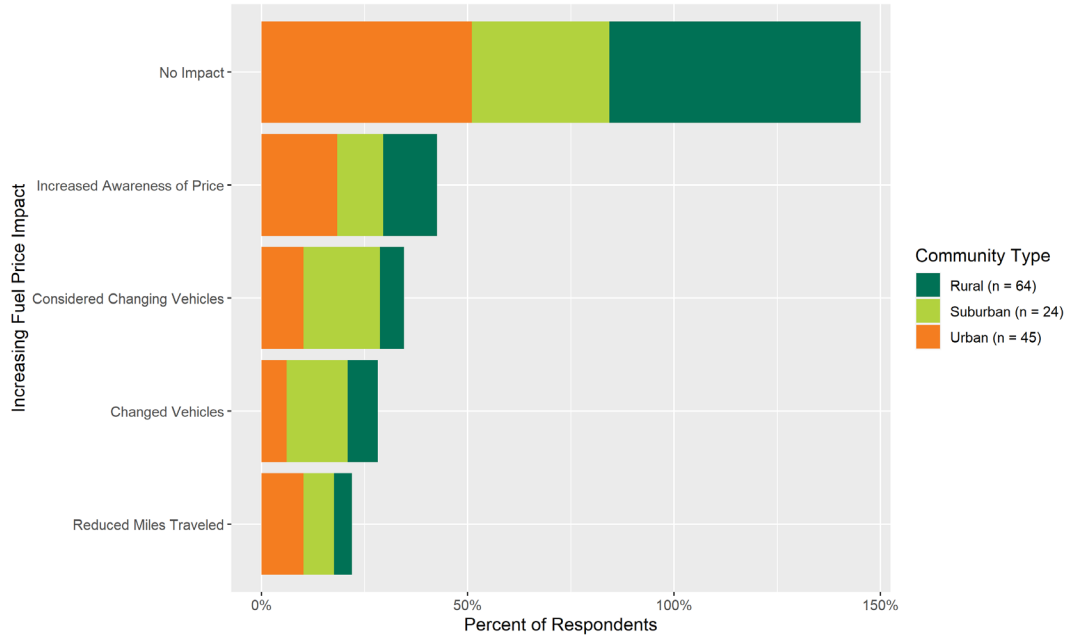
**Figure 12 EV Ownership Likelihood vs. EV Rebate Awareness**

### 3.2.5. Impacts of Fuel Prices

Participants were informed that between 2009 and 2011, gas and diesel prices went up by about \$1.00 and increased another \$0.60 per gallon between 2014 and 2016. They were then asked if this had an any impact on their travel behavior or choice of vehicle.

Overall, there was usually no impact on travel in response to increasing fuel prices. This likely points back to the car dependency previously mentioned. One rural participant put it succinctly saying, “the price you have to pay is the price you have to pay”. A participant from a suburban area also stated, “We still go where we're going to go. We don't not go somewhere because price was going up”. One respondent even mentioned that they would work additional hours just to pay for gasoline so that they could travel the way they wanted to with their family, even if gas prices were upwards of \$6.00 per gallon. The responses provided by interviewees in response to this question are shown in Figure 13.

When asked if they thought gas prices would go up, down, fluctuate, or stay the same over the next 5 – 10 years, most respondents said they thought gas prices would increase. The predictions for fuel prices were cross tabulated against likelihood of owning an EV to see if thinking that gas prices would increase would impact the chance of a person purchasing an EV. Most people said they would consider an EV, so the predictions varied across this chance of ownership. Some people, however, expressed that they hoped gas prices would increase so that EVs would become more widely appealing. An individual from a rural area mentioned, “I hope they will increase as a way of encouraging people to seek alternative forms of transportation.” Participants were also asked if they would ever relocate to change the way they travelled. Despite the prediction of rising fuel prices, the majority of people said that they would not move to reduce or change their travel for reasons including enjoying where they currently live, lack of affordability in other regions, and living close to their job. According to the responses, Vermonters generally like where they live and if they were to move, traffic would not be a consideration. The cross-tabulated responses to these questions, organized by rurality are shown in Figure 14.



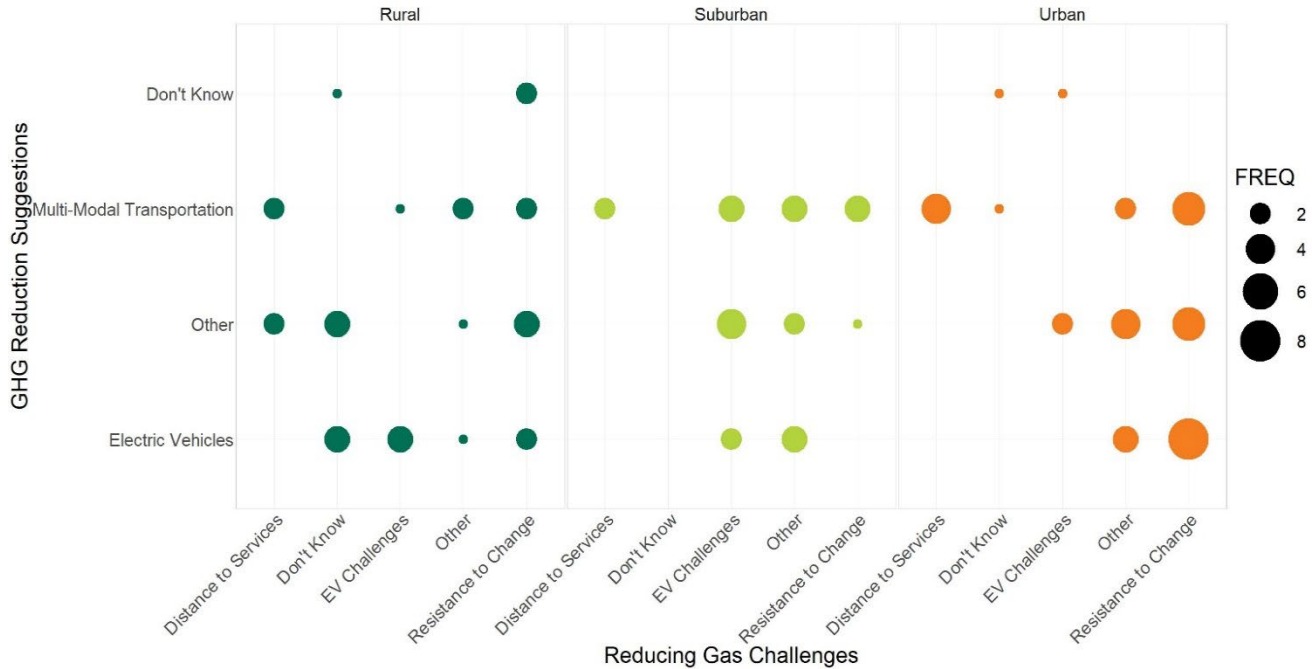
**Figure 13 Increasing Fuel Price Impact**



**Figure 14 Moving to Change Travel vs. Fuel Price Prediction by Rurality**

### **3.2.6. Attitudes on Reducing Greenhouse Gas Emissions**

The final section of interest in the interviews was discussing greenhouse gas emissions reductions and associated challenges to meeting the statewide reduction goals. As previously mentioned, the state aims to reduce emissions from transportation by 75% from 1990 levels by 2050. The participants were informed of this goal and then asked what could be done in their communities to help meet this goal. One of the most common answers was to increase access to public transportation. Responses around transit included recommending increasing frequency, the number of stops, and the number of routes. A participant from a suburban area stated, “I think buses are the answer...but I think it's just the reputation... wish somehow government could put the resources into changing public perception of taking the public bus.” The second most common response was to increase the number of EVs on the road. This was a more common answer in rural areas than urban areas. Another common answer in rural areas was to increase carpooling options. One rural respondent said, “I think there's a lot of opportunity for carpooling that doesn't happen”, when referencing people traveling to their place of work. When asking rural participants what they see as the largest challenges to reducing gas use in their community, nearly 26% noted distances to services, 22% said lack of sustainable alternatives, and 16% thought there was general resistance to change. This aligns well with the challenges they see to reducing gas. It may be possible to draw the conclusion that if services are going to be far away in rural areas, there should be more EVs making those trips or there should be public transportation to get them there. The complete range of cross-tabulated responses to these two questions are shown in Figure 15.



**Figure 15 Reducing Gas Challenges vs. Greenhouse Gas Reduction Suggestions by Rurality**

### 3.3. Conclusions

By using in-person interviews, this research has provided a unique point of view in studying individuals who are often neglected in the current body of literature on travel behavior. This study has increased understanding of the barriers and opportunities in rural communities across Vermont, and likely in similar regions, for changing behavior for the sake of reducing GHG emissions from transportation. Climate change is a global crisis that must be combatted and with over one third of emissions coming from transportation, we must act quickly and encourage behavior that is conducive to a world in which we can thrive sustainably.

This research showed some key differences between urban and rural areas which are relevant to understanding how we can shift to reduce GHG emissions. In this study, all urban-dwelling participants had access to public transportation, whereas less than half of rural-dwelling participants did not have access. Of

those that had access in rural areas, they usually did not use it because the services were inadequate, or they preferred to use their vehicles. Increasing routes and frequency of public transportation in rural communities may make transit a more viable option for commuting and other travel needs. Another notable difference was in the daily challenges people faced in rural versus urban areas. In rural areas, people most frequently commented on the road conditions or the distance they must travel for services. In urban areas, the common challenge was traffic. The distances to services may be abated by the encouragement of denser, mixed-use village centers which can allow for closer access to basic needs like food and retail services. Density, even if in small clusters, provides opportunities for more active and public transportation (Ao et al., 2020).

While there are vast differences between urban and rural areas, there are shared characteristics which can be leveraged to reduce GHG emissions from transportation. Currently, vehicles are the primary mode of transportation across all levels of rurality, but many people would consider owning an electric vehicle. 25% said they would definitely consider owning one, and this grows to 43% of people if EVs become less expensive. EVs provide an opportunity for individuals to maintain their culture of vehicles and independence, while drastically reducing emissions. The most common barrier to EV ownership is the cost, yet most people are unaware of the rebate and incentive programs offered by the state and for those that are aware, many do not think they are enough to counteract the cost of the vehicle. Even with awareness, it has been seen that cost is generally a barrier to entry into the EV market for consumers (Haider et al., 2019). Increasing education and awareness of these programs, while also bolstering them to provide larger incentives, may push many Vermonters to make the switch to an EV. If adoption of EVs becomes widespread, lifecycle emissions can be reduced by upwards of 10 – 20% per kilometer of travel (Mashayekh et al., 2012). The transition to EVs will take time, an increase in supply of vehicles, a more diverse array of vehicle styles, increased infrastructure, and overall lower costs, but there are opportunities to encourage this transition through subsidies, incentives, and education.

## **CHAPTER 4: STATEWIDE RESPONSES TO FUEL PRICES SURVEY**

Ongoing research developed from the responses received during the interview process described in the second article is a statewide survey analyzing responses to recent increases to fuel prices. This survey has been distributed to approximately 46,000 Vermonters via email and asks questions regarding their current travel behavior, attitudes and values towards topics such as the environment and technology, their behavior changes in response to increasing fuel prices, and potential behavior changes if the fuel prices were to remain high for more than one year. Fuel price elasticities are often evaluated through revealed data such as VMT data over time which can be correlated to fuel prices. The types of behavioral changes beyond VMT shifts, such as modal shifts or VMT reduction through combining trips, are harder to evaluate. Beginning in March 2022, a natural experiment began with a sudden increase in fuel prices related to national and global factors. Gasoline and diesel prices increased by approximately one dollar between early February and early March 2022 (US Energy Information Administration, n.d.). This natural experiment provided an opportunity for a combination of revealed and stated preference survey questions. The following sections outline the design process of the survey as well as preliminary results from the survey.

### **4.1. Survey Design**

The survey includes questions regarding attitudes and values, responses to fuel prices, general travel behavior, and demographics. The goal of this survey is to identify factors which influence the likelihood or magnitude of behavior change in response to increasing fuel prices. Examples of these changes include switching to multi-modal transportation options, carpooling, reducing trip frequency or length, using a more fuel-efficient vehicle, or moving to live closer to employment or essential services. This survey uses many of the potential changes that were identified by participants during the interview phase of this research as a starting point. Individuals were asked how they have responded to fuel prices in the past as well as how they could envision making reductions in transportation GHG emissions in their

communities. The interview phase had a small sample size, so a statewide survey with a larger sample is required to examine statistically significant behavior changes that have occurred or may occur in the future.

### **2.1.1. Attitudes and Behavior**

The link between attitudes and travel behavior has been studied extensively using the theories of planned behavior, cognitive dissonance, and others (Anable, 2005; Bamberg et al., 2003; De Groot & Steg, 2007; Heath & Gifford, 2002; Kroesen et al., 2017). The theory of planned behavior was first discussed by Icek Ajzen in 1985 and he later reviewed the theory deeper to explain that intentions to perform behaviors are quite predictable upon examination of attitudes, norms, perceived control, and intentions (Ajzen, 1991). This theory has been applied to travel behavior in terms of mode choice, the use of park and rides outside of metropolitan areas, and adoption of electric vehicles (Bamberg et al., 2003; De Groot & Steg, 2007; Wang et al., 2016). These studies confirmed Ajzen's initial thesis that behavior can be predicted accurately based on previously held beliefs and intentions. For example, public transportation use significantly increased after the implementation of a free bus pass, but primarily for those whose values were already aligned with environmental concerns surrounding transportation. They also found descriptive norms, or what is typical behavior in a given situation, to be statistically significant predictors of transit use (Heath & Gifford, 2002).

The theory of cognitive dissonance entered the world of decision making studies in 1957 by Leon Festinger (Festinger, 1957). This theory rests on the idea that when one makes a decision that does not align with their needs or wants, they undergo a feeling of dissonance which then motivates the individual to make a more cognitively consistent decision when presented with a similar choice in the future. One study using the theory of cognitive dissonance found that when it comes to travel behavior, behavior actually has more of an influence on attitudes rather than vice versa and those experiencing high levels of dissonance are more likely to change their attitudes and not their behavior (Kroesen et al., 2017). This result goes counter to the originally proposed idea by Festinger but is logical when combined with the theory of

planned behavior. If attitudes are significant predictors of behavior, it may be easier for the individual to modify their attitudes when behavior change is not a viable option.

While this proposed research does not attempt to determine if attitudes influence behavior or vice versa, we do seek to draw upon these theories to identify the attitudes held by those most willing to change travel behavior or pay for increased fuel prices. To examine these types of attitudes and values, methods previously employed in numerous studies were combined and adapted to fit the needs of this work. These studies explored skepticism towards technology and attitudes regarding environmentalism, government, and vehicle dependence (Abraham et al., 2017; Anable, 2005; Beach et al., 2009; Brick & Lewis, 2016; Engels et al., 2013; Konisky et al., 2008; Lee et al., 2020; Taviss, 1972). In many cases, attitudes and beliefs were used to identify types of people (e.g. the “resilient”, the “restraint”, and the “restless”) which can then be used as predictors of behavior choices (Sârbescu & Boncu, 2018). It has been found that different sets of attitudes and values require different types of intervention to achieve behavioral shifts (Anable, 2005). A classic way of defining personality traits relating to values is by using the Five-Factor Model (McCrae & John, 1992). The five dimensions of this model are Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness to Experience. In Brick and Lewis’ study, it was found that Openness and Conscientiousness were independent predictors for emissions-reducing behavior which included transportation choices (Brick & Lewis, 2016). While the study involved in this thesis does not directly use the Five-Factor Model, this theoretical background can provide a foundation for hypotheses about who is more or less likely to change behavior for the sake of environmentalism. This does not, however, provide a rationale for those who make changes relating only to price signals.

When looking at car dependence and environmentalism, it has been found that existing attitudes towards the environment were more important than factual information in determining pro-environmental actions and lower-emitting travel behavior (Nilsson, 2000). This indicates that presenting material on the environmental need to switch to more sustainable transportation will not be enough for most people to take action and change their behavior; these individuals require greater intervention. For example, interventions

to reduce barriers to EV adoption include overall increased understanding of the true relationship between fuel economy and emissions, decreases in price, and highlighting technical and design features of these low-carbon vehicles (Lane & Potter, 2007). For those who are already pro-environment in their attitudes and values, they can be seen as “potential adopters” of sustainable travel behaviors, such as buying a cleaner fuel vehicle (Lane & Potter, 2007). For these potential adopters it is not just important that they make this change, but that they use these vehicle appropriately to realize the full benefits of the cleaner fuel.

Taking an attitudinal approach to one of the predictor variables in a model seems to provide a level of nuance that is not captured simply by looking at demographic or socio-economic patterns. Particularly, attitudes towards the environment and openness to technology have been found to be significant predictors of willingness to shift behavior.

A sample of the attitudinal questions included in the survey are shown in Table 7.

**Table 7 Attitude and Values Survey Questions**

Question	Answer Options
Please indicate your level of agreement or disagreement with the following statements: Humans are responsible for taking care of the environment. I am worried about the health impacts of air pollution. Protecting the environment is not important to me. Etc.	(a) Strongly disagree (b) Somewhat disagree (c) Neither agree nor disagree (d) Somewhat agree (e) Strongly agree
Please indicate your level of agreement or disagreement with the following statements: Technology has made life easier. I like to keep up with the latest technology. Technology has done more harm than good. Etc.	(a) Strongly disagree (b) Somewhat disagree (c) Neither agree nor disagree (d) Somewhat agree (e) Strongly agree
Please indicate your level of agreement or disagreement with the following statements: Global warming should be a priority for the government.	(a) Strongly disagree (b) Somewhat disagree (c) Neither agree nor disagree (d) Somewhat agree (e) Strongly agree

<p>More research should be funded for renewable energy sources.  The government has no role in protecting ecologically sensitive areas.  Etc.</p>	
<p>Please respond to the following statements based on your actions over the last 12 months:  I have contacted a local government official.  I have posted about politics on social media.  I donated to political organizations.  I attended a rally, protest, or demonstration.  I engaged in political conversations with friends and/or family.</p>	<p>(a) Never  (b) Rarely  (c) Sometimes  (d) Often  (e) Very Often</p>
<p>Please indicate your level of agreement or disagreement with the following statements:  I like traveling in a car.  Driving a car is good for society.  I am actively trying to use my car less.  Etc.</p>	<p>(a) Strongly disagree  (b) Somewhat disagree  (c) Neither agree nor disagree  (d) Somewhat agree  (e) Strongly agree</p>

### 2.1.2. Responses to Fuel Prices

There still exists very little literature on fuel price elasticities in S&R communities as most research that has been conducted is centered around urban and metropolitan areas. These studies look at travel behavior responses as well as behavior around when and how they fuel up at the pump in the short- and long-term (Chi, 2016; Circella et al., n.d.; Dahl, 2012; Ritter et al., 2016). Many of these studies relate to heterogeneity in income and household demographics rather than on place-based analysis, making it difficult to draw meaningful conclusions about urban versus rural elasticities. The few studies that have taken place in rural areas have shown that rural households may respond differently to changes in fuel prices as compared to their urban counterparts (Delbosc & Currie, 2011; Gillingham, 2014; Gillingham et al., 2015; Spiller et al., 2017). These studies point to rural households potentially being more elastic in their responses to fuel prices, despite some variance across demographic variables, which goes counter to some hypotheses around their behavior (Gillingham, 2014; Gillingham et al., 2015). One overlooked component of these studies is why and how individuals and households change. Understanding the magnitude of

change is important at a higher level so that we can understand which types of people are more responsive than others but understanding how they change is critical for knowing which parts of the transportation system require attention and improvements.

The survey questions related to responses to fuel prices are shown in Table 8.

**Table 8 Responses to Fuel Prices Questions**

Question	Answer Options
Considering the recent increase in gasoline and diesel prices in Vermont, how important is it to you to reduce your driving expenses?	<ul style="list-style-type: none"> <li>(a) Not at all important</li> <li>(b) Somewhat important</li> <li>(c) Very important</li> </ul>
Have you done any of the following in response to the recent increase in gasoline and diesel fuel prices?	<ul style="list-style-type: none"> <li>(a) Drive more efficiently</li> <li>(b) Considered purchasing or leasing a more efficient gas or diesel vehicle</li> <li>(c) Considered purchasing or leasing an electric or plug-in hybrid vehicle</li> <li>(d) Considered moving to reduce the amount you drive</li> <li>(e) Increased use of a more fuel-efficient vehicle you have access to</li> </ul>
<p>Considering essential trips that you make such as going to work, school, buying food and medical appointments, have you done any of the following in response to the recent increase in gasoline and diesel fuel prices in Vermont? Select all that apply.</p> <p>(Also asked about likelihood of these options if prices were to remain high for more than 1 year)</p>	<ul style="list-style-type: none"> <li>(a) Increased amount of remote work</li> <li>(b) Increase amount of carpooling</li> <li>(c) Increased amount of walking or biking</li> <li>(d) Increased amount of public transportation</li> <li>(e) Increased amount of internet shopping</li> <li>(f) Made fewer shopping trips</li> <li>(g) Chose closer options</li> <li>(h) Combined trips</li> <li>(i) Adjusted household budget</li> <li>(j) Made no changes</li> </ul>
<p>Considering less essential trips that you make such as visiting friends and family, recreational activities, and social events, have you done any of the following in response to the recent increase in gasoline and diesel fuel prices in Vermont? Select all that apply.</p> <p>(Also asked about likelihood of these options if prices were to remain high for more than 1 year)</p>	<ul style="list-style-type: none"> <li>(a) Increase amount of carpooling</li> <li>(b) Increased amount of walking or biking</li> <li>(c) Increased amount of public transportation</li> <li>(d) Replaced activities with at-home options</li> <li>(e) Reduced number of activities</li> <li>(f) Chose closer options</li> <li>(g) Combined trips</li> <li>(h) Adjusted household budget</li> <li>(i) Made no changes</li> </ul>

<p>If fuel prices were to remain high for more than 1 year, how likely would you be to make the following changes?</p>	<ul style="list-style-type: none"> <li>(a) Considered purchasing or leasing a more efficient gas or diesel vehicle</li> <li>(b) Considered purchasing or leasing an electric or plug-in hybrid vehicle</li> <li>(c) Considered moving to reduce the amount you drive</li> <li>(d) Increased use of a more fuel-efficient vehicle you have access to</li> </ul>
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### 2.1.3. Barriers to Change

There exist many barriers to switching to more sustainable forms of transportation such as lack of access to public transportation, missing connections in active transportation infrastructure, challenges surrounding EVs, affordability in areas with closer services and employment opportunities, and potential attitudinal barriers. These barriers that may cause people to resist or prolong making changes for environmental improvements have been found to be either individual, or internal, barriers or societal, or external (Stankuniene et al., 2020). Examples of internal barriers are lack of information, no interest in pro-environmental behavior, engrained habits, and demographic factors. External barriers include cultural, economic, institutional, or regulatory challenges. When related to transportation, overcoming these barriers may require financial incentives, education campaigns, improved infrastructure, or simply just seeing their neighbor make changes which can begin the process of cultural change. In terms of financial incentives, it was found in one study in Canada that cash incentives played an important role in increasing the uptake of electric vehicles (Abotalebi et al., 2019). While Vermont has an incentive program for EV purchases, the interview phase of this thesis found that very few Vermonters actually know that they exist, leaving individuals to believe that EVs may be cost prohibitive whether or not that is the case. This study will examine the factors most important to respondents when considering purchasing or leasing an EV.

As will be shown in the interview phase of this thesis, a general resistance to change plays a significant role in a lack of travel behavior change for environmental or other reasons. This survey did not

ask individuals if they would change their behavior for a specific reason, but rather asked how different types of changes to their community’s infrastructure and land use would change their behavior, if at all.

The survey questions related to barriers to change are shown in Table 9.

**Table 9 Barriers to Change Questions**

Question	Answer Options
<p>Would you ever consider moving to reduce the amount you drive or spend on transportation?</p>	<p>(a) Definitely not                      (b) Probably not                      (c) Maybe                      (d) Probably                      (e) Definitely</p>
<p>How would the following changes in your community affect the amount you currently drive in a week?</p> <ul style="list-style-type: none"> <li>More frequent public transportation</li> <li>Public transportation connects you to more places you go</li> <li>Bus routes on state highways are replaced by trains</li> <li>Most streets are made safe for walking</li> <li>Most streets are made safe for biking</li> <li>More local employment opportunities</li> <li>Closer shopping locations</li> <li>Closer public schools</li> </ul>	<p>(a) Would not change my driving                      (b) A small decrease in my driving                      (c) A moderate decrease in my driving                      (d) A large decrease in my driving                      (e) I would stop most of my driving</p>
<p>Considering your next vehicle purchase or lease, how important would the following changes be to your decision to buy an electric vehicle instead of a gasoline or diesel vehicle?</p> <ul style="list-style-type: none"> <li>Cost is reduced</li> <li>More charging stations</li> <li>More miles per charge</li> <li>Faster charging</li> <li>4-wheel drive is available</li> <li>Trucks and SUVs are available</li> </ul>	<p>(a) Not at all important                      (b) Slightly important                      (c) Somewhat important                      (d) Very important</p>

#### 4.2. Preliminary Results

As of April 20, 2022, there were 771 completed responses to the online statewide survey. This represents a response rate of 1.64% to the email campaign. These 771 responses were a result of 809

surveys started, showing a completion rate of 94%. The median duration for survey completion was 15.7 minutes. Table 10 shows the demographic representation of the survey sample, for those that responded to the demographic questions, compared to those from the 2020 American Community Survey 5-year estimates for the state of Vermont. As can be seen, the survey sample slightly overrepresents men, individuals with higher degrees of education, and high-income individuals. The survey sample was over-representative of older individuals, as can be seen by the high percentage of retirees as well as the median age for the sample which was 64 years. The statewide median age is 42.8 years as of the 1098 ACS. The sample is, however, is similar to the state racially.

**Table 10 Survey Demographics**

<b>Variable</b>	<b>Count</b>	<b>Study Sample</b>	<b>2020 ACS</b>
<b>Gender</b>			
<i>Male</i>	318	51.5%	49.5%
<i>Female</i>	296	48.0%	50.5%
<i>Non-Binary</i>	3	0.5%	
<b>Race</b>			
<i>White</i>	595	95.0%	93.6%
<i>Black or African American</i>	4	0.6%	1.3%
<i>American Indian or Alaska Native</i>	10	1.6%	0.3%
<i>Asian or Asian American</i>	12	1.9%	1.6%
<i>Native Hawaiian or Other Pacific Islander</i>	5	0.8%	0.0%
<i>Other</i>	0	0.0%	3.2%
<b>Education</b>			
<i>12th grade - no diploma</i>	5	0.8%	6.5%
<i>High School or GED</i>	85	13.6%	28.3%
<i>Some college - no degree</i>	109	17.5%	16.7%
<i>Associate's</i>	95	15.2%	8.8%
<i>Bachelor's</i>	172	27.6%	23.5%
<i>Graduate or Professional Degree</i>	158	25.3%	16.1%
<b>Income</b>			
<i>Less than \$35k</i>	77	12.9%	26.9%
<i>\$35k - \$49.9k</i>	72	12.0%	12.3%
<i>\$50k - \$74.9k</i>	117	19.5%	18.3%
<i>\$75k - \$99.9k</i>	129	21.5%	13.9%
<i>More than \$100k</i>	204	34.1%	28.6%
<b>Employment</b>			
<i>Full or part time</i>	412	62.0%	62.9%

<i>Unemployed</i>	5	0.8%	2.5%
<i>Retired</i>	233	35.0%	
<i>Student</i>	0	0.0%	
<i>Unable to Work</i>	15	2.3%	

The survey began by asking respondents about their general community and primary vehicle characteristics. Most of the sample responded that they live in a rural area (56.5%), while less than 24% stated they live in a city or urban area. Cars and SUVs powered by gasoline or diesel were the most common responses for vehicle and fuel type. Only two respondents to the survey said they do not make any trips by vehicle, so those respondents were not asked any further questions. Table 11 shows the complete distribution of community, vehicle, and fuel types for all respondents.

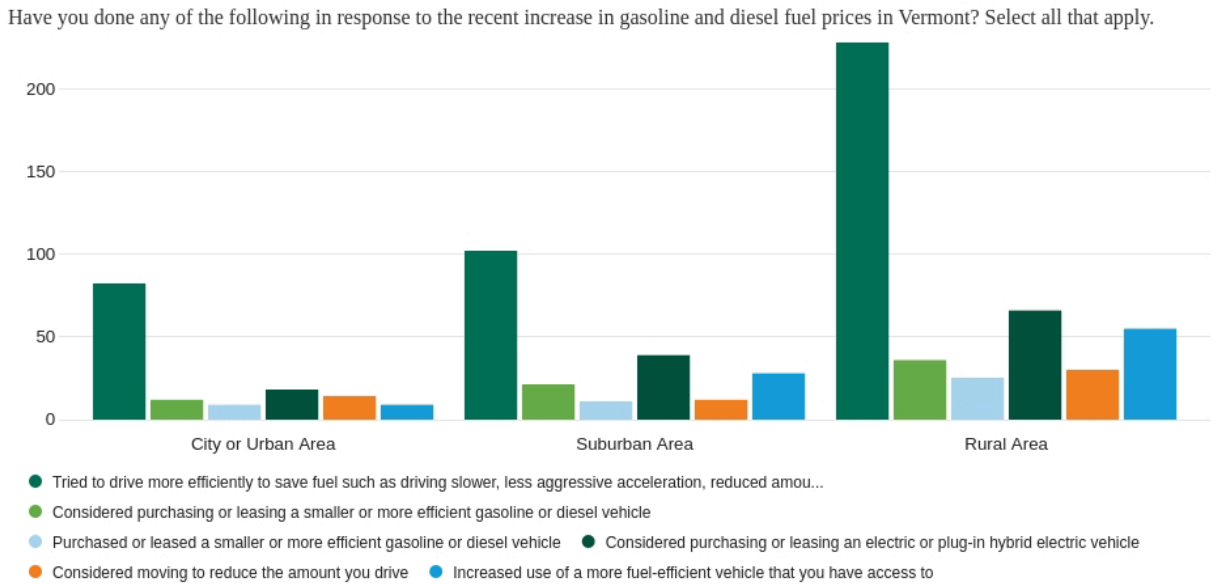
**Table 11 General Survey Respondent Characteristics**

<b>Variable</b>	<b>Count</b>	<b>Percent</b>
<b>Community Type</b>		
<i>City or Urban Area</i>	144	19.3%
<i>Suburban</i>	181	24.2%
<i>Rural</i>	422	56.5%
<b>Vehicle</b>		
<i>Car</i>	379	51.1%
<i>Van</i>	15	2.0%
<i>SUV</i>	201	27.1%
<i>Pickup Truck</i>	146	19.7%
<i>Other Truck</i>	1	0.1%
<i>Motorcycle</i>	0	0.0%
<b>Fuel Type</b>		
<i>Gasoline or Diesel</i>	674	90.8%
<i>Hybrid Electric</i>	41	5.5%
<i>Plug-In Hybrid Electric</i>	12	1.6%
<i>Battery Electric</i>	11	1.5%
<i>Other</i>	4	0.5%

#### 4.2.1. Responses to Fuel Prices

To begin the survey questions related to responses to increasing fuel prices, respondents were asked how important it is to them to reduce their expenses on driving considering the recent fuel price increases. 51% of respondents stated that it was “Somewhat Important” and 34% stated it was “Very Important”. The remainder of respondents felt that it was “Not at All Important” to them to reduce travel related costs.

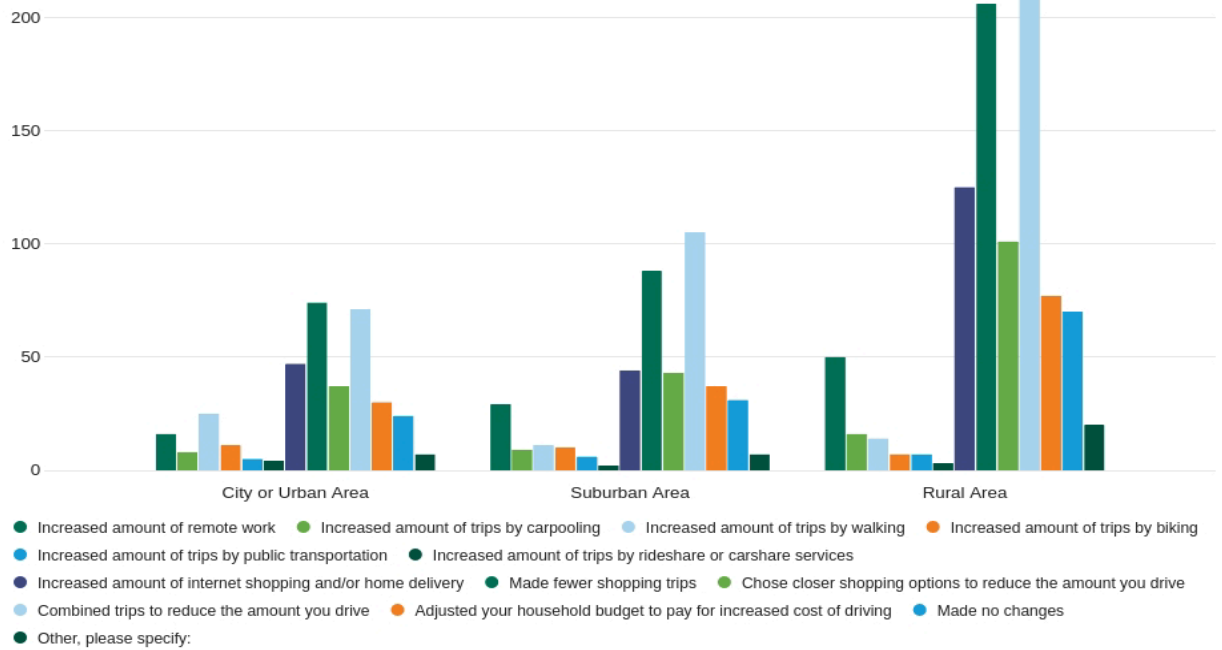
First, looking at the revealed preference data, most respondents have changed behavior in some way in response to fuel price increases. The most common behavioral shift (52% of responses) was beginning to “eco-drive” or trying to drive more efficient by driving slower, less aggressive acceleration, and reduced amount of idling. The second most common response, albeit much less common, was the consideration of purchasing or leasing an electric or plug-n hybrid vehicle. 15% of responses indicated they were considering making this change. The complete distributions of responses to this question are presented in Figure 16.



**Figure 16 Overall Responses to Increasing Fuel Prices**

After asking about overall behavioral changes, respondents were then asked how they have responded to increasing prices when making both essential and less-essential trips. When answering with regards to essential trips, the most common response was that individuals had begun combining trips to reduce the amount they drive with 24% of responses indicating this change. The next most frequent responses were to make overall fewer shopping trips (21% of responses) and increased amount of internet shopping and home delivery (13%). Only 7% of responses stated that the individual had made no changes in response to fuel prices when making essential trips. The complete distribution of responses is shown in Figure 17.

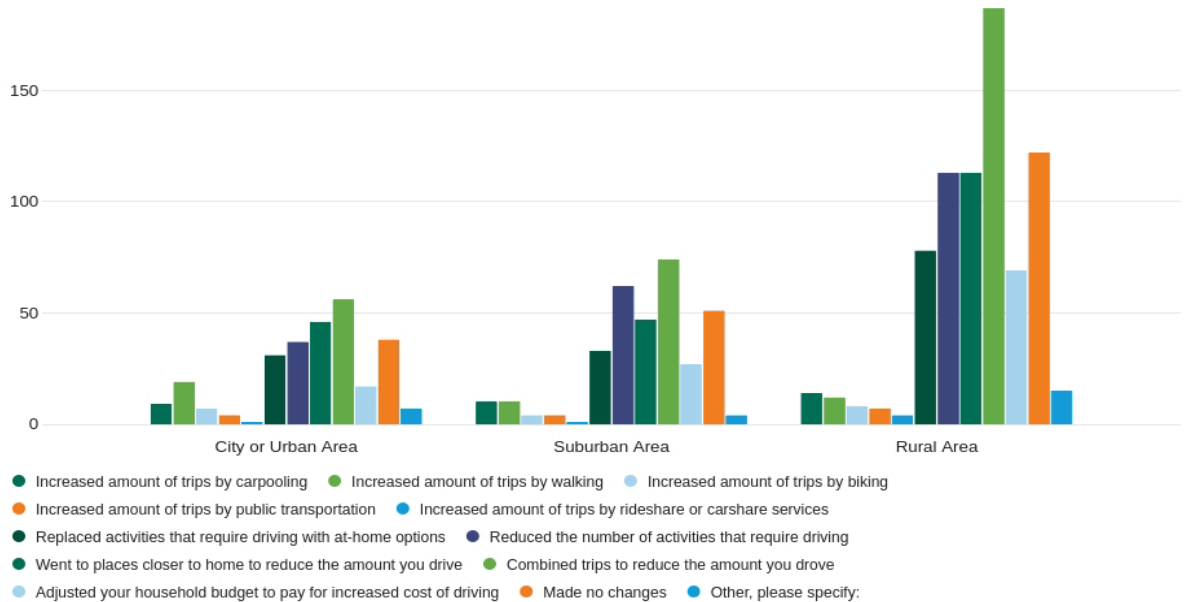
Considering **essential trips** that you make such as going to work, school, buying food and medical appointments, have you done any of the following in response to the recent increase in gasoline and diesel fuel prices in Vermont? Select all that apply.



**Figure 17 Responses to Increased Fuel Prices for Essential Trips**

In terms of less essential trips such as making social trips, recreational activities, and visiting friends and family, 16% of responses indicated that no changes to their behavior were made. Of those responses that involved behavioral change, the most frequently mentioned change was to again combine trips to reduce the amount of required driving (24%). The next most common responses were to reduce the number of activities requiring driving and went to places closer to home, both of which received approximately 15% of total responses. The distribution of responses to this question about less-essential trips is shown in Figure 18.

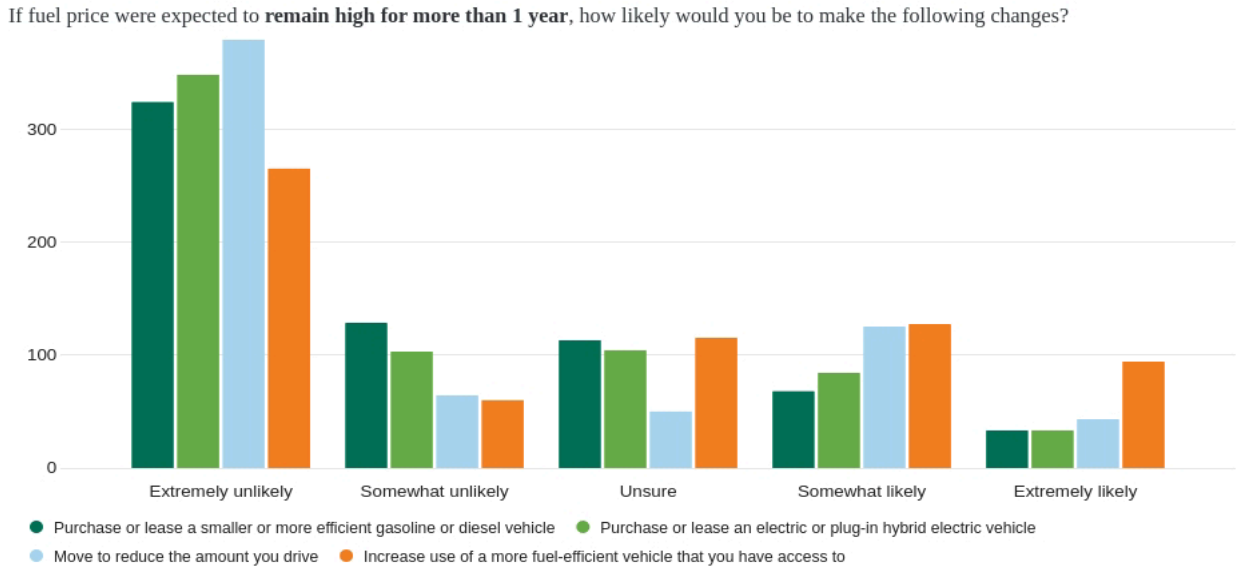
Considering **less essential trips** that you make such as visiting friends and family, recreational activities, and going to social events, have you done any of the following in response to the recent increase in gasoline and diesel fuel prices in Vermont? Select all that apply.



**Figure 18 Responses to Increased Fuel Prices for Less Essential Trips**

At the conclusion of the revealed preference portion of the survey, participants were asked stated preference questions regarding how they may respond if prices were to remain high for more than one year. They were asked the same sequence of questions regarding overall changes and changes for essential and less essential trips. 49% of all responses indicated that any potential change presented as an option would

be “Extremely unlikely” and 19% responded that these changes would be “Somewhat unlikely”. Of those responses that indicated a change would be “Somewhat likely” or “Extremely likely” (23% of all responses), 36% stated that the change they would make is to increase the use of a more fuel-efficient vehicle that they already have access to. The complete distribution of responses to this stated preference questions is shown in Figure 19.

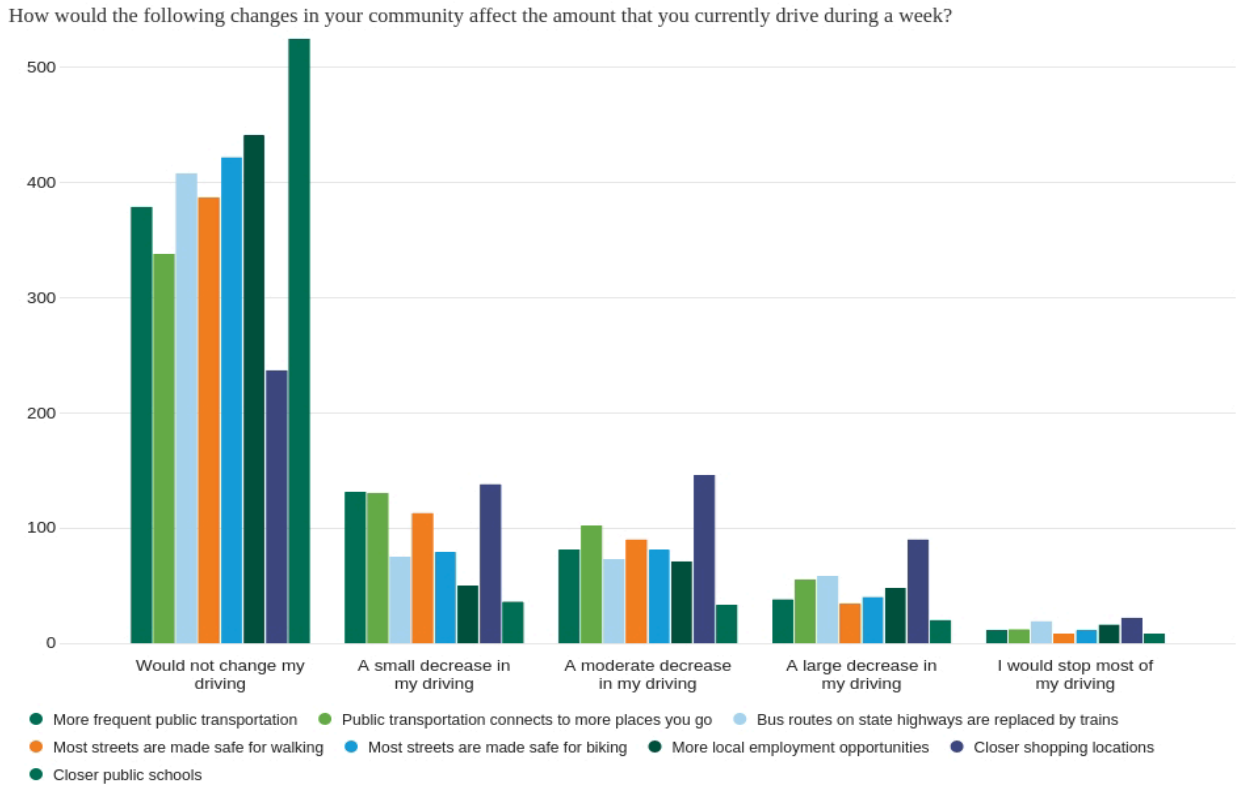


**Figure 19 Stated Preference Responses to Sustained Increase in Fuel Prices**

#### 4.2.2. Barriers to Change

Based on responses received during the interview phase of this thesis, potential barriers to change were identified. In the survey, participants were presented with the opportunity for that barrier to be lowered and they were asked if these changes would change their amount of driving. No matter the intervention, 63% of responses indicated that it would make no change to their driving. Only 10% of responses stated that one of the changes would reduce in a large decrease in driving or that they would stop most of their driving. The one response that would reduce the amount of driving done by the participants

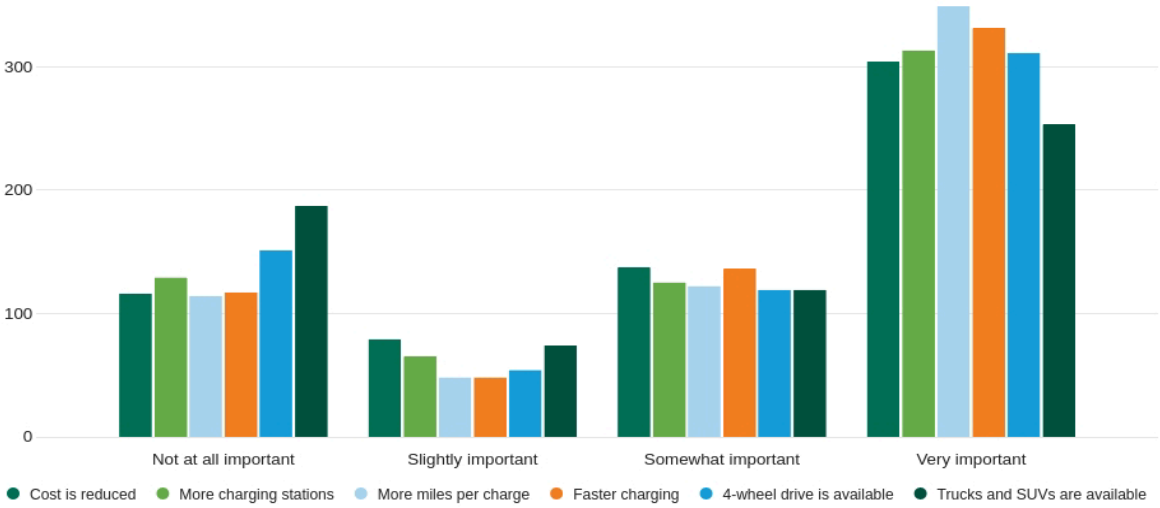
was the presence of closer shopping locations. The complete distribution of responses is shown in Figure 20.



**Figure 20 Changes to Amount of Driving from Community Changes**

Respondents were then asked about barriers related to the purchase or lease of an electric vehicle. Again, the potential barrier reductions provided as options came from responses received during the interview phase. All options were deemed “Very important” when considering their next vehicle purchase or lease, with nearly double the responses citing this level of importance over “Not at all important”. Of the options provided, the least important change to EVs in terms of their adoption is that trucks and SUVs are made available. Based on the responses gathered, the largest concerns around EVs in Vermont are about charging. Having the ability to charge faster and having more miles per charge were the most important factors to the survey respondents. The distribution of responses to this question is shown in Figure 21.

Considering your next vehicle purchase or lease, how important would the following changes be to your decision to buy an electric vehicle instead of a gasoline or diesel vehicle?



**Figure 21 Importance of Changes to Electric Vehicles When Considering Next Purchase**

**4.3. Conclusions**

The design of this survey intends to capture a wide range of explanatory variable encompassing existing attitudes and values, household characteristics, and demographics. These variables will be used to explain changes that have been made in response to recent fuel price increases in Vermont. This natural experiment in price change has provided an opportunity to examine both revealed preference and stated preference data. Revealed preference data often relate to changes in VMT as a result of prices to calculate numeric elasticities but this survey is unique in that it looks at specific behavioral changes that are hidden underneath VMT values. While this component of the analysis is yet to be completed due to the recent nature of the survey distribution, a cursory analysis of trends could be completed in the preliminary results presented here.

An initial look at the demographics of these data show that a relatively large sample size was captured, yet older and higher-income individuals were overrepresented compared to the statewide demographics. These individuals have likely changed in different ways than lower-income Vermonters as

low-income individuals have been shown to be more price responsive. With the ongoing nature of this survey, it would be productive to engage directly with younger and lower-income people to ensure that the sample is more representative of the state upon completion and final analysis.

Although the sample is not fully representative, some trends were made clear for the population sampled. Most people have changed their driving behavior but have not substantially changed overall travel behavior beyond combining trips. The most prominent behavioral shift is the introduction of “eco-driving” or attempting to drive more fuel efficiently by driving slower or accelerating less harshly. This change does not result in lowered VMT which is often the goal for reducing transportation GHG emissions. The one change that was observed in this survey that could lower VMT was the combining of trips. This also relates to the desire for closer shopping options, which was indicated by respondents as a means to reduce the amount of driving they do. This suggests that instead of multi-modal infrastructure improvements or large-scale land use changes which aim for denser city centers and villages (sometimes referred to as “smart growth”), cities and towns can invest in local economic development in the form of retail opportunities. If the behavior of combining trips is sustained in addition to the ability to shop and work closer to home, there exists a chance for noticeable VMT reductions. This is particularly true for rural communities where shopping and other errands is often done in areas quite far from the home.

If widespread VMT reduction is unlikely in the short-term, as the data suggests, there may be opportunities to encourage EV adoption, although some barriers clearly exist. Survey respondents viewed improvements in vehicle range and speed of charging as being of high importance when considering an EV for the next vehicle purchase or lease. The introduction of trucks and SUVs to the EV market was not seen as a large barrier to adoption as many respondents deemed this as less important or even unimportant to their decision. EV adoption will also take time as has been seen by trends in the adoption across Vermont. In the interim, continued efforts towards reduced VMT should be made, whether this is through sustained pricing on gas vehicles or educational efforts about the harms of transportation GHG emissions.

If high fuel prices were to be sustained for more than one year, most respondents said that it is unlikely that they would purchase or lease a more efficient or electric vehicle or move to change their travel. Some respondents, however, did indicate that it is likely they would increase use of a more fuel-efficient vehicle they already have access to. This shows that fuel-efficient vehicles have penetrated the market and are in the hands of many Vermonters but are not being used as frequently as they could be. This does not necessarily reduce VMT, which may be a long-term goal of the state, but it does help to curb emissions and save individuals money on their fuel costs.

These preliminary data from this survey point to a reliance on vehicles across the state and many barriers to changing driving behavior. These barriers may be physical, attitudinal, or related to their household characteristics. These relationships will be examined further upon completion of the survey's distribution. Based on the literature reviewed for this thesis and over the course of survey design, it is likely that attitudes will play a strong role in determining behavior. This remains to be seen, however, as Vermonters in small and rural communities, often face challenges of distance and weather which may lead people to believe they must drive to most of their destinations. At this point in the analysis, it can be said that Vermonters are taking notice of the increasing fuel prices, and many see a need to reduce their expenses on transportation. The staying power of these price signals and behavioral changes, albeit small changes, will only be shown over time as prices continue to fluctuate and impacts from emissions are realized closer to home.

## CHAPTER 5: CONCLUSIONS AND DISCUSSION

### 5.1. Rural Definitions

VMT is a widely used and comprehensive metric that can show the impact of many decisions that make up travel behavior and this metric was examined under six classification schemes of urbanicity and rurality. By applying the same dataset to six different definitions, large discrepancies were illuminated and highlighted the uncertainty that exists surrounding the quantifying of rural travel behavior. Policy decisions and funding allocations are at stake under these definitions and the need to understand this impact is paramount to the success of these policies and the efficient use of state and federal funds. As was shown, numerous funding mechanisms apply to rural communities and require an official designation under one classification scheme or another. If these definitions do not truly capture the behavior of these areas, it cannot be said with any certainty that meaningful change will be realized.

Travel behavior can be defined in a multitude of ways including mode choice, number of trips, vehicle miles traveled, or safety. Most of the research on these behavioral components occur in urban areas or simply dichotomize urban and rural. In these studies, it is generally agreed upon that individuals living in rural areas have higher rates of vehicle ownership, increased trip distances, walk less for transportation, and generally have less accessibility to services than their urban counterparts (Carlson et al., 2018; Millward & Spinney, 2011; Pucher & Renne, 2005). These conclusions may not show the whole picture due to their lack of nuance provided in their definitions of what constitutes urban versus rural areas. Can it really be said with certainty that all rural communities exhibit this pattern of more and longer distance travel than urban communities? Policymakers and planners must rely on existing representations of urban and rural travel behavior, whether it is an accurate picture of behavior or not. To know if these claims are true, more in-depth analysis needs to be completed which captures additional information about how these rural communities are made up in terms of transportation systems, public transit access, land use, and other characteristics related to these areas. Only when planners and policymakers have a more informed view of

the communities they serve can impactful policy be designed and implemented to improve transportation in rural areas.

I hope to grow the body of literature on defining rural and how this impacts the study of travel behavior as the need for better data is constantly expanding. While we race against the pressures of problems such as climate change, travel behavior is under scrutiny, as transportation is such a large contributor of emissions. This makes it even more imperative that we understand the problem so that we can learn how to tackle the problems at hand with proper policy mechanisms. When inconsistencies are present at the definitional level of a field of study, all outcomes using these definitions are sure to exhibit some of that inconsistency as well. By shedding light on part of the issue in classifying rural areas, I aim to show transportation researchers, planners, and policy makers that what we know about rural areas is based upon which definition is used to identify these areas, rather than on an objective truth under a common classification.

## **5.2. Vermonters' Opinions on Transportation**

This thesis has shown that people living in urban, suburban, and rural areas in Vermont vary in terms of the daily challenges they face while traveling, but also share some notable attributes. This has impacts on current and future policy decisions aimed at changing behavior to reduce GHG emissions. Many researchers and policymakers have claimed that pricing policies are going to be effective in reducing emissions, and they are in some areas, but this may not be the case in rural communities. This research sought to further investigate this responsiveness to fuel prices. Many Vermonters expressed that they would do what they must do to pay for fuel, regardless of prices. This perceived inelasticity may have merit over the course of long-term price increases. When a sudden price shock hits, people tend to be more responsive, however these changes do not always withstand the test of time, even if prices do not go back down (Chi, 2016). This idea of dependence often leads people to be opposed to gas taxes because they say that they

will pay whatever they have to in order to maintain their current travel patterns. Stated preference surveys have shown that people say they would seek alternative forms of transportation if gas prices were to reach six dollars per gallon (Mattson et al., 2010). The relationship between stated preference and revealed data is often studied as humans do not always act in the ways in which they say they will, meaning their stated preferences do not align with the eventual revealed preferences. This is particularly prevalent when asked to perform valuations of public goods. In these cases, valuations are frequently overexaggerated (de Corte et al., 2021; Yu & Jayakrishnan, 2018).

Further research is suggested to examine this closer and analyze whether people truly maintain their behavior or if there are changes in behavior in response to increasing prices. To achieve these changes, further research must be completed. We are using data from these interviews to implement a more comprehensive stated-preference survey to dig deeper into what it would take to change rural travel behavior and increase the sustainability of rural travel. The research presented here draws from a diverse, but small sample size. There were also limited questions asked to keep the interviews short and maximize participation. Future research aims to capture a larger sample of individuals across many small and rural communities. The lines of questioning may include scenarios with specific gas prices or distance to bus service to establish elasticities of individuals who may change their behavior. Additional research can help to establish a baseline of where people are at with their behavior and where they may change to reduce emissions from transportation. There is likely no silver bullet for reducing transportation emissions in small and rural communities, but through a deeper understanding of the challenges that people face and changes they are willing to make, a diverse suite of options for reducing GHG emissions can be developed and implemented over time. Behavior change is a complex thing to achieve, but it is only possible through continued study and close communication with the people that are directly impacted.

### 5.3. Responses to Fuel Prices

The survey used in this thesis is still an ongoing process and responses will continue to be collected before analysis is complete. A cursory examination of responses thus far has shown that people are highly aware of the increasing fuel prices and most Vermonters are making some sort of change to their daily travel. The most common behavioral change observed has been to combine trips will result in overall VMT reduction. This reduction can help to lessen the impact transportation has on statewide GHG emissions and may continue to impact emission rates if fuel prices remain high. The responses to a sustained increase in fuel prices must be taken as predictions only and not the definite future as these were stated preference questions and the impact is only hypothetical at this point. It is unclear if people truly will begin to use more fuel-efficient vehicles as they indicated or if widespread change would occur.

Future analysis of these responses will include the results from the attitude and values section of the survey to identify whether certain attitudinal factors play a role in determining who is more likely to change behavior in which ways. This survey is unique in that it examines how people change their behavior rather than simply calculating elasticities from observed VMT changes. This elasticity calculation will be conducted to supplement the behavioral change results. These results in tandem provide a comprehensive of look at the extent to which Vermonters change their VMT as well as understanding which behavioral shifts caused these VMT reductions or increases. This will help to inform future research particularly in rural areas where previous research has been rare and, at times, contradictory in their results.

Thus far, existing literature has provided inconclusive results on the responses to fuel prices in rural areas, with some studies showing them to be more elastic and others showing less elasticity. The analysis of these survey results has initially shown that Vermonters in rural, suburban, and urban areas have nearly all been making changes to their travel to cope with rising fuel prices. The continuation of this survey is vital to better understanding how, why, and to what extent rural-dwelling individuals are shifting travel behavior. With the need to reduce VMT for the sake of GHG emissions reduction becoming ever

more urgent, understanding the mechanisms for change also becomes more urgent and this thesis has begun to do exactly that.

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