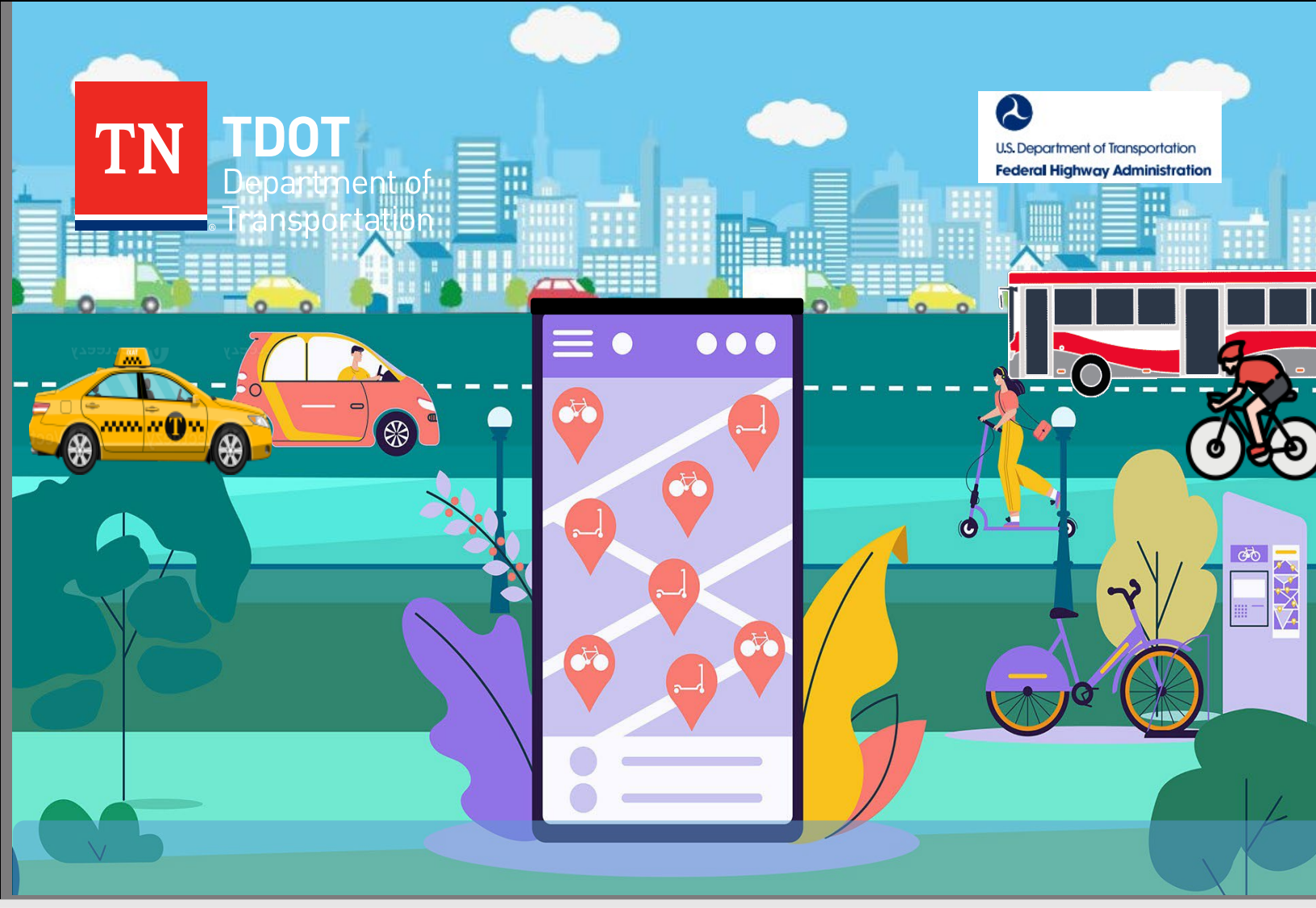

Influencing Mode Shift through Behavioral Change Strategies

Research Draft Report from The University of Memphis and University of Tennessee Knoxville | (Sabya Mishra, Mihalis M. Golias, Candace Brakewood, and Avani Aravind) | July 31, 2024

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16. Abstract

This research is behavioral approach to addresses the critical transportation challenges in Tennessee, particularly the reliance on Single Occupant Vehicles (SOVs). Despite efforts by different agencies across US to promote sustainable alternatives through Travel Demand Management (TDM) initiatives, public participation and the effectiveness of these measures remain limited. This study aims to bridge this gap by evaluating successful strategies from literature and case studies, assessing current TDM practices, and gathering stakeholder feedback to propose enhancements. The primary objective is to provide TDOT with viable message-framing techniques to influence travel choices towards sustainable modes over SOVs. The research involves a comprehensive literature review, stakeholder surveys, and a user survey utilizing a stated choice questionnaire to assess the effectiveness of nudging messages to promote alternative modes of transport. Key findings indicate that while stakeholders are inclined towards alternative transportation modes, significant gaps exist in strategic planning and regional TDM committees. The study also reveals the positive impact of nudging techniques, particularly emotional, normative, and gain nudging, on promoting public transit choices. By integrating qualitative and quantitative methodologies, this research offers actionable recommendations to refine TDM initiatives, ultimately enhancing sustainable mobility in Tennessee.

17. Key Words **Travel Demand Management** **Bias-Busting** **Nudging** **Goal Framing Theory** **Randomized Control Trials**	18. Distribution Statement		
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Glossary of Key Terms and Acronyms

SOV: Single Occupant Vehicle

GFT: Goal Framing Theory

RCT: Randomized Control Trials

TDM: Travel Demand Management

TDOT: Tennessee Department of Transportation

MPO: Metropolitan Planning Organization

1. Executive Summary

1.1 Statement of Purpose

The purpose of this research is to address the transportation challenges in Tennessee by promoting sustainable alternatives to Single Occupant Vehicles (SOVs) through effective Travel Demand Management (TDM) strategies. By leveraging behavioral psychology and evaluating various nudging techniques, this study aims to influence commuter habits, reduce congestion, and enhance mobility across the state.

1.2 What was the research need?

The necessity for this research arises from the pressing transportation challenges confronting Tennessee, particularly the widespread reliance on SOVs for commuting, leading to substantial congestion in major urban areas throughout the state. Despite concerted efforts by the Tennessee Department of Transportation (TDOT) to promote sustainable alternatives through TDM initiatives, there persists a notable lack of positive response towards the effectiveness of these measures and public participation. This research endeavors to bridge this gap by conducting a comprehensive examination of successful strategies gleaned from existing literature and case studies, evaluating the current state of TDM practices in Tennessee, and soliciting feedback from stakeholders to propose enhancements. By delving into the behavioral psychology underlying commuter habits and perceptions, as well as quantifying the potential impacts of various interventions on traffic patterns, this research seeks to establish a more effective feedback mechanism between TDM stakeholders and inform decision-making processes to encourage mode shift towards sustainable transportation options, ultimately alleviating congestion and enhancing mobility across the state.

The primary objective of this study is to provide guidance to the TDOT on viable message-framing techniques to serve as nudging mechanisms aimed at influencing travel choices and promoting more sustainable mode selections over SOVs. Additionally, the study aims to offer strategic direction for stakeholders and TDM agencies. The study entails three main components. Firstly, a comprehensive review of published literature on existing strategies for promoting public transit usage and proposed methodologies is conducted. Secondly, the study presents the proposed methodology, which involves administering two distinct types of questionnaire surveys. The first type targets stakeholders and TDM organizations in Tennessee to elucidate the current landscape of sustainable mobility options in the state. The second type involves a user survey utilizing a stated choice questionnaire to assess the effectiveness of various nudging messages in facilitating mode shift. Finally, the study visualizes the results through an online dashboard and provides recommendations for the implementation of effective strategies.

1.3 What were the research objectives?

The overarching goal of the research is to establish a better feedback mechanism between stakeholders and users to develop strategies that can nudge commuters from SOVs to their sustainable alternatives. To accomplish this goal, the research team proposes a set of specific milestones with the following objectives.

- Conduct a literature review and identify case studies to acquire a state-of-the-art understanding of TDM practices and policies that have proven effective.
- Identify currently implemented TDM measures/policies, and challenges in their implementation and provide recommendations to TDOT using tools developed to obtain feedback.
- Develop a survey tool with different nudging strategies to understand travel behavior and perceptions across the state.
- Develop an interactive ArcGIS visualization tool that communicates collective traveler behavior and the impact of various TDM scenarios through a set of GIS maps and figures.

1.4 What was the research approach?

The research approach adopted in this study is characterized by its comprehensive and multifaceted nature, combining diverse methodologies and techniques to fulfill its objectives. Initially, a stakeholder analysis was undertaken through the administration of a structured questionnaire, targeting two primary cohorts: TDM stakeholders and TDM organizations. This methodological strategy facilitated the acquisition of invaluable insights into the prevailing landscape of TDM initiatives, elucidating both achievements and areas necessitating improvement. Subsequent to data collection, meticulous analysis of survey results ensued, aimed at discerning prevalent trends, evaluating perceptions, and pinpointing specific challenges encountered by stakeholders and organizations actively engaged in TDM endeavors.

Furthermore, the study ventured into experimental research, employing a discrete choice analysis framework to ascertain the efficacy of distinct treatments on individuals' tendency towards selecting public transit modes. Through meticulous randomized control trials and manipulation checks, the project sought to gauge the effectiveness of varied nudging techniques, encompassing emotional, normative, and gain nudging, in molding mode choice behaviors. The incorporation of manipulation checks served to validate participants' attentiveness towards the administered treatments and substantiate the efficacy of the experimental design. Employing a survey experiment facilitated the examination of how different nudges influence commuter choices, leveraging a web panel for the recruitment of a diverse cohort of Tennessee residents. Participants were randomly assigned to one of four groups, including three treatment groups and a control group. Following exposure to

information pertaining to various transportation modalities, respondents were prompted to designate their preferred mode for a hypothetical 10-mile journey. Subsequently, a multinomial logit model was employed to scrutinize the impact of nudge treatments alongside respondent characteristics on mode selection.

The research approach seamlessly integrates qualitative stakeholder analysis with quantitative experimental methodologies, culminating in a comprehensive understanding of behavioral methodologies for sustainable mode shift. By assessing the efficacy of different nudging techniques in fostering sustainable transportation choices, this holistic approach furnishes nuanced insights into the determinants of mode choice behaviors. Ultimately, the findings derived from this multifaceted inquiry furnish actionable recommendations for refining TDM initiatives to propel sustainable transportation solutions forward.

1.5 What were the findings?

The key findings of the project are as follows:

- **Stakeholder Engagement and Initiatives:** The stakeholder analysis revealed both positive aspects and areas for improvement in Tennessee's Transportation Demand Management (TDM) initiatives. While some stakeholders have successfully developed strategic plans and expressed positive inclinations towards alternative transportation modes, significant gaps exist, including the lack of long-range strategic plans and regional TDM committees. However, stakeholders generally prioritize TDM strategies and express willingness to engage in promoting alternative modes of transportation.
- **TDM Organization Operations:** TDM organizations also show a mix of positive aspects and areas for improvement. Notable focus is placed on meeting specific transportation needs, with some organizations providing demand-responsive/paratransit services and employing a significant fleet size. However, challenges include the lack of mobile applications, tailored travel options, and mixed results regarding the effectiveness of incentives with an emphasis on improved data collection practices.
- **Nudging Effects on Public Transit Choice:** The treatments under examination, including Emotional Nudging, Normative Nudging, and Gain Nudging, demonstrated favorable impacts on respondents' likelihood to choose public transit modes. Compared to the control group, respondents in treatment groups showed a higher preference for Public Transit-Bus and Multimodal Transit, indicating the effectiveness of nudging interventions in promoting alternative transportation choices.
- **Mode Choice Preferences:** Analysis of respondents' stated choices revealed a notable difference in mode choice preferences after the survey. Treatments, particularly Gain Nudging with the "Health Gain" treatment, were effective in reducing the preference for Personal Car and increasing the preference for Public Transit-Bus. These findings highlight the potential of nudging strategies to influence mode choice behavior positively.

1.6 What were the benefits and Implementation?

The findings from this study offer substantial benefits for the TDOT and other stakeholders involved in TDM initiatives. By identifying effective nudging techniques—such as emotional, normative, and gain nudging—this research provides actionable insights into how strategic message framing can influence commuter behavior towards more sustainable transportation modes. These nudging strategies have shown promise in increasing the preference for public transit options over SOVs, which can lead to significant reductions in urban congestion, lower greenhouse gas emissions, and improved overall mobility within the state. Furthermore, the comprehensive analysis of stakeholder and TDM organization operations reveals critical areas for enhancement, including the need for long-range strategic planning, the establishment of regional TDM committees, and the adoption of advanced data collection practices.

To implement the recommendations derived from this study, TDOT and TDM stakeholders should integrate the identified nudging techniques into their communication and outreach strategies. This can be achieved by developing marketing campaigns and informational materials that utilize emotional appeals, normative messages, and health-related benefits to encourage public transit use. Furthermore, improving mobile application capabilities and data collection practices will enhance the responsiveness and adaptability of TDM initiatives, ensuring that they remain relevant and effective in addressing the evolving transportation challenges faced by Tennessee. The study's actionable recommendations[1] will support the creation of more engaging and effective TDM campaigns, encouraging a modal shift away from SOVs towards more sustainable transportation options, thereby alleviating congestion and enhancing overall mobility across the state.

2. Introduction

The majority of commuters in Tennessee utilize single-occupant vehicles (SOV). The percentage of Tennessee commuters who drive alone to work rose from 68.2% in 1980 to

[1] For further reading on this topic, this study has been published in the journal *Transportation Research Part D* titled "*Nudging towards sustainable urban mobility: Exploring behavioral interventions for promoting public transit*" (https://doi.org/10.1016/j.trd.2024.104130). Additionally, the findings were presented at the TRB Annual Meeting 2024.

83.3% in 2019 according to the Bureau of Transportation Statistics (Figure1). This has caused considerable congestion throughout the state's cities. Five Tennessee cities, Nashville, Cleveland, Memphis, Chattanooga, and Knoxville, are among the 200 most congested in the United States. The factors influencing the reliance of Tennesseans on personal vehicles remain ambiguous, despite public perceptions that cite concerns about the reliability of public transportation.

Car commuters report much higher levels of stress than train commuters (Wener & Evans, 2011). They also express less life satisfaction and a greater sense of time constraint (Hilbrecht et al., 2014). In fact, driving to work every day is related with an increased chance of acquiring excessive blood sugar and cholesterol, putting individuals at a higher risk of cardiovascular death (Hoehner et al., 2012). At the same time, when too many people drive alone, communities suffer implications on congestion, pollution, greenhouse gas emissions, accidents, and emergency responders, to mention a few. Due to these societal effects, multiple agencies have enacted a policy to decrease the proportion of SOV. Bus, rail, bicycle, walking, and carpooling with coworkers are all ways of commuting that relate to lower stress, higher well-being, and improved physical health (*Applying Behavioural Insights to Transportation Demand Management A Report by Alta Planning + Design and the Behavioural Insights Team (BIT)*, n.d.).

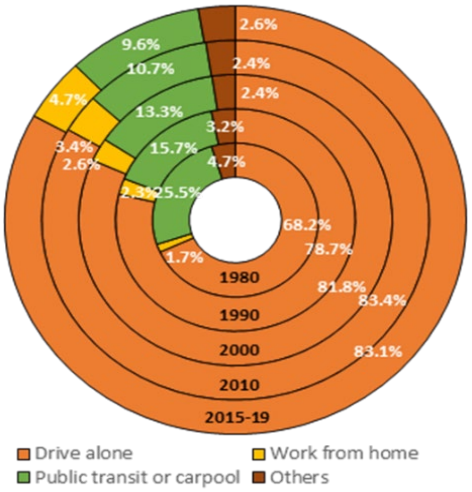


Figure 1. Mode share in Tennessee (1980-2019)
(Source: US Census - Decennial and ACS)

This study aims to address several pressing issues related to transportation and urban mobility (Figure 2) by exploring the potential for behavioral change toward public transit through nudging messages.

- **Transportation Challenges:** The transportation sector contributes significantly to environmental degradation, social inequality, and economic inefficiencies. Issues such as air pollution, carbon emissions, unequal access to transportation services, and the high cost of infrastructure maintenance and expansion pose challenges to sustainable development.
- **Private Vehicle Impact:** Private vehicle usage exacerbates various problems, including traffic congestion, increased fuel consumption leading to higher emissions, and reduced productivity due to time spent in traffic jams.
- These factors not only affect individuals but also have broader implications for urban environments and economies.
- **Solution: Alternative Transportation:** Promoting alternative modes of transportation, such as public transit, cycling, walking, and carpooling, can mitigate the negative impacts of private vehicle usage. By encouraging a shift towards these

alternatives, cities can alleviate traffic congestion, reduce emissions, and enhance the overall livability and sustainability of urban areas.

- **Health and Lifestyle Impact:** Emphasizing the health and lifestyle benefits of using public transit can incentivize individuals to make the switch. Public transit encourages physical activity through walking to and from transit stops, reduces exposure to air pollution compared to sitting in traffic, and can lower stress levels associated with driving.
- **Economic Benefits:** Shifting towards public transit and other alternative modes of transportation can yield economic benefits. Reduced reliance on private vehicles decreases the need for costly road infrastructure projects, saving taxpayer money and freeing up funds for other public services and investments.
- **Human Behavior and Policy:** Understanding human behavior is crucial for designing effective policies and interventions aimed at promoting alternative transportation. By applying insights from behavioral economics and psychology, policymakers can develop nudging strategies to influence people's transportation choices positively.
- **Mode Shift for Sustainable Transportation**: Encouraging a mode shift towards sustainable transportation options, such as public transit, can lead to a more efficient, equitable, and environmentally friendly transportation system. This shift has the potential to generate positive outcomes for individuals, communities, and the planet.

Given the significance of these issues and the potential for behavioral interventions to promote positive change, this study seeks to explore how nudging messages can effectively encourage individuals to choose public transit over private vehicles

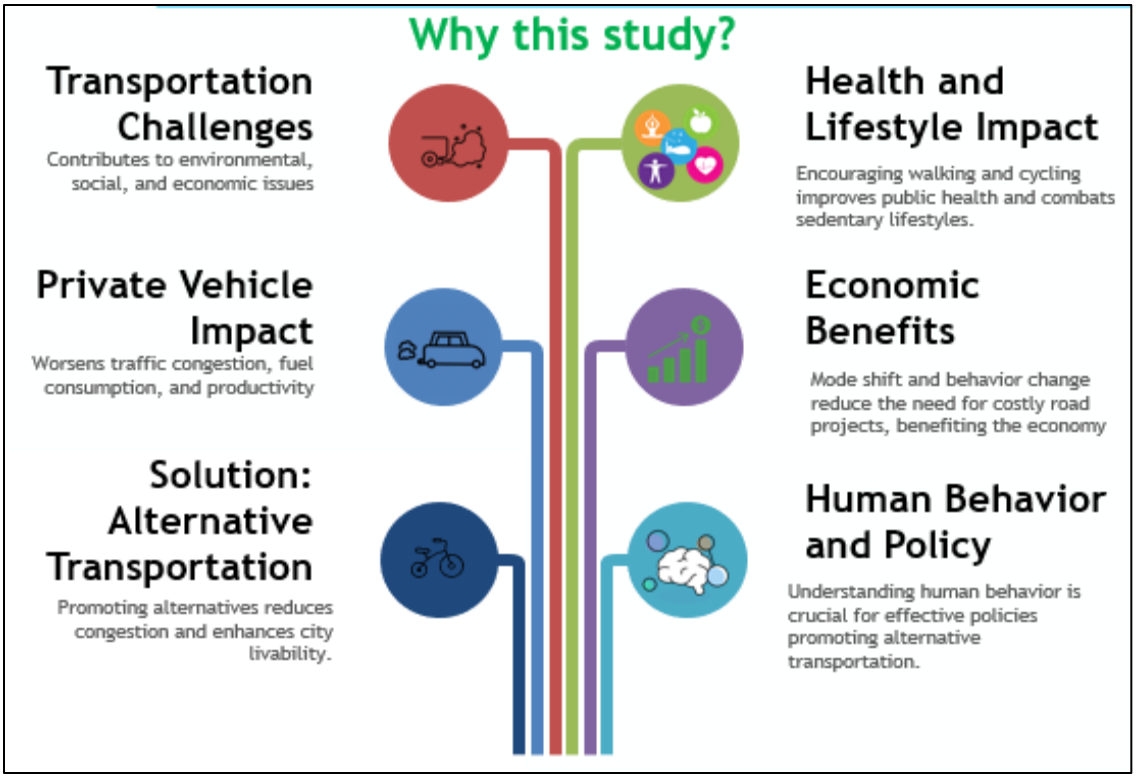


Figure 2 Pressing issues related to Transportation

Prior to the COVID-19 pandemic, the transport industry was responsible for 23% of global energy-related carbon dioxide emissions, and these emissions were on the rise (*Public Transportation Facts - American Public Transportation Association*, n.d.). It was evident that public transportation was essential for reducing carbon emissions, saving the United States around 4.2 billion gallons of gasoline annually (*Energy Technology Perspectives 2017 – Analysis - IEA*, n.d.). Given that 88% of Americans still own cars, there exists an immense opportunity to mode shift people to more sustainable options of mobility and there is a huge space for improvement. Officials concerned with global climate change and sustainability will have to employ every available strategy to increase ridership (Kormos et al., n.d.). Increasing the usage of public transportation is a crucial strategy for reducing carbon emissions and addressing climate change. However, such approaches may not always be effective in practice. Changes in policy occur slowly, especially in the transportation sector. Moreover, people's patterns of transportation use are notoriously difficult to alter, in part because these patterns are frequently essential to an individual's lifestyle and identity and can impact their sense of well-being (Chatterjee et al., 2019).

> "**Bus, rail, bicycle, walking, and carpooling** with coworkers are all ways of commuting that relate to **lower stress, higher well-being, and improved physical health**."

The manner individuals get around also tends to be determined by deeply ingrained habits. Therefore, even when technological advancements and infrastructure investments make public transportation more attractive and accessible, massive changes in human behavior will still be required to ensure that a substantial portion of the American population transitions to environmentally friendly public transport (Avineri, 2012; Steg & Vlek, 2009a). By integrating behavioral science principles, policymakers can design successful programs to encourage the use of public transit.

Existing research discusses the use of soft and strong methods to induce this transition from private mode to sustainable travel modes (Franssens et al., 2021). Soft measures are those that address the psychological motivations for travelers by focusing on changing their attitudes, beliefs, values, and norms. On the contrary, hard measures entail physical improvements to transportation infrastructure (Cairns et al., 2008a). It is often observed that soft measures are economical and easier to implement considering the cost and challenges involved in undertaking physical improvements (Esztergár-Kiss et al., 2021). Furthermore, research from behavioral economics and psychological identified "nudge-based measures" which do not require an individual to change their attitudes. As per Trudel (2019), nudge can be defined as "any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives." This research team utilizes such nudge-based measures to develop approaches to encourage Tennesseans to shift from SOVs to sustainable travel alternatives like public transport, shared mobility and non-motorized travel modes.

By understanding the mechanisms behind behavioral change and designing targeted messaging strategies, policymakers and urban planners can work towards creating more sustainable and resilient transportation systems. Specifically, the research team will 1) investigate strategies that have successfully nudged travelers towards SOV alternatives through behavioral change, 2) gather detailed information on the current state of TDM practices in the state and provide recommendations, 3) survey travel behavior and preferences of commuters concerning TDM implementations for potential interventions, and 4) The research team will develop survey and visualization tools to accomplish these aims.

3. Literature Review

The existing research on capturing the impact of behavioral measures on commute behavior. This section provides a comprehensive review of such measures and case studies.

3.1 Scholarly Research on Behavioral Science Theory

A number of behavioral theories provide recommendations for modifying people's transportation choices. Some believe that behavior change is caused by internal variables (such as values, attitudes, and personal conventions), whilst others believe that change is the result of external forces (such as social norms and financial incentives). Another belief is that transformation outcomes are influenced by both internal and external variables (Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research, n.d.; Modal Shift in the Boulder Valley: 1990-2018, 2019; Models of Man: Social and Rational; Mathematical Essays on Rational Human Behavior in Society Setting | WorldCat.Org, n.d.; Ajzen, 1991; Gärling et al., 2001; Kahneman et al., 1979; Lee et al., 2013). Extensively researched *Rational Choice Theory* postulates that individuals make logical judgments with the intention of maximizing their own best interests (Becker, 1976). This theory has been debunked by a growing body of research examining decisions in a variety of domains, including transportation, although one of its implications that people are more likely to choose an option when they are given an incentive to do so can be used in certain contexts to encourage a switch from cars to public transportation (Anable, 2005; Barr et al., 2011; Maki et al., 2016).

"Based on the premise that individuals are influenced not **just by logic**, but also by other **conscious cognitive processes, unconscious processes, and minor situational signals."**

Other behavioral theories, like *Prospect Theory*, *Theory of Planned Behavior*, and *Habit Formation Theory*, offer more complex insights (Ajzen, 1991; *Fishbein & Ajzen (1975)*, n.d.; Gärling et al., 2001; Kahneman et al., 1979). Based on the premise that individuals are influenced not just by logic, but also by other conscious cognitive processes, unconscious processes, and minor situational signals, these theories are used to comprehend and anticipate the hidden influences on human behavior with more precision.

Central to these ideas is the concept of bounded rationality (*Models of Man: Social and Rational; Mathematical Essays on Rational Human Behavior in Society Setting | WorldCat.Org*, n.d.), which holds that individuals' actions are constrained by the limited willpower, time, and energy they can commit to carefully considering their options. Bounded rationality can lead to systemic biases in people's decision making.

By explicitly considering strategies for overcoming travelers' cognitive constraints and exploiting their behavioral biases, planners should be able to design more effective behavior change campaigns.

In recent years, an increasing number of experiments have examined behavioral interventions for altering the travel habits of individuals. Nonetheless, attempts to consolidate the research have shown contradictory results. Several literature reviews (Brög et al., 2009; Cairns et al., 2008b; Richter et al., 2010) and meta-analyses which combine data from multiple related research (Fujii et al., 2009; Möser & Bamberg, 2008; Taniguchi et al., 2007) have indicated that behavioral science–based interventions are generally effective at encouraging automobile users to switch their mode of transportation. A more recent systematic review and meta-analysis concentrating on research with control groups, however, revealed no significant influence on the proportion of travels made by alternative means of transportation (Arnott et al., 2014). In addition, few of the experiments cited in the literature reviews and none of the meta-analyses focused solely on persuading travelers to switch from cars to public transportation; therefore, the potential and limitations of behavioral science–based interventions for increasing public transportation are not yet known well (Sussman et al., 2020).

3.2 A Systematic Approach to Behavioral Interventions

Kormos et al., n.d.. proposed that all interventions in behavioral science aimed at increasing public transportation usage can be classified into three primary categories: communication-based methods, bias-busting approaches, and technology-based approaches. There are a total of eight therapies that belong to one or more of these categories. After conducting a comprehensive analysis of the review by Adjei & Behrens, 2012) on theories related to experiments aimed at reducing the demand for single-occupancy car use, as well as the review by Garcia-Sierra et al., 2015 on behavioral economics concepts and travel behavior insights, we have identified eight actions that appear to be the most promising. Additionally, behavioral economics contrasts with classical economics in that it considers the psychological and social elements that influence decision-making and frequently drive people to make decisions that differ from those of a completely rational actor.

Out of the eight major intervention strategies, three of these strategies are communication-based: (a) information Distribution, (b) Goal setting & Plan-Making, and (c) Message Framing. Four of the intervention strategies focus on the "bias-busting" approach. They are intended to combat (d) Confronting Negative Perceptions About Public Transportation, (e) Breaking Habits, (f) Getting Past the Anticipated Dislike of Social Interactions on Public Transportation, and (g) Utilizing the Influence of Emotions on Decisions. Emotionally targeted interventions have not been explored extensively to date, although the evidence shows they may be crucial to include.

The last intervention strategy is technology-based and includes (h) the utilization of feedback and gamification (Kormos et al., n.d. ; Garcia-Sierra et al., 2015).

3.2.1 Communication-Based Approaches

Information Distribution: The most prevalent intervention for encouraging commuters to utilize public transit is the public awareness campaign, which assumes that commuters lack enough knowledge of their transportation options and that supplying such information will influence their behavior. In fact, a number of studies indicate that when ignorance is a barrier to action, providing information can be beneficial. Frequently, the impressions of travelers regarding the quality of public transportation services contradict the factual reality (Friman & Fellesson, 2009). As a result, when factual information is distributed to the public, people may find public transportation to be more appealing, as their misconceptions have been corrected (Friman & Gärling, 2001). Researchers conducted a randomized controlled trial to determine if inaccurately negative public opinions of bus travel could be altered through the dissemination of factual materials and found that providing factual information increased bus use among frequent bus users and those with good preexisting attitudes toward bus use, but caused a significant decline among infrequent bus users and those with negative preexisting attitudes toward bus use (Beale & Bonsall, 2007a). In one study, individuals who received a customized travel information package opted for public transportation much more frequently than those who received a conventional information package of public transportation brochures (Bamberg, 2013a).

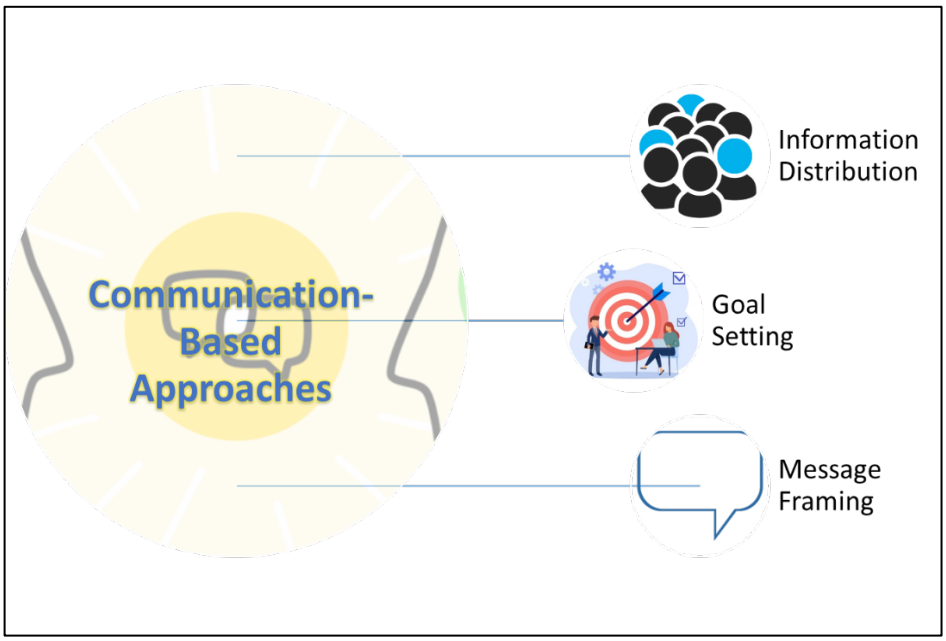


Figure 3 Communication Based Approaches

> "When **factual information is distributed to the public**, people may find public transportation to be more appealing, as their misconceptions have been corrected**."**

Three important components of communication-based approaches are information distribution, goal setting, and message framing (Figure 3).

Goal setting & Plan-Making:

Another information-based strategy for changing people's mode of transportation employs approaches that capitalize on their willingness to alter their behavior willingly to achieve goals (Bamberg et al., 2011; Gärling et al., 2002). Goal setting theory is a psychological theory that explains how setting goals can motivate people and improve their performance. Bamberg, 2013a have suggested a theoretical framework for transportation behavior change, with the first two stages consisting of establishing a change objective and developing a strategy to attain the objective. In Japan, for instance, a travel feedback program that specifically requested that participants set goals (that is, participants chose the percentage by which they wanted to increase their public transportation use) resulted in a 76% increase in public transportation use, compared to a 25% increase among those who were not asked to set goals (Taniguchi et al., 2007). Similar results were found in a second investigation by some of the same authors (Fujii & Taniguchi, 2005a).

> "Goal setting theory is a psychological theory that explains how setting goals can motivate people and improve their performance. "

Message Framing: Framing is the process of rearranging words and concepts inside a communication to support a specific change in decisions or attitudes without affecting the message's overall meaning. The purpose of framing is also to induce conduct without restricting the recipients' freedom of choice. For instance, a message may be designed to encourage employees to sign up for a cheap train pass by default, while allowing them to opt out of the program if they want. Message-framing is most effective when decision-makers base at least a portion of their decisions on the messages they read. Message framing studies have investigated the effect of social norms on travel behavior modifications.

> "Framing is the process of rearranging words and concepts inside a communication to support a specific change in decisions or attitudes without affecting the message's overall meaning "

At the University of Victoria in British Columbia, Canada, for instance, researchers conducted a month-long randomized controlled field experiment to assess the influence of descriptive social norms on the desire of faculty, staff, and student participants to limit their private car use.

Participants received personalized e-mails that exaggerated the true social norms for the use of sustainable transportation, and this helped increase their use of sustainable transportation (including public transportation, carpooling, and cycling) for commuting by approximately five times[2].

3.2.2 Bias-Busting Approaches

Three important components of bias-busting approaches are confronting negative perceptions, breaking habits, and influence of emotions (Figure 4).

Confronting Negative Perceptions About Public Transportation:

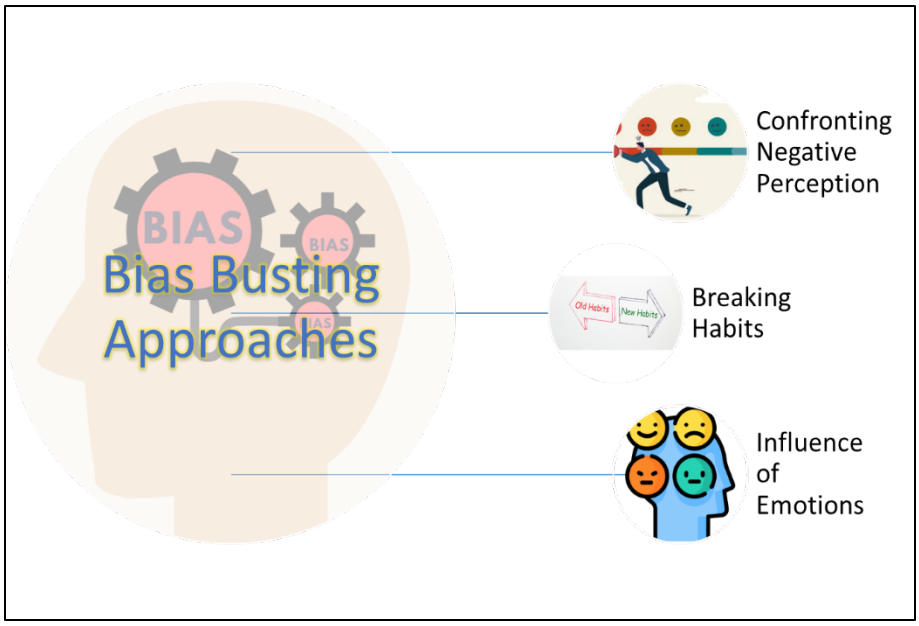


Figure 4 Bias Busting Approaches

When deciding how to go from point A to point B, individuals may be influenced by a number of biases, or systematic deviations from a rationality norm. Confronting negative perceptions involves addressing and challenging the biases or negative beliefs that individuals may hold about a particular subject or experience. In the context of transportation, it entails recognizing and acknowledging the biases that influence individuals' decisions about how to travel from one point to another and implementing strategies to counteract these biases. Negative perceptions about public transportation include biases such as hyperbolic discounting (favoring immediate rewards over future ones), the waiting time paradox (overestimating wait times), and ambiguity aversion (preferring certainty over uncertainty). Confronting these negative perceptions involves implementing interventions to prevent this.

As a result of bounded rationality, individuals who are pressured for time or confront many demands on their cognitive abilities frequently rely on heuristics; these simplified decision-making rules can result in biases that can influence transport mode selection. Such as the

[2]The intervention consisted of personalized e-mails sent to participants. These e-mails provided information about the commuting behaviors of their peers, specifically exaggerating the prevalence of sustainable transportation modes such as public transportation, carpooling, and cycling https://doi.org/10.1177/0013916513520416

immediacy effect, often known as hyperbolic discounting: This is the tendency for individuals to favor immediate rewards over future rewards of equal or greater objective value. Interventions have successfully targeted a few additional biases that influence transportation behavior. When utilizing public transit, individuals who are accustomed to driving may grow frustrated and overestimate the length of the wait. This irritation results in the waiting time paradox, in which individuals perceive their wait time to be longer than it actually is. Moreover, ambiguity aversion shows that uncertainty over journey time is more undesirable to travelers than longer travel durations itself. By providing real-time arrival information for public transportation options, such as through mobile apps and signage, the waiting time paradox and ambiguity aversion can be mitigated. Commuters waiting for buses in Seattle who utilized real-time travel applications had much shorter actual and perceived wait times, probably because they were able to plan their travels with greater precision.

"Negative perceptions about public transportation include biases such as **hyperbolic discounting** (favoring immediate rewards over future ones), the **waiting time paradox** (overestimating wait times), and **ambiguity aversion** (preferring certainty over uncertainty). "

Breaking Habits:

"**Habits** while they serve as convenient shortcuts, sparing travelers the mental burden of constantly evaluating their commuting options, **can also pose a significant barrier to considering alternative modes of transportation**, "

Habits, those automatic behaviors that require minimal cognitive effort, can sometimes hinder individuals from making rational decisions. Habits while they serve as convenient shortcuts, sparing travelers the mental burden of constantly evaluating their commuting options, they can also pose a significant barrier to considering alternative modes of transportation. Once the decision to drive to work is made, for example, it may be repeated daily without reevaluation. Interventions designed to break a travel habit should not only attempt to reduce the undesirable behavior, but also to replace it with one that is more environmentally sustainable. The resistance of travelers to an intervention designed to promote their use of public transportation can be predicted by the tenacity of a travel habit, as evaluated by the diversity in their transport choices.

A review of qualitative research reveals that reduced-fare advertisements can successfully persuade automobile users to try out public transportation options. Changes in the decision situation might also aid habit breaking. For instance, the optimal time to undertake an

intervention (such as the supply of information about local public transit) is immediately after a person has moved into a new residence or begun a new work — times when habits are weak or have not yet been formed. Six weeks after participants went to Stuttgart, Germany, a randomized controlled experiment commenced. An intervention capitalized on a shift in context, provided customized information (about public transit in the area), and offered a monetary reward (a free one-day travel pass). Six weeks following the intervention, the experimental group's use of public transportation grew considerably from 18% to 47%, while the control group of recently relocated individuals exhibited a much lesser rise (18% to 25%). The intervention was most beneficial among individuals who indicated a strong goal to limit automobile use.

Getting Past the Anticipated Dislike of Social Interactions on Public Transportation:

The satisfaction derived from one's daily commute significantly impacts overall life fulfillment. Surprisingly, bus commuters often report the lowest levels of satisfaction among all commuters, despite the inherent opportunity for social interaction during their journey, a factor consistently ranked as a top contributor to trip satisfaction. Engaging in conversation while commuting has been found to increase enjoyment of the journey, even when individuals may initially feel reluctant to do so. Research suggests that when individuals are encouraged to be more extraverted during their commute, they report experiencing more positive emotions. This highlights the potential for public transportation companies to enhance commuter satisfaction and ridership by promoting interaction and sociability on buses and trains. A notable study conducted in 2014 demonstrated the effectiveness of promoting social interactions on public transit. In a randomized controlled trial conducted in Illinois, commuters who were encouraged to engage in conversation with strangers reported significantly higher levels of satisfaction with their commute compared to those who were instructed to keep to themselves. Interestingly, this finding contradicted the expectations of commuters, as revealed in a parallel experiment conducted by the same researchers.

Utilizing the Influence of Emotions on Decisions:

Affective influences on transit choices have been found to rival the influence of practical concerns, however no research have explored interventions aiming at modifying emotions so as to encourage individuals to prefer public transportation. The pleasant sentiments of freedom, independence, comfort, and seeming control that people associate with driving a car are obstacles to utilizing public transportation. People may opt to commute by car rather than public transit if driving makes them feel good, employing the affect heuristic to make decisions. Various emotions play a role in transportation decision-making, according to the findings of numerous studies. For instance, individuals are poor in affective forecasting, or estimating the future emotional impact of a given event on them. For example, individuals tend to be poor at predicting their future emotional responses to events, often

overestimating the intensity or duration of their emotional reactions. Commuters may exaggerate their dissatisfaction with switching from driving to public transportation.

"The pleasant sentiments of freedom, independence, comfort, and seeming control that people associate with driving a car are obstacles to utilizing public transportation. "

A Swedish study gave participants a 30-day public transportation pass if they used it to go to and from work. Before, during, and after the test, they were asked about their current and future happiness with public transportation. Their final ratings were substantially higher than their initial ratings and higher than the control group members. bad feelings about one's choice of less environmentally friendly modes of transportation, such as guilt, humiliation, or disappointment, might promote public transportation use. Policymakers could explore strategies to trigger psychological mechanisms that elicit such feelings, such as a sense of duty or moral obligation to environmental ideals. By tapping into these emotions, policymakers may be able to encourage greater adoption of public transportation and reduce reliance on less sustainable modes of travel.

3.2.3 Technology-Based Approaches: Feedback & Gamification

The important factors for technology-based approaches are feedback and gamifications (Figure 5). Feedback from web-based applications can alter transportation practices. Feedback often consists of a moderate form of reward or punishment, which can encourage goal-directed behavior; but it can also just consist of information that is beneficial for evaluating one's progress toward a goal.

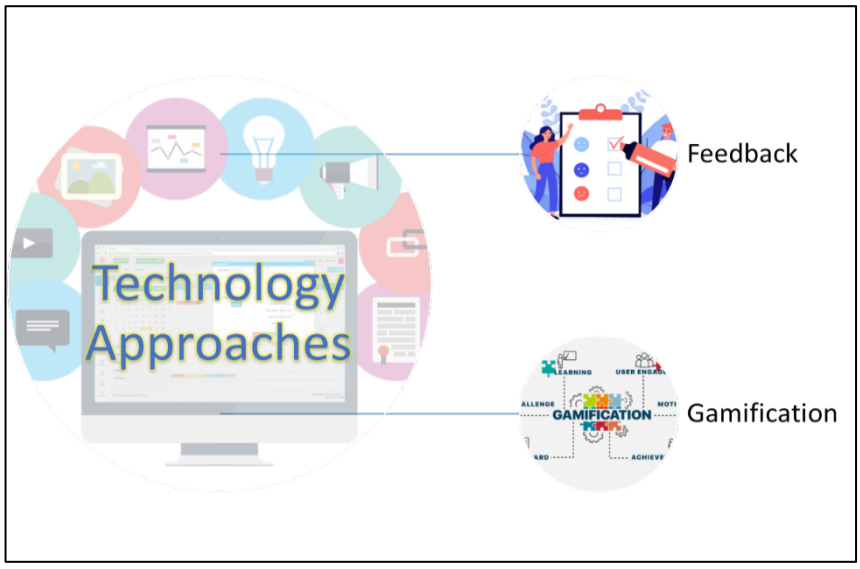


Figure 5 Technology Approaches

Therefore, feedback can serve as the foundation for other treatments that magnify its effects, such as gamification—the use of game-design features to nongame environments to make behavior modification enjoyable. Using gamification elements such as earning points,

badges, and free bikeshare memberships, smartphone apps such as Viaggia Rovereto[3] have decreased automobile usage among commuters by 13% while increasing biking, walking, and public transportation use.

Researchers examined ten apps that promoted sustainable transportation and found that most used personalization, feedback (self-monitoring), and information sharing. Three studies found true behavioral changes. Pre-smartphone feedback and gamification software experiments in Japan showed one way to use feedback to improve public transit utilization. Participants kept daily transportation diaries for researchers. The researchers used psychological studies to change behavior by increasing self-efficacy, eliciting thoughts about how to implement intentions, and activating personal norms (such as the belief that the individual is the type of person who wants to protect the environment). The intervention reduced family car use by 15% and increased public transport use by 4% compared to a non-random control group. Over three weeks in 2012, this diary-feedback technique was tested with a specialized app and found to greatly increase walking and cycling (but not public transportation) and significantly decrease driving among a limited sample of frequent commuters.

3.3 Research on Influencing Travel Mode Choice

Whillans et al., 2021 identified behavioral barriers to change and execute commute behavior to develop a behaviorally informed framework that can be used by transportation planners, researchers, and policymakers. The researchers partnered with various organizations across the US and tested TDM measures such as carpooling, bike-sharing, personalized route tools, etc. to address psychological barriers and encourage the use of alternative modes of transportation. The authors concluded that as long as SOV is the cheapest and most convenient of all alternatives, nudging commuters to other modes will be difficult. White et al., 2019 in their review of consumer behavior found that consumer behavior to adopt more sustainable choices depended on five components that can be collectively referred to as the SHIFT (i.e., Social influence, Habit formation, Individual self, Feelings and cognition, and Tangibility) framework. By addressing these five components, consumers can be encouraged to make sustainable choices.

The authors concluded that as long as **SOV is the cheapest and most convenient of all alternatives, nudging commuters to other modes will be difficult.**

3.4 Goal Framing and Attitudinal Factors

[3] Viaggia Rovereto is a smartphone application designed to promote sustainable transportation among commuters in Rovereto, a town in northern Italy. The app uses gamification elements to encourage users to reduce their reliance on private automobiles.

Various theoretical frameworks have been employed in research examining the significance of attitudes in promoting pro-environmental behaviors and intentions. These frameworks include the Theory of Planned Behavior (TPB) (Donald et al., 2014), the Norm Activation Model (NAM) (Schwartz, 1977), the Value Belief Norm model (VBN) (Stern et al., 1999), and the more recently developed Goal Framing Theory (GFT) (Lindenberg & Steg, 2007; Steg, Perlaviciute, et al., 2014). The NAM and VBN, which partially originated from TPB, propose that the activation of social norms is influenced by underlying values, perceived threats such as awareness of consequences or problem awareness (Bamberg & Möser, 2007), and an individual's sense of responsibility and self-efficacy to mitigate the consequences of the perceived threat. The activation of a personal norm is manifested as a moral obligation to engage in behaviors within a particular domain. Extensive research has been conducted on the TPB, NAM, and VBN models in relation to various environmentally related behavioral choices (Bamberg & Möser, 2007; De Groot & Steg, 2009; Eriksson et al., 2006; Jansson et al., 2017; Lane & Potter, 2007; Milfont et al., 2010; A. M. Nordlund & Garvill, 2002; A. Nordlund & Westin, 2013). However, limited literature exists on GFT.

According to the GFT (Goal-framing Theory), our behavior is influenced by our motivation and the goals we have in a given situation. The GFT identifies three important goal frames about behavioral change: the hedonic, gain, and normative goal frames (Figure 6). These goal frames and the attitudinal factors associated with them have been extensively studied in separate research (Steg, Bolderdijk, et al., 2014; Steg & Vlek, 2009b). However, the GFT combines the well-established fields of research on gains and losses and normative influence with the less explored field of affective influence (Esfahani et al., 2015).

A hedonic goal frame leads individuals to prioritize feeling good about their actions and can involve choosing behaviors that maximize well-being and excitement while avoiding demanding behaviors. A gain goal frame makes individuals aware of changes in their resources, such as money and status. Lastly, a normative goal frame drives individuals to seek out behaviors that are perceived as the morally right thing to do, or what they ought to do (Westin et al., 2020). These goal frames can vary in their importance to individuals and can shape their attention towards certain information and their perception of available behavioral choices. The focal goal, which is the primary goal at a given time, exerts the strongest influence on our thoughts and behaviors. The other goals, either by supporting (when they are compatible) or undermining (when they conflict with the focal goal), exert a secondary influence in the background (Lindenberg & Steg, 2007; Steg, Perlaviciute, et al., 2014).

Figure 6 Different Goals for Framing

Sustainability-oriented or pro-environmental actions can be influenced by different motivations. These motivations can be driven by seeking pleasure or a sense of well-being (hedonic), achieving personal benefits like saving money (gain), or following social norms and doing what is perceived as right (normative). However, these motivations can also lead individuals to continue engaging in environmentally harmful behaviors if they prioritize hedonic, gain, or normative reasons over environmental concerns. When studying the role of motivations, it is crucial to consider values, beliefs, and norms (Simićević et al., 2013). Values are said to affect the degree to which hedonic, gain and normative goals are specific to an individual in a given situation, which is significant in terms of whether a particular goal will become the focal point in that situation. Values serve as governing principles in our daily lives (Schwartz, 1992), as they transcend situations and influence a vast array of beliefs, attitudes, norms, intentions, and behaviors. As values have predominantly been shown to influence intentions and behaviors indirectly, via attitudes, behavior-specific beliefs, and norms, (Nayum & Klöckner, 2014; Ozaki & Sevastyanova, 2011; Schuitema et al., 2010) these factors are crucial when examining the full GFT theory. Using a variety of interventions and policies, it is of utmost significance to encourage sustainable and pro-environmental behavior. In this process, it is necessary to comprehend the antecedents and motivations associated with the desired behavior and acceptance of these policies and examine the significance of framing.

3.5 Randomized Control Trial in Transportation

A common approach in assessing experimental TDM measures is the use of randomized controlled experiments (RCT). Under this approach, the participants are divided into separate groups at random. The first group is called the control group while the others are called the experimental groups.

TDM interventions are implemented in the experimental groups over a period. After completion of the experimental period, the groups are compared with the control group to quantify the effect of interventions. This randomization ensures that the groups are statistically similar in terms of various characteristics such as gender, age, motivation, and other observable or unobservable traits. The only distinction between the groups is that one receives the intervention while the other remains unchanged. By comparing the outcomes of the treatment and control groups, biases that typically complicate evaluation processes are eliminated (Alta Planning, 2018; Haynes et al., 2012). Numerous behavioral interventions have been tested to reduce the use of SOVs using randomized controlled experiments. Communication-based approaches assume that lack of knowledge is a barrier to sustainable travel behavior. When commuters are well-informed, they can alter their behavior and choose SOV alternatives. The approach usually encompasses providing information regarding available transportation facilities, their quality, and available incentives.

In the field of transportation research, there have been limited instances of properly randomized and controlled experiments due to the challenges in creating such experimental settings. For example, (Yang et al., 2010) identified only two RCTs out of twenty-five studies on interventions to promote cycling, while (Ogilvie et al., 2007) found nineteen RCTs focused on interventions to encourage walking, mostly from a public health standpoint, and noted a lack of similar research from the transportation sector. (Graham-Rowe et al., 2011) reviewed 77 studies on reducing car usage and discovered that many of them had weak methodological foundations, although six of them were RCTs. In a more recent study by (Petrunoff et al., 2015) that specifically examined workplace-based RCTs and controlled longitudinal studies, ten out of twelve studies reported positive outcomes, but there was a risk of significant bias in many of them. Some studies have shown successful outcomes from interventions. Bamberg & Möser, 2007investigated whether residential relocation presented an opportunity to intervene and reduce car usage. The study found that a combination of information provision and a day of free public transit resulted in a reduction in the frequency of car trips. Similarly, (Jakobsson et al., 2002) employed a combination of financial disincentives for driving and an informational campaign, leading to a decrease in the distance and frequency of car trips. However, the effects were unlikely to be sustained once the financial incentive was removed.

(Adjei et al., 2012) conducted a review of experimental studies in transportation that examined TDM techniques. TDM interventions, which focus on psychological factors rather than physical infrastructure, involve providing information, persuasion, or incentives to individuals. This makes them suitable for RCTs because they can be offered to some people while excluding others, facilitating the randomization process. RCTs necessitate clearly defined treatment and control groups, which can be challenging when the treatment variable is continuous, like the distance to campus.

Randomization into treatment groups can also pose difficulties, particularly in cases where it is impractical to exclude a random segment of the population from new or

improved transportation services. On the other hand, RCTs offer advantages such as automatically controlling for the effects of unmeasured variables, including attitudes, and addressing the issue of self-selection. Cross-sectional research designs may have an edge over RCTs in terms of external validity since they can more easily incorporate diverse populations and contexts (Merlin et al., 2022). While we acknowledge that experimental designs are generally preferred, there are situations in transportation research where conducting experiments is not feasible or leads to significant constraints in terms of external validity. As a result, researchers often have to rely on quasi-experimental designs. Consequently, we deemed it important to evaluate how closely the findings from quasi-experimental studies align with those from experimental studies, which are considered the most reliable. Since the existing evidence is inconclusive, we approach this as an exploratory inquiry (Merlin et al., 2022).Studies exploring the three types of interventions along with their data, method, targeted travel modes, and key findings are summarized in Table 1.

Table 1. Existing literature on utilizing behavioral interventions to influence mode shift from SOVs

Source	Data	Method	Modes	Intervention type (CB, BB & TB)	Approaches	Key findings
(Bamberg, 2006)	241 German residents	Theory of planned behavior (SEM)	Public transport	CB	TFP: one day free ticket and schedule information to recently relocated residents	Intervention increased PT usage from 18% to 47%. Furthermore, attitude, perceived behavioral control and subjective norm strongly predicted intention to use PT.
(Bamberg, 2013b)	625 Berlin residents	Stage model of self-regulated behavioral change	Car, public transport, cycling and walking	CB+BB	TFP: Delivering information package and social marketing campaign to reduce car use	Stage based dialog intervention through social media resulted in decrease in car use due to increase in PT usage.
(Beale & Bonsall, 2007b)	205 UK residents	Attitude analysis and randomized controlled experiment	Bus transit	CB+BB	TFP: Marketing campaign highlighting benefits of bus transit	Marketing campaigns are successful if done selectively for different population segments.
(Franssens et al., 2021)	4000 Dutch commuters	Field experiment	Bus transit	CB	TFP: Free travel cards with sustainable branding of environmentally friendly behavior	Approach resulted in 1.18 rides per day greater on experimental lines than on control lines.
(Fujii & Kitamura, 2003)	43 Japanese students	ANOVA and ordered logit	Bus transit and automobile	CB	Travel mode habit and TFP: one month bus pass and route map	A 20% increase in the bus usage after intervention. Habit formation towards bus use was related positively to the

						ridership and less use of automobile.
(Fujii & Taniguchi, 2005b)	292 Japanese fifth grade students	Field experiment	Multiple modes	CB+BB	TFP: Individualized information and advice and encouraging behavioral changes to reduce CO2 emissions	Travel feedback program urging users to make a behavioral plan to reduce car-use is more effective than more conventional systems that provide advice.
(Kazhamiakin et al., 2015)	40 Italian residents	Gamification mechanism	Multiple modes	CB+TB	Recommending best available mode based on trip dairy and introducing game-based rewards for using sustainable travel mode, walk and bicycling and park and ride	Recommendations for sustainable options of travel increased the usage of sustainable travel modes. In addition, gamification resulted in the less usage of cars (based on percentage of Km).
(Kristal & Whillans, 2019)	68,915 educational institution employees	Five field experiments and two onde-sided tests (TOST)	Carpool, public transport, SOVs	CB+BB	TFP: reducing friction costs, peer testimonials, personalized recommendations, opportunity cost, free bus trials, loss aversion in not utilizing free passes and personalized travel plans	Emails including direct link to register to carpool service resulted in minuscule increase in the number of registrations. Other interventions did not result in any postive impact on less use of SOVs.
(Pedersen et al., 2011)	1007 and 106	Principal component	Public transport	CB+BB	Satisfaction from existing PT services, Self-	PT users reported greater satisfaction with PT. The satisfaction with PT increased

	Swedish residents	analysis, t-tests and ANOVA			Report Habit Index for car use and TFP: 30-day pass and signed contract to mandate using PT	significantly after the intervention and car use habit resulted in imprecise rating towards PT attributes except travel time.
(Pedersen et al., 2012)	50 and 42 participants from a Swedish university	Regression analysis	Public transport and car use	BB	Defocusing technique: 10 pre-selected daily activities; and car use habit	Car use habit was negatively realted with satisfaction from PT. Self-relevant defocusing technique representing high degree of self-involvement was related positively with satisfaction from PT.
(Taniguchi & Fujii, 2007)	495 Japanese households	Mobility management and regression analysis	Community bus service	CB	One-shot TFP: advertising leaflet, travel behavior plan sheet and two free bus tickets	One shot TFP and word-of-mouth recommendation increased bus ridership by 34%
(Watkins et al., 2011)	655 American commuters	Difference of means t-test	Bus transit	TB	Real time information about bus schedules through mobile app	For riders with no access to real-time information, perceived wait time was more than the measured wait time. The provision of real time information decreased perceived time by about 13%.

3.6 Case studies

Arlington County, VA

Arlington County, Virginia uses three main strategies for their TDM program which are i) Walkable, Mixed-Use "Urban Villages.", ii) Balanced Array of Transportation Resources, and iii) TDM: Information, Encouragement, and Incentives. The count has also partnered with Mobility Lab to develop and strategize TDM solutions. For example, the county began a yearly initiative to encourage walking among residents using an 8-week challenge in October 2020. Under this initiative, participants were provided motivational content and personal connections on social media with awards and recognition after program completion. Surveys administered on the participants before and after the program showed that participants driving SOVs to school and for non-commute trips reduced by 6% and 8%, respectively. There was a 27% increase in participants walking for errands with considerable growth in attitude towards walking. Additionally, the county also requires every site plan development to undergo a TDM study before approval. For residential buildings, the site plans include providing travel information to residents, shuttle to metro connections, transit support such as free or discounted SmarTrip cards, bicycle parking, paid car parking and educating residents on available transportation options and amenities. Recent surveys undertaken to assess the impact of TDM measures showed that unbundled parking reduced auto ownership by 13% per adult resident and 6% per unit (Nelson/Nygaard Consulting Associates Inc., 2018). The study reported that the trip generated from the studies buildings was 40-50% lower than standard values in ITE Trip Generation Manual. Similarly, introducing paid parking at the workplace reduces SOV use from 71% to 28% according to a 2016 study (Crim et al., 2016). The county also reports ample parking spaces available to residents due to reduced SOV use. As a result, unutilized parking spaces in the county are also being converted to green spaces. Overall, the county has reported a 10% reduction in SOV use between 2001 and 2013 among residents when driving to work.

Mobility Lab website: https://mobilitylab.org/

Metropia mobile app for commuters, Metropia, Pima county, AZ

A private company, Metropia, in partnership with the Regional Transportation Authority of Pima County, AZ, and RubyRide, a subscription-based personalized driver service has developed an app-based Mobility-as-a-Service tool. The goal of the developed collaboration project and the app is to eliminate difficulties that commuters face when searching for mobility options and facilitate the use of public transportation. The app integrates multiple mobility options particularly to encourage willing commuters to reduce the use of SOV. The project is expected to increase access to affordable mobility options to residents who are economically disadvantaged and establish a higher quality of service to the commuters without compromising benefits to the system.

Metropia website: https://www.metropia.com/

Lumm app for employers

Lumm is a smartphone app like Metropia. Unlike Metropia, Lumm is tailored to serve employers through an enterprise-grade commute management platform. The platform promotes behavior change in employees through incentives and benefits. The app allows managers to optimize employee commute trips and provide targeted incentives. The app also enables managers to administer subsidies provided to employees, form carpools and vanpools, manage parking priorities, and send targeted messages to a group of commuters (e.g., employees carpooling to work). Lumm also supports integration with popular mobility applications such as Waze Carpool and Lyft.

Lumm worked with Delta Dental of Washington (DDW) in 2016 to create the MyCommute program to help employees decide the best mobility alternative to get to work. The program resulted in a 60% reduction in driving SOV to work. DDW also added four vans to facilitate their employees with Vanpooling. In 2020, Lumm partnered with Seattle Cancer Care Alliance to manage parking spaces to reduce parking space by automating parking charges from monthly permits to daily parking charges. This reduced extended use of parking to free space for employees arriving at work.

Lumm website: https://go.luum.com/

The one-less-car Challenge, Seattle, WA

In 2000, the Transportation Operations Program in Washington sponsored a "One-less car[4]" for Seattle, WA. Under this Challenge, the participants were instructed to park or sell one of their cars and use environmentally friendly ways to travel. The challenge lasted from 6-9 weeks. Over this period, the participants were provided on average a weekly stipend of $80 based on their driving habits and asked to report their daily trip using a weekly journal. The one-less-car challenge was discontinued in 2013. At the end of the challenge, the following was observed.

- Drive alone car miles reduced by 27%.
- Bicycle miles driven increased by 38% and walking by 30%.
- Transit miles driven increased by 25% and carpooling increased by 23%.
- 26% of participating households sold an extra car and 80% reduced their car usage.

The Eco-Pass program, Boulder, CO

The Regional Transportation District (RTD) that operates in the Denver-Aurora-Boulder Combined Statistical Area, Colorado offers Eco-Pass program in Denver to increase transit and reduce SOV use. The Neighborhood Eco (NECO) Pass initiative under the program provides yearly transit passes to participating neighborhoods in Boulder at subsidized rates to incentivize transit use such as a 50% subsidy for first-time participants.

[4] Uber newsroom: Introducing the One Less Car Challenge https://www.uber.com/newsroom/one-less-car/.

The NECO Pass program started in 1997 provides transit passes to all households at the same price regardless of its size. This initiative has increased the use of public transit resulting in less congestion. Between 1990 and 2018, SOV trips in Boulder have reduced from 44.2% to 36.7%. Over the same period transit use has increased from 4% to 12.3% (Modal Shift in the Boulder Valley: 1990-2018, 2019b).
Eco-Pass program website: https://bouldercolorado.gov/services/ecopass-program

Access MIT Program, MIT, MA

Massachusetts Institution of Technology introduced the Access MIT program in 2016 to reduce parking demand on campus by encouraging students and staff to use alternative mobility options to SOVs when traveling to campus or work. The program provided free transit access, daily parking pricing from annual parking permits, subsidized parking at transit locations, increased rail subsidy, and an online commuter dashboard to earn points for using public transit, carpooling, cycling, and walking. Two years since the program, parking registrations have been reduced by 15%. Underutilized parking spaces have also been demolished to expand the university's infrastructure (Bauer et al., 2018).
Access MIT website: https://sustainability.mit.edu/access-mit

Florida Driverless Research, FL

Florida Department of Transportation (FDOT) started a program called "Idriveless" to provide financial rewards to people who reduced their VMT in collaboration with the University of South Florida. VMT of the participants was measured every 14 days and incentives were provided based on their reduction compared to their baseline VMT. The incentives were as follows: $5 for the first 20 miles and an additional $5 for every 20 miles capped at $40 for 160 miles or more. Therefore, the maximum incentive to participants who reduced their VMT by 160 miles or more and completed the survey was $200. It was observed that participants were able to reduce more VMT than what they were compensated for. Participants identified trip chaining, biking, walking, public transit use, and telecommuting as the common strategies adopted to reduce their VMT (Lee et al., 2013b).
Idriveless research report: https://www.nctr.usf.edu/wp-content/uploads/2014/11/77947_508.pdf.

Congestion And Parking Relief Incentives (CAPRI), Stanford University, CA

Stanford University with funding from Federal Highway Administration Value Pricing Pilot Program launched the CAPRI program from April 2012 to September 2014. The program goal was to reduce congestion by decreasing demand, particularly at peak periods around the university. Under this initiative, program participants were provided radio-frequency identification tags that logged their entry and exit at campus access points. The participants were provided points for traveling at off-peak periods and using non-motorized modes to work.

These points could be exchanged for deterministic cash rewards, or a random cash reward won in a recreational game created for the project that utilized the CAPRI points earned.

The rewards system also encouraged participants to travel at off-peak periods by providing achievements that could be viewed on the CAPRI smartphone app. Participants with higher achievements had better chances of winning prizes. The program also allowed participants to invite eligible friends and view their status in the program (such as achievements, rewards, etc.). Additionally, participants were also offered tickets to gaming events through the program to increase participation.Over the study period of two and half years, it was found that program participants avoided peak hours and preferred traveling before peak hours. A 21.2% and 13.1% in morning and evening peaks were observed during the period (Zhu et al., 2015).

CAPRI website: https://prabhakargroup.stanford.edu/research/societal-networks/capri-project

4. Experiment Design and Methodology

4.1 Stakeholder Questionnaire

To gain a comprehensive understanding of TDM interventions in Tennessee, a stakeholder analysis was conducted. A structured questionnaire was developed with two distinct sections, targeting two key groups: TDM stakeholders and TDM organizations. This approach yielded a total of 46 valuable responses. Notably, 81% of the participants belonged to the TDM stakeholder category, which includes entities like Metropolitan Planning Organizations (MPOs) and Transportation Planning Organizations (TPOs). The remaining 19% of responses originated from TDM organizations themselves. Table 2 provides a detailed list of the agencies that explicitly consented to the disclosure of their names.

Table 2 Stakeholders and TDM organizations

	Organization Name
Stakeholders	Knox County Transportation Planning Office
	TN Dept. of Safety and Homeland Security
	Vanderbilt University
	Williamson County
	Jackson MPO
	GNRC
	Morristown / LAMTPO
	Kingsport MTPO
	Memphis MPO
	TDOT*
	Burch Transportation
	Knoxville Regional Transportation Planning Organization
	Memphis Area Transit Authority
	Knoxville TPO Executive Board
	Knoxville Regional TPO
	LAMTPO
	Clarksville MPO
TDM organization	Bird
	Innovate Memphis
	TDOT*

4.1.1 Summary of TDM Stakeholder Survey Results:

The stakeholder survey results on TDM initiatives present a nuanced picture of both achievements and areas for improvement. While a notable percentage of stakeholders have successfully developed strategic plans and expressed positive inclinations towards alternative transportation modes, significant gaps exist. A considerable portion lacks long-

range strategic plans and regional TDM committees, indicating a need for focused intervention and support. Additionally, perceptions of TDM effectiveness vary, with a fair rating from nearly half of respondents. Encouragingly, stakeholders generally prioritize TDM strategies and express willingness to engage in promoting alternative modes of transportation. However, there's a call to action to enhance collaboration, improve TDM effectiveness, and address gaps in supporting transit integration into new developments. Recommendations include offering tailored assistance to stakeholders, fostering regional collaboration, refining TDM effectiveness based on feedback, and providing additional support for integration projects. The findings underscore the importance of ongoing engagement and targeted actions to optimize TDM initiatives and drive sustainable transportation solutions. A detailed analysis of the survey is given below.

Pros:

- 19% of stakeholders have successfully developed and implemented a TDM long-range strategic plan.
- 23.8% of stakeholders have an established regional TDM committee.
- 41.2% of respondents rate the effectiveness of transport demand management as good.
- 58.8% of stakeholders express a positive inclination towards alternative modes of transportation.
- The majority of stakeholders assign priority ratings of 3 and 4 to most TDM strategies.
- 13.4% of stakeholders provide aid in informing individuals about transit options, and 10.4% provide assistance in carpool and vanpool options.
- The majority of stakeholders rate various aspects of TDM programs as 3 and above.

Cons:

- 57.1% of stakeholders lack a long-range strategic plan tailored for TDM initiatives.
- 61.9% of stakeholders do not have an established regional TDM committee.
- 47.1% of respondents consider the effectiveness of transport demand management as fair.
- 62.5% of stakeholders do not have established guidelines to assist developers in designing new developments.
- Low success percentages of policies aiming to integrate transit systems into new developments.

Unexpected outcomes:

- The lack of long-range strategic plans (57.1%) and regional TDM committees (61.9%) is higher than anticipated.
- The effectiveness of TDM is perceived as fair by a significant portion of respondents. The effectiveness of TDM initiatives is rated as fair or good by a little over 80% of the respondents. While stakeholders have made commendable endeavors to promote

alternative modes of transportation, there is still room for improvement as only a small percentage provided aid in informing individuals about various transit options.

- The absence of established guidelines to assist developers who are designing new developments is a concern for more than half of the TDM stakeholders, and the success rates of the current policies aimed at facilitating the seamless integration of transit systems into new developments are relatively low.

Recommendations:

- Reach out to stakeholders who lack a long-range strategic plan and offer assistance in developing tailored TDM initiatives.
- Encourage the establishment of regional TDM committees to enhance collaboration and coordination.
- Explore ways to improve the effectiveness of TDM initiatives based on feedback from stakeholders.
- Provide additional support and resources to stakeholders who have ongoing or planned projects involving integration with public bus transit services.
- Conduct further research or reach out to stakeholders to gather more information on specific aspects where data is incomplete, such as the guidelines for new developments.
- Overall, the survey results highlight both positive and negative aspects of TDM implementation. While some stakeholders have made progress and received positive feedback, there are areas that require improvement, such as the lack of strategic plans, regional committees, and guidelines for developers. Further actions and engagement with stakeholders are necessary to address these issues and enhance the success of TDM initiatives.

4.1.2 Summary of TDM Organizations Survey Results

The survey results on TDM organizations reveal both positive aspects and areas for improvement in their operations. On the positive side, findings indicate a notable focus on meeting specific transportation needs, with 20% of organizations providing demand-responsive/paratransit services. Additionally, a significant portion (60%) of TDM organizations operate a fleet size of 50-100 vehicles, showcasing their capacity to serve transportation demands. Furthermore, incentives aimed at enhancing ridership, such as preferential parking and cumulative trip incentives, are offered by approximately 60% of TDM organizations. Moreover, the utilization of personalized messages through mobile applications and regional policies supporting public transit integration into new developments reflects proactive strategies employed by TDM organizations.

However, there are areas requiring attention. For instance, only 20% of organizations have mobile applications, potentially limiting accessibility and convenience for customers.

Additionally, the absence of tailored travel options and mixed results regarding the effectiveness of incentives pose challenges. Furthermore, the lack of ongoing or upcoming projects involving public bus transit services and the refusal of some organizations to report their service's success suggest areas for improvement in data collection and evaluation practices. To address these gaps, recommendations include reaching out to organizations for further insights, conducting additional research to understand adoption barriers, exploring factors contributing to reported effectiveness issues, and considering further surveys or studies to delve deeper into challenges faced by TDM organizations. By implementing these recommendations, TDM organizations can enhance their effectiveness and better serve their target audience. A detailed analysis of the survey is given below.

Pros:

- 20% of TDM organizations provide demand-responsive/paratransit services, indicating a focus on meeting specific transportation needs.
- 60% of TDM organizations operate a fleet of 50-100 vehicles, indicating a significant capacity to serve transportation demands.
- Incentives aimed at enhancing ridership, such as preferential parking, cumulative trip incentives, and help finding carpool partners, are offered by approximately 60% of TDM organizations.
- 60% of TDM organizations employ personalized messages through mobile applications to nudge their target audience, potentially increasing ridership.
- Tax incentives and development regulations are the most common regional or local policies supporting the integration of public transit into new developments by TDM organizations.
- The suitability of various program aspects, such as urban and rural areas, is generally rated 3 and above by most TDM organizations.
- The outcomes of the survey reveal some positive aspects, such as the availability of demand-responsive services, fleet size, and use of incentives, but also highlight areas for improvement.

Cons:

- Only 20% of TDM organizations have a mobile application to engage with customers, potentially limiting their ability to provide convenient and accessible services.
- 80% of TDM organizations do not offer tailored travel options to customers, relying solely on standard brochures.
- The effectiveness of incentives in boosting ridership is inconclusive, with 60% of respondents not providing an answer and 20% reporting mixed results or early judgment.
- 60% of TDM organizations do not have ongoing or upcoming projects involving integration with public bus transit services.

- Obstacles or challenges faced by TDM organizations include a lack of market research and coordination with private services.
- 80% of TDM organizations refuse to answer whether their service has been successful or not, potentially indicating a lack of data or evaluation.

Unexpected Outcomes:

- The percentage of TDM organizations providing demand-responsive/paratransit services and mentioning scooter-share is lower than expected (20%).
- The lack of mobile applications and tailored travel options is more prevalent among TDM organizations than anticipated.
- The low percentage of TDM organizations reporting success or providing information about their service's effectiveness is noteworthy.
- The lack of response to certain questions, such as the effectiveness of nudging techniques and the success of services, requires further investigation or follow-up with the TDM organizations.

Recommendations:

- Reach out to TDM organizations that did not provide complete information to gather more insights and data.
- Conduct further research to understand the reasons behind the low adoption of mobile applications and tailored travel options.
- Explore the factors contributing to the lack of reported success or effectiveness among TDM organizations.
- Consider conducting additional surveys or studies to delve deeper into the challenges faced by TDM organizations and increase the number of survey's respondents.

4.1.3 Some Important questions and their answers

This section presents important questions from the survey and their corresponding outcomes.

Does your organization have a TDM long-range strategic plan?

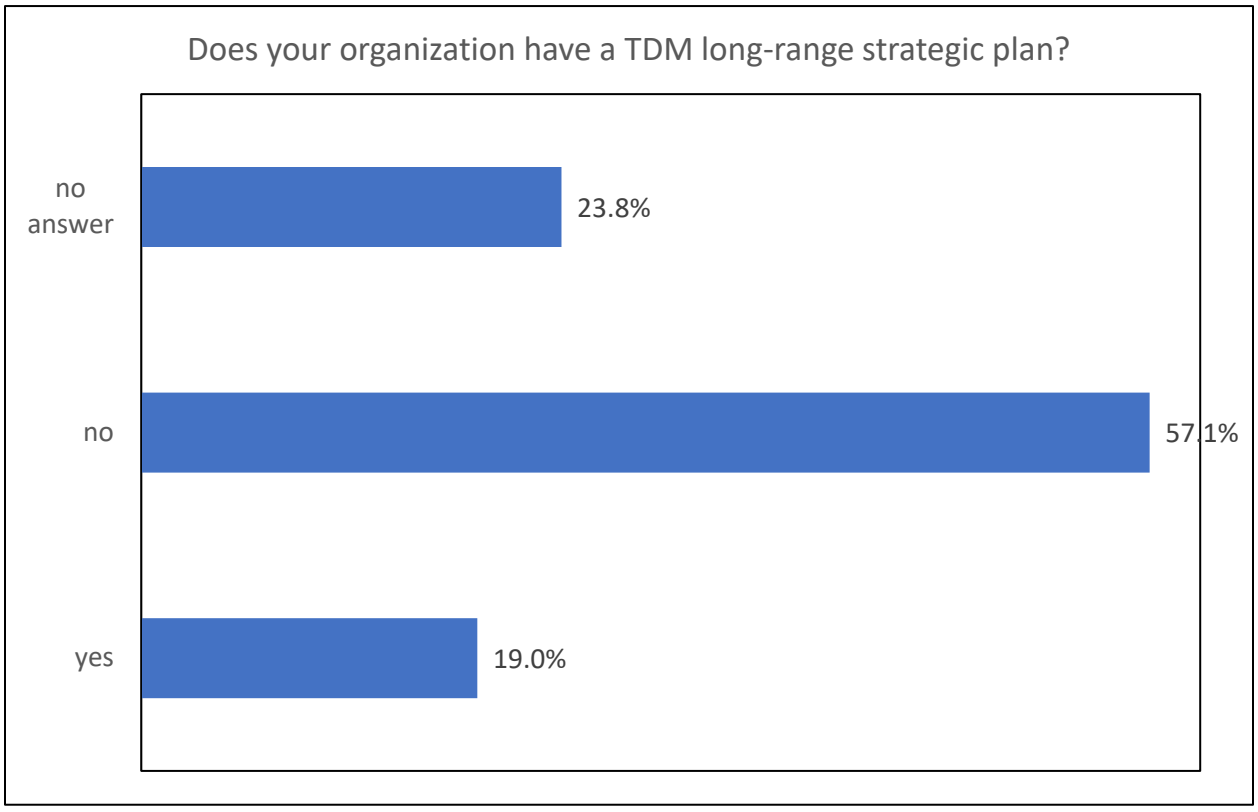


Figure 7 Organizations with Long Range TDM plan

- Out of the stakeholders involved in TDM, 57.1% currently lack a long-range strategic plan specifically tailored for TDM initiatives. Conversely, 19% of the stakeholders have successfully developed and implemented a TDM long-range strategic plan.

Overall, how well TDM is being managed within the region?

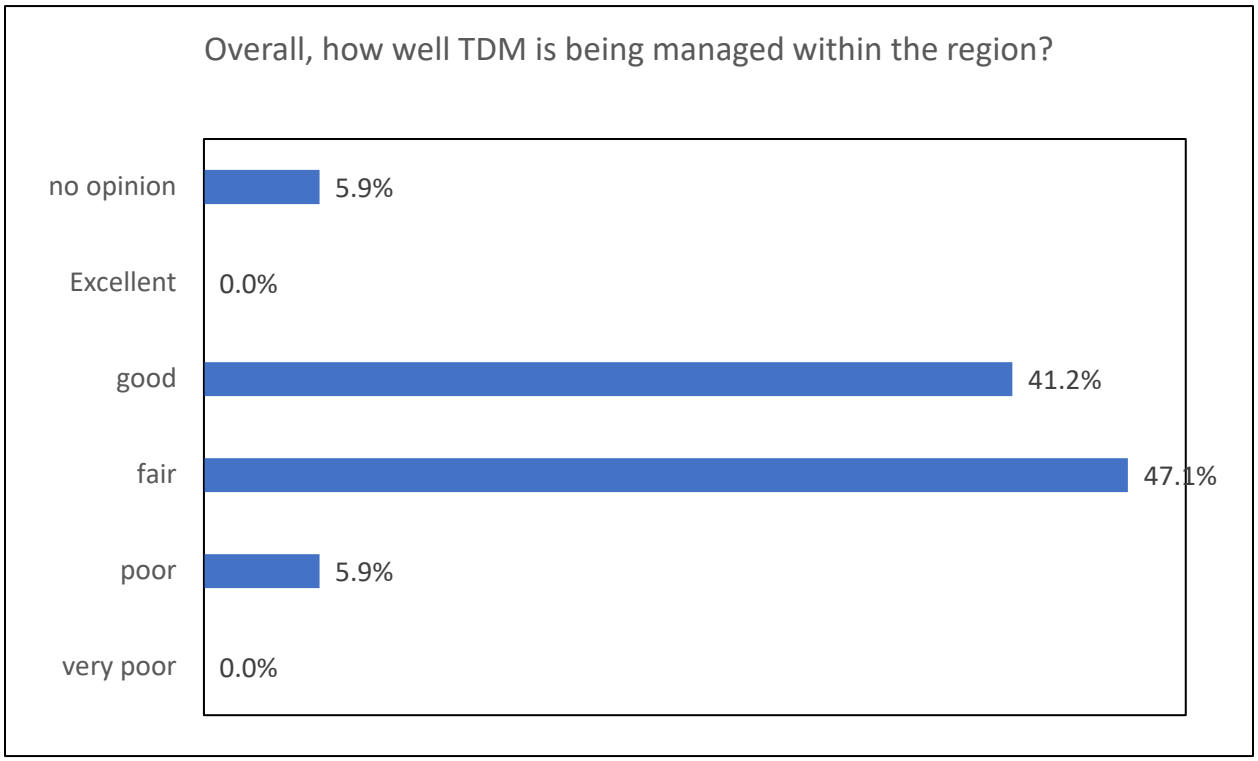


Figure 8 TDM management Rating

- The stakeholder feedback regarding the effectiveness of transport demand management in their respective area indicates that 47.1% of respondents consider it to be fair, while 41.2% of respondents rate it as good.

Please indicate the type of service you provide. (Please select multiple options if applicable)

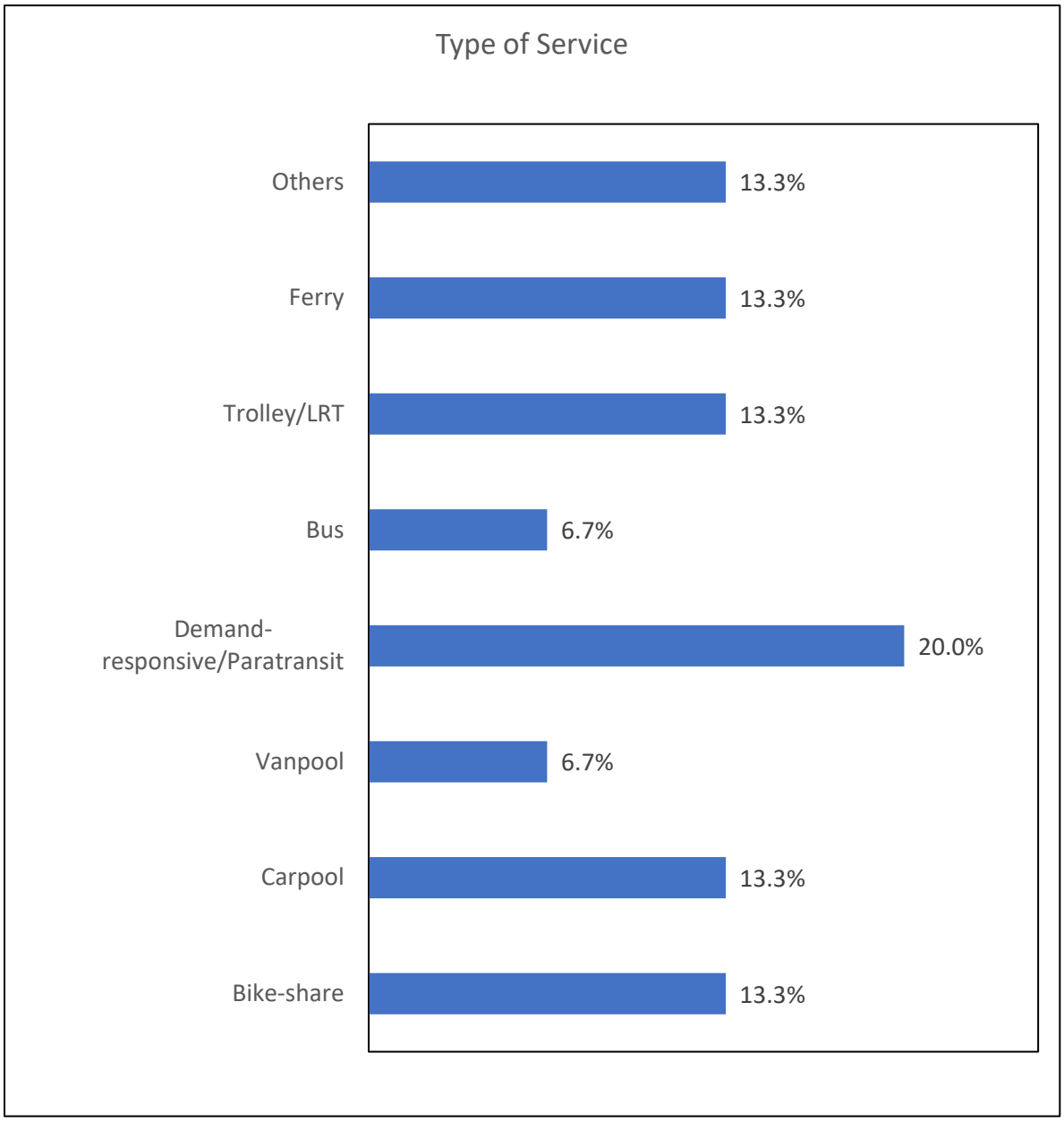


Figure 9 Type of Services Provided

- 20% of the responses provide Demand-responsive/Paratransit services. Additionally, services mentioned in others include scooter-share.

Does your agency's app send personalized messages as a nudging technique?

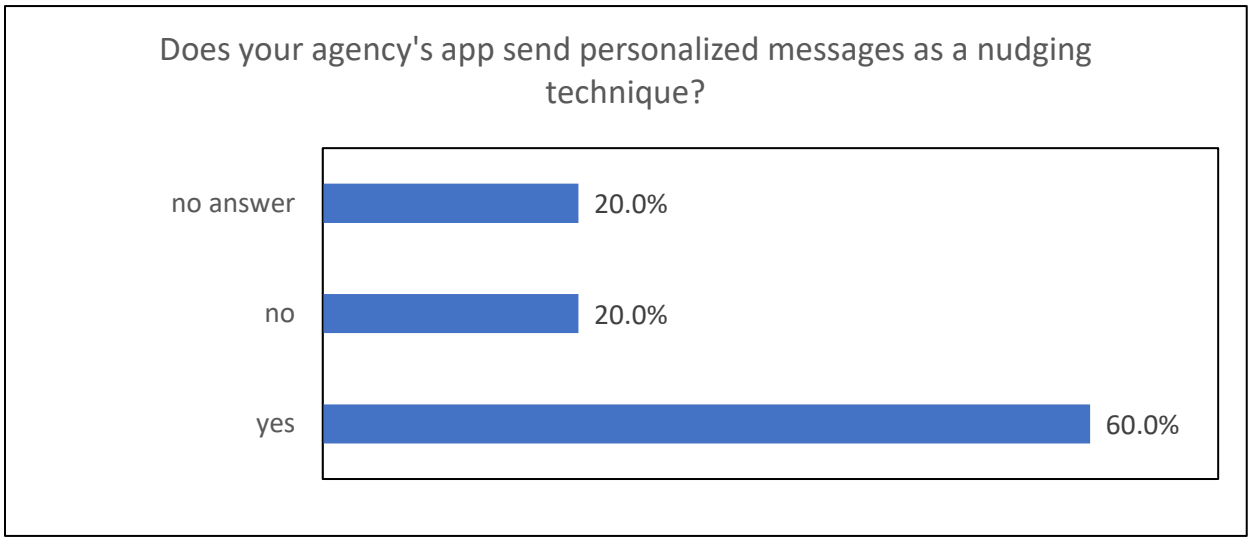


Figure 10 Apps with Personalized Nudging messages.

- It has been observed that 60% of organizations utilizing TDM employ the use of personalized messages sent through mobile applications as a technique for nudging their target audience.

Have your agency's nudging techniques been successful in increasing ridership?

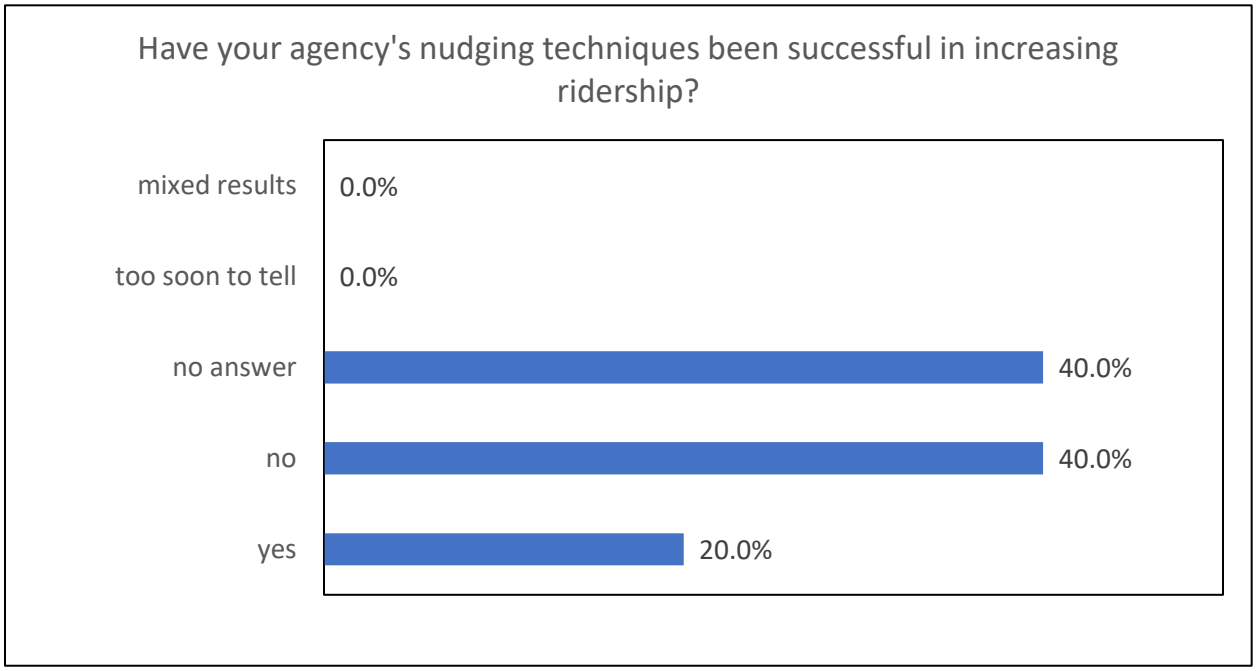


Figure 11 Nudging and ridership.

- It seems that only 20% of the TDM Organizations agreed to that nudging techniques have been successful in increasing ridership.

4.2 Commuter Questionnaire

This study focused on the residents of the state of Tennessee and employed a survey administered by a diverse web panel in terms of race, gender, age, education level, and income. The survey, was designed by the authors and administered by a survey company, consisted of five sections: fundamental transit usage, stated choice experiment, manipulation check, basic human value questions, and socio-demographic questions. The principle of Nudging was used to design the questionnaire.

Nudge

A nudge is any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives.

4.2.1 Methodology

This section begins by outlining the characteristics of the data involved in the survey. Subsequently, it introduces and offers a comprehensive explanation of the stated choice experimental design employed in the study. Lastly, it presents the discrete choice model utilized in the research.

Data and Study Area

This research focused on the residents of the state of Tennessee and utilized a survey designed by the authors and administered by a selected web panel with diverse representation in race, sex, age group, education level, and income. The sample size for the survey was calculated using Cochran's formula (Cochran, 1977). The experimental design as shown in Figure 12 shows the respondents being randomly divided into four groups with three treatments and a control group in randomized control trials. The three treatment groups are treatment 1-Emotional Nudging, treatment 2-Normative Nudging, and treatment 3-Gain Nudging. The survey consists of five sections: Information about transportation modes in the survey, stated choice experiment, manipulation check, basic human value

questions, and socio-demographic questions. The survey was structured in a manner that the information intervention was conducted early in the survey so as not to bias the answers of the respondents.

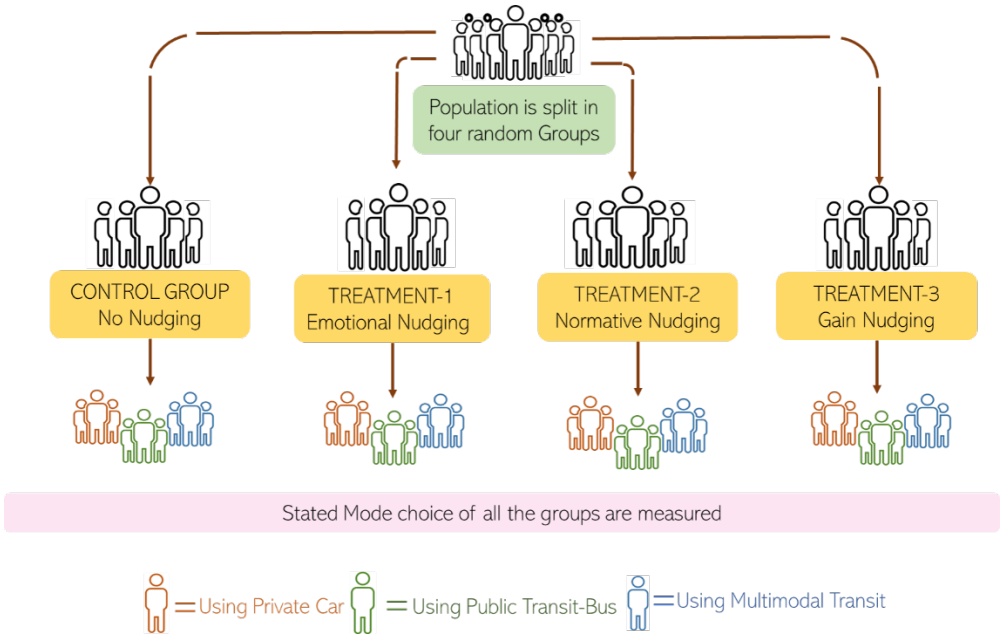


Figure 12 Randomized Control Experiment Design

Experimental design with treatments

In the stated choice experiment, six different nudge treatments were introduced based on three goal framings with two treatments per framing as shown in Figure 13 In this study, message framings were randomly assigned to respondents who indicated their preferred mode of travel for a 10-mile trip. Prior to the stated choice, the participants were provided with information regarding the available modes of transportation, namely Personal Car, Public Transit-Bus, and Multimodal Transit (Figure 14). For the purposes of this study, Multimodal Transit is defined as any form of public transportation that includes the use of bikes, scooters, vanpools, etc., either individually or in combination that is used to complete a trip. Respondents also evaluated statements concerning values, beliefs, and norms. These statements were presented on a Likert scale and could potentially serve as variables for assessing behavioral change in response to the nudge treatments.

Nudging using Message Framing

- Theoretical frameworks used in studying the significance of attitudes in promoting pro-environmental behaviors include
  - Goal Framing Theory (GFT) with messages
- GFT emphasizes the influence of motivation and goals on behavior, with three important goal frames:
  - **Emotional- prioritizes feeling good and maximizing well-being.**
  - **Normative-emphasizes morally right actions.**
  - **Gain- focuses on improving personal resources.**
- Motivations in messages can drive pro-environmental actions but can also lead to harmful behaviors if prioritized over environmental concerns
- Framing of messages plays a significant role in studying pro-environmental behavior and policy acceptance

Treatment	Name	Description
Treatment-1 **Emotional Nudging**	Emotional Nudging-1 **Smileys**	Information on mode sustainability conveyed through smileys
	Emotional Nudging-2 **Color Scale**	Information on air quality conveyed through color scale
Treatment-2 **Normative Nudging**	Normative Nudging-1 **Environment Conscious**	Informed the impact of public transit on being ecofriendly
	Normative Nudging-2 **Nation Building**	Informed the impact of public transit in helping nation building
Treatment-3 **Gain Nudging**	Gain Nudging-1 **Money Gain**	Quatified the money gain with using public transit
	Gain Nudging-2 **Health Gain**	Quantified the health gain with using public transit

Figure 13 Nudge Treatments

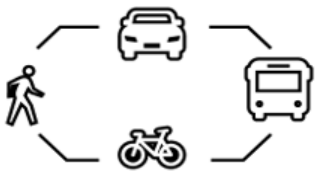
Personal Car 	▪ **91.7%** of households had at least one vehicle in 2021 ▪ There was a total of **278 million** registered vehicles in the United States in 2020 ▪ The **average car** is driven **13,476** miles per year in the U.S
Public Transit-Bus 	▪ In 2019, Americans took **9.9 billion trips** on public transportation. ▪ Approximately **6,800** organizations provide public transportation in the United States.
Multimodal Public Transit e.g., ***Moovit, Bird*** 	▪ Multimodal public transportation **coordinates several modes** of transportation - carpool, trains, bus, bicycles, and pedestrians - into a convenient hub. ▪ It is an efficient method to utilize existing public transportation facilities through a **coordinated system** of multiple modes primarily **under one ticket.** ▪ Google Maps launched a new multimodal trip-planning feature in 2019.

Figure 14 Information on the available Modes of Travel

Emotional Nudging

The concept of Emotional Nudging involves employing emotional framing in messages to evoke specific emotional responses, such as happiness, excitement, or sadness. Applying this concept to information about multiple transportation modes can be done using colors or emoticons, such as smiling faces or frowning faces. Emoticons, represent emotions and can be used to express approval or disapproval of a behavior, such as conveying an injunctive norm (Schultz et al., 2007). Another method of evoking emotions is by utilizing colors, which can significantly influence decision-making due to their associations with specific emotions, such as red symbolizing anger or blue representing calmness. Additionally, colors can be linked to concepts like cleanliness (blue), dirtiness (brown), or environmental awareness (green) (Derefeldt et al., 2004; Elliot, 2015; Kauppinen-Räisänen & Luomala, 2010; Valdez & Mehrabian, 1994). In this study, we use two different cue cards with two types of emotional Framing using "Smileys" (Figure-15) and "Color Scale" (Figure-16).

Smileys: Smileys were employed as visual cues, also the first approach for emotional message framing to nudge respondents.

The cue card depicts how different modes of transportation contribute to the promotion of "Environmental Sustainability, a means to achieve a sustainable future" as the underlying objective. Public transit was represented by a highly elated smiley face, conveying a sense of joy and amusement. Multimodal transit was represented by a happy smiley face, also reflecting satisfaction. On the other hand, personal car usage was symbolized by a sad smiley face, expressing a sense of disappointment. Using this information, survey participants were requested to select a mode of transportation for a 10-mile trip, and their stated choice was subsequently recorded for analysis.

Color Coding: The second approach employed for framing emotional messages to influence respondents involved the utilization of a color scale that ranged from red to green. Specifically, the color scale was used to represent the air quality associated with different modes of transportation. In this scale, the color red denoted poor air quality, while the color green indicated good air quality. Public transit was depicted as being on the extreme end of the green spectrum, representing excellent air quality. Multimodal transit was represented by a lighter shade of green, still falling within the favorable air quality range. Conversely, the Personal Car was positioned towards the red end of the color scale, signifying inferior air quality. Additionally, as part of the nudging technique, another visual cue was incorporated into the same card. This cue consisted of a child wearing a mask on the roadside, strategically designed to elicit an emotional response from the respondents. The survey participants were then requested to select a mode of transportation for a 10-mile trip.

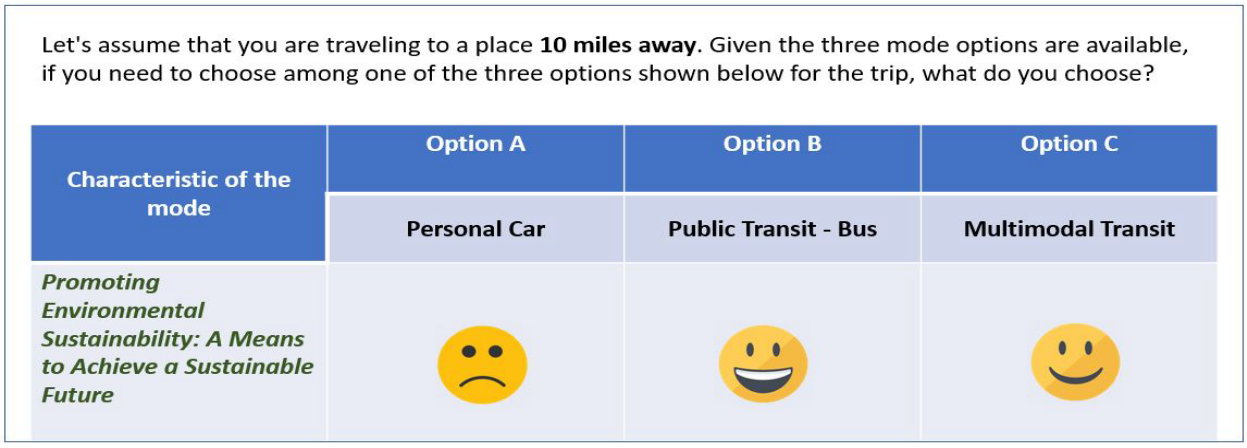


Figure 15 Emotional Nudging-1: Smileys

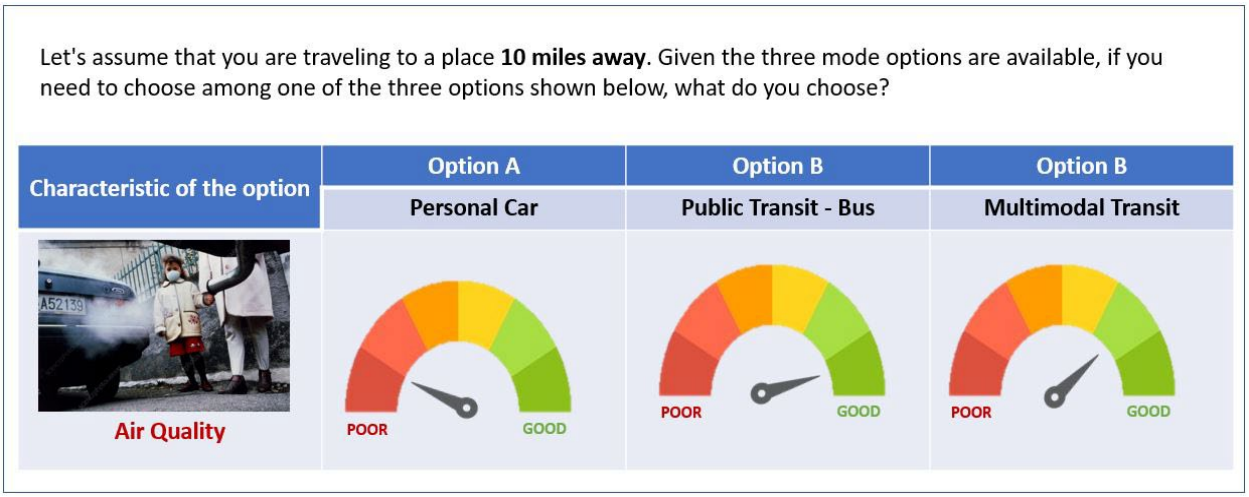


Figure 16 Emotional Nudging-2: Color Scale (Image source:(MAURO FERMARIELLO & SCIENCE PHOTO LIBRARY, n.d.))

Normative Nudging

Normative framing emphasizes the societal implications of a particular issue. For instance, presenting greenhouse gas (GHG) emissions information in relation to a societal objective of reducing those emissions can be considered an example of norm-framing. In this study, Normative Nudging employs normative framing of messages, emphasizing societal implications and moral obligations regarding a specific issue. It was discovered that individuals, even those not particularly concerned about climate change, were motivated by this framing. This motivation stemmed from their desire to align with perceived moral correctness and individuals do not necessarily require environmental motivation, as the information presented is associated with being a responsible and ethical citizen (Daziano, 2018). With this information, the study used two cue cards, each employing different normative framings: “Environment Conscious” (Figure 17) and “Nation Building” (Figure 18).

Environment Conscious: In this normative message-framing nudging technique, cue cards were specifically designed to accentuate the importance of public transit in fostering environmental sustainability. The provided information, which was highlighted within green boxes, included the following statements: "By transitioning from a 20-mile commute via personal vehicle to utilizing public transportation, an individual can effectively reduce their annual CO2 emissions by 20 pounds per day, amounting to over 48,000 pounds per year" and "Public transportation in the United States contributes to the preservation of the environment by saving 37 million metric tons of carbon dioxide annually. This amount is equivalent to the emissions produced by the electricity consumption of approximately 4.9 million households" (KCATA, n.d.). The intention behind presenting this information on the cue cards was to enhance the respondents' consciousness and concern for environmental issues. Consequently, the respondents were requested to choose a mode of transportation for a 10-mile trip based on the information provided.

Nation Building: In this normative framing cue cards were specifically designed to emphasize the significance of public transit in the context of nation building. Enclosed within a green box, the provided information comprised the following information: "Investing $1 billion in the public transit sector has the potential to generate approximately 49,700 jobs. By the year 2040, these investments are expected to yield long-term cost reductions, with an estimated economic impact valued at $3.2 billion in GDP." Additionally, the cue cards stated, "The adoption of public transit signifies a collective commitment to constructing a more sustainable and prosperous future for all individuals in the country" (EDRG, 2020). The objective behind presenting this information on the cue cards was to heighten the respondents' awareness and concern regarding the utilization of public transit in the context of nation building and the employment opportunities it creates.

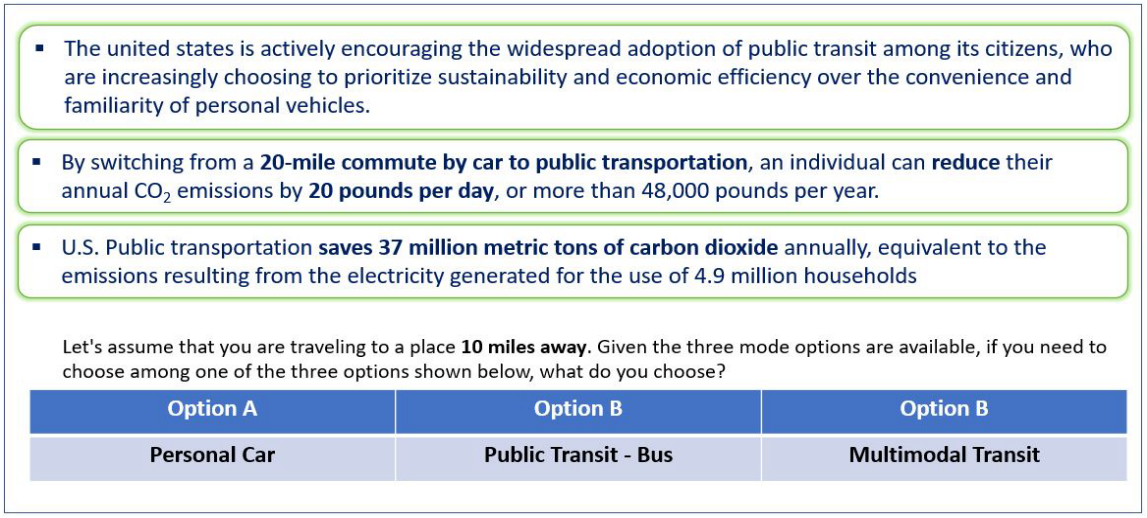


Figure 17 Normative Nudging-1: Environment Conscious

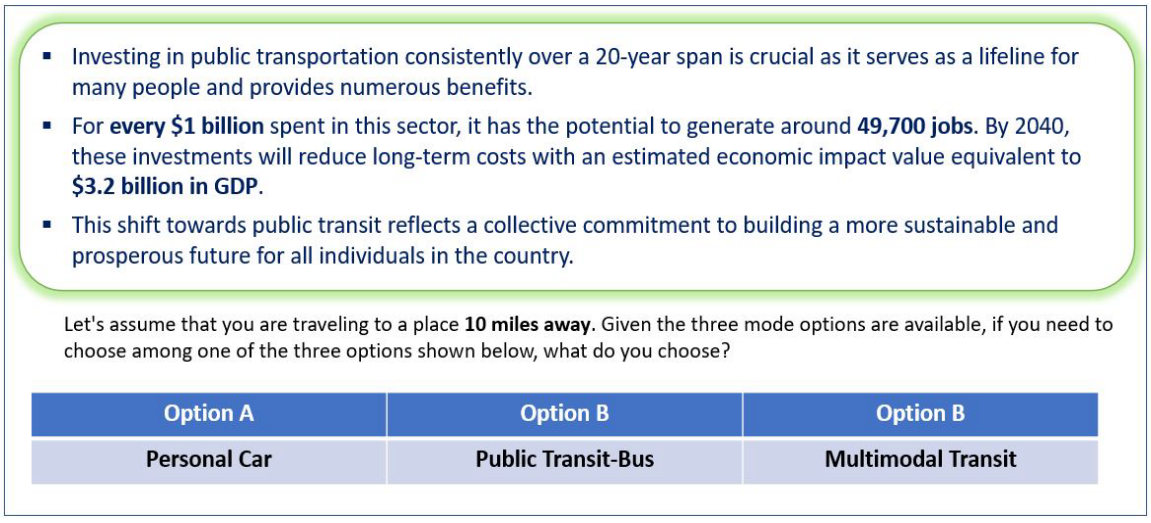


Figure 18 Normative Nudging-2: Nation Building

Gain Nudging

Gain Nudging involves framing messages to emphasize the positive outcomes of a choice, particularly the benefits to one's resources, such as saving fuel costs. This concept, as demonstrated by (Brazil et al., 2019) is applicable in the transportation context, where factors like money and time are significant. The fuel costs displayed on Natural Resources Canada's label serve as an example of gain-framing (Wang et al., 2021). It is widely believed that people are most responsive to financial incentives or disincentives, and the implementation of a carbon price aims to encourage individuals to reduce their emissions. Nevertheless, individuals are also motivated by other factors, such as a sense of social responsibility (Ariely & Jones, 2008; Heyman & Ariely, 2004). In this study, we use two different cue cards with two types of Gain Nudging: "Money Gain" (Figure 19) and "Health Gain" (Figure 20).

Money Gain: The "Money Gain" framing method employs cue cards containing specific values to provide individuals with a perspective on the financial benefits associated with utilizing various modes of transportation. These cue cards also contain fundamental information regarding the costs associated with different transportation options, emphasizing the advantages of utilizing affordable modes such as Public Transit-Bus. Specifically, the cue cards highlight that the cost per mile for using a Personal Car is $0.9, whereas it is $0.4 per mile for Public Transit-Bus and $0.5 per mile for Multimodal Transit (*Victoria Transport Policy Institute*, n.d.). By providing the cost information, participants may be encouraged by the gain framing to refrain from using their personal vehicles, resulting in potential financial savings.

Health Gain: The Health Gain message framing method employs cue cards that contain specific values to provide individuals with a perspective on the health benefits associated with utilizing different modes of transportation. These cue cards also contain fundamental information regarding the various health benefits of Public Transit. Furthermore, the costs associated with different external factors are quantified in monetary terms to assign a value to each transportation option, with a focus on emphasizing the advantages of using healthier modes such as public transit. Specifically, the cue cards highlight that the cost per mile for using a Personal Car is $1500 per user, whereas it is $150 per user for Public Transit-Bus and $440 per user for Multimodal Transit (*Victoria Transport Policy Institute*, n.d.). By presenting this cost information, the health gain framing can potentially convince respondents to consider the large health benefits associated with refraining from using personal vehicles.

- In general, ***"affordable transportation"*** indicates that a person's total travel expenses account for less than 20% of their household income.
- Car payments, gas prices, and parking can be significant budget drains, but public transportation reduces these costs by eliminating the need to own and operate individual vehicles
- Saving a household approximately **$6,251 per year**

Cost per mile of various modes($ per mile)	Personal Car	Public Transit-Bus	Multimodal Transit
Subsidy	0	0.1	0.02925
Vehicle ownership	0.3	0	0.12075
Vehicle operating	0.2	0.2	0.14175
Roadway infrastructure	0.08	0.05	0.047
Parking	0.2	0.013	0.0825
Traffic congestion	0.04	0.013	0.02375
Barrier effect	0.02	0.005	0.00625
Resource externalities	0.02	0.013	0.00875

Let's assume that you are traveling to a place **10 miles away**. Given the three mode options are available, if you need to choose among one of the three options shown below, what do you choose?

	Option A	Option B	Option C
	Personal Car	Public Transit-Bus	Multimodal Transit
Cost per mile of various modes	$0.9 per mile	$0.4 per mile	$0.5 per mile

Figure 19 Gain Nudging-1: Money Gain

Health Benefits of Public Transit

Public transit users are more active	▪ **Three times** the amount of **physical activity** per day of those who don't
Buses are safer than individual vehicles.	▪ In the USA, fatality rate for car occupants were found to be **23 times higher** than those for bus occupants, per 100 million person-trips
Public transportation reduces stress.	▪ Public transportation **reduces noise pollution**. It also enhances education, employment, and long-term economic potential. It also fosters neighborly relations.
Public buses keep air cleaner.	▪ Public transportation **generate less pollution** per passenger mile than automobiles due to their use of advanced technologies and higher standards
Public transportation provides access to essential needs later in life	▪ Public transportation allows non-drivers, especially low-income seniors and disabled people, to access health services, basic shopping, banking, education, and work.

Let's assume that you are traveling to a place **10 miles away**. Given the three mode options are available, if you need to choose among one of the three options shown below, what do you choose?

Average annual costs per full time user	Option A	Option B	Option C
	Personal Car	Public Transit-Bus	Multimodal Transit
crash damages(external)+ Noise and air pollution	$1500/User	$150/User	$440/User

Figure 20 Gain Nudging-2: Health Gain

Control group

The control group was designed to compare against three other groups, each receiving different information and message framing. However, the control group itself did not receive any specific information, instead, the participants in the control group were asked directly to select a mode of transportation for a 10-mile trip (Figure 21).

Let's assume that you are traveling to a place **10 miles away**. Given the three mode options are available, if you need to choose among one of the three options shown below for the trip, what do you choose?

Option A	Option B	Option C
Personal Car	Public Transit - Bus	Multimodal Transit

Figure 21 Control Group

4.2.2 Model Specifications

This paper employs discrete choice analysis, where respondents are presented with various modes and the attributes of each mode are compared using a utility structure (McFadden, 1986). Consequently, they choose the alternative from a given set that provides the highest level of utility. Due to the random assignment of respondents to treatments, the treatment allocations provide exogenous variation in the information provided to respondents prior to expressing their choice. To analyze the impact of treatment and human values on choice, the study employs a multinomial logit model. Mathematically, the model is specified as:

$$U_{i,m} = \alpha_{i,m} + \beta * T_{i,mj} + \gamma * X_{i,m} + \epsilon_{i,m}$$

Where $U_{i.m}$ is the utility for alternative *'m'* and individual '*i*'. $T_{i,m,j}$ is an indicator for whether the respondent '*i*' was treated by treatment *'j'* (*j*=1,2,3) when choosing alternative *'m'*, X_i denotes the set of respondent-specific values and socio-economic variables for alternative *'m'*. $\alpha_{i,m}$ denotes the intercept and $\epsilon_{i,m}$ denotes the residual. And further the probability of individual '*i*' choosing alternative 'm' can be expressed as follows:

$$P_{i,m} = \frac{exp(U_{i,m})}{\sum_{m=0}^{m=2} exp\,(U_{i,m})}$$

Where m can take the values 0 (Personal Car), 1 (Public Transit-Bus), and 2 (Multimodal Transit). To estimate the average treatment effects on individuals who received treatments, denoted as 'β', we calculate this parameter separately for each of the three treatment groups *('j').* Additionally, we have a combined model that includes all three treatment indicators. Figure 22 presents the model variables, the investigation particularly underscores four types of values deemed pivotal in the anticipation of both environmental attitudes and behaviors: biospheric values (pertaining to environmental concern), altruistic values (pertaining to the welfare of others), egoistic values (relating to personal interests and resources), and hedonic

values (relating to personal comfort and enjoyment). Moreover, the variables associated with general beliefs and societal norms encompass Positive Personal Norms, Positive Social Norms, Negative Personal Norms, and Negative Social Norms. This inclusion is grounded in the understanding that influential figures within an individual's social network exert a significant impact on their choices and actions. These variables were evaluated through a Likert scale survey to discern and categorize individual attitudes. To analyze the variables “Positive Personal Norm" and "Positive Social Norm," questions were asked to discern instances of favorable influence promoting the utilization of public transit. Conversely, "Negative Personal Norm" and "Negative Social Norm," questions center on adverse influences that impede the use of public transit. Due to the random assignment of respondents to treatments the potential for selection bias, whether influenced by observable or unobservable factors, is minimal. In addition, the coefficients in our models represent the average treatment effect on the individuals who received the respective treatments, rather than representing the average treatment effect for the entire population.

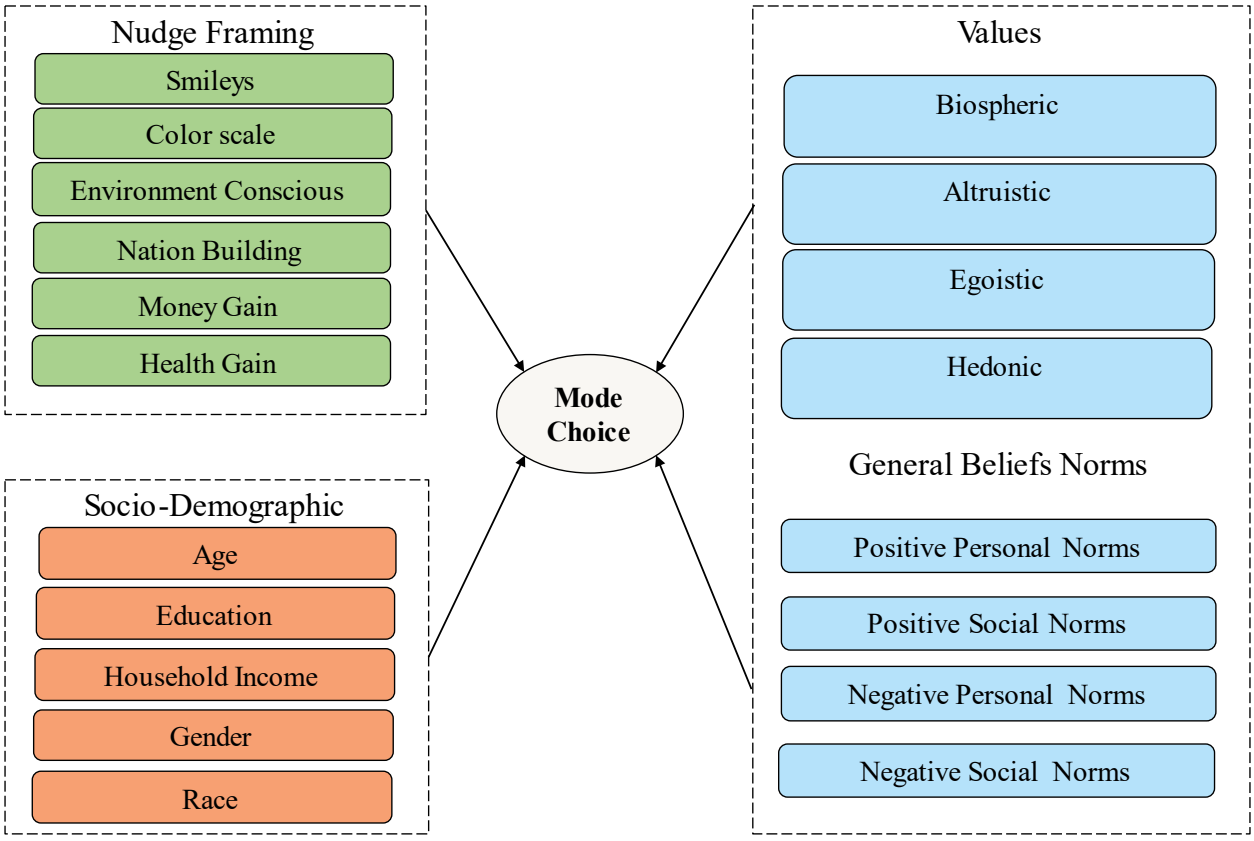


Figure 22 Model Design and Variables

Manipulation Check

In the context of empirical research, it is frequently advised to incorporate manipulation checks into experimental investigations. In order to get treatment right, it is typically required that respondents demonstrate attentiveness towards the prescribed treatments (Kane &

Barabas, 2019). However, the task of ensuring that participants effectively attend to stimuli poses challenges, particularly in light of the increasing prevalence of online surveys and the utilization of subjects from opt-in panels, who may be prone to distractions. One approach to assess this is through the use of a manipulation check (MC). In the field of experimental research, multiple-choice questions serve the purpose of assessing whether the manipulation implemented during an experiment is perceived by the participants in accordance with the intentions of the study (Morton & Williams, 2010). In this study, we employ factual manipulation checks (FMCs), which involve posing objective questions to respondents that have definitive correct answers and it has the potential to serve as valuable instruments for researchers conducting experiments (Kane & Barabas, 2019).

In the context of Emotional Nudging, the primary focus lies in assessing the affect heuristic of the participants, and in this check, we examine the impact of priming and emotional reaction on decision-making processes (Finucane et al., 2000). As part of this assessment, a specific question was asked "To what extent does this photograph elicit an emotional response from you?" while showing a figure of a child wearing a mask on the roadside. The available response options are as follows: a) Not at all b) To a minor extent c) To a moderate extent d) To a significant extent e) To a considerable extent. An outcome is indicative of successful evaluation is indicated when respondents choose any option beyond "To a moderate extent". In the context of Normative Nudging, the evaluation primarily revolves around assessing instances of limited attention and imperfect information displayed by the respondent. To activate the moral compass of the respondents effectively, the information provided should be imparted perfectly. An MC query was presented as follows: "Do you hold the belief that single-occupancy vehicles contribute to elevated air pollution levels and exert a detrimental influence on sustainability?" The available response options were "True" and "False." A successful outcome for the respondent is when the response chosen is "True." In the context of Gain nudging, the primary focus of assessment pertains to the cognitive limitations of the respondent's cognitive abilities. The respondents should not have cognitive skill limitations and should be able to understand the long-term benefits described. For the MC, a precise question involving a straightforward mathematical calculation was presented: “On average, a car emits around 400 grams of CO_2 per mile. What is the total amount of CO_2 produced during a 10-mile car trip?". The options provided for response are as follows: a) 400 b) 4000 c) 100 d) 1000. The successful completion of the assessment rests upon the accurate selection of the response, which, in this instance, is option "a," denoting 400 grams of CO2.

4.2.3 Results and Discussions

Data and Descriptive Statistics

The survey participants included in this study were selected from various regions of the state of Tennessee. Following data cleaning procedures, the initial sample size was reduced to 2,250 observations.

The survey data was cleaned by excluding incomplete responses and those surveys that were completed in less than 5 minutes. Out of these, 557 respondents were assigned to the control group, 514 respondents to Treatment 1 (Emotional Nudging), 583 respondents to Treatment 2 (Normative Nudging), and 591 respondents to Treatment 3 (Gain Nudging). To further evaluate the quality of randomization, Table 3 presents information regarding the distribution of significant covariates among the four groups within our data sample. The variables were analyzed individually across the treatment groups, and it was observed that each category of variables was comparable in number across groups. Considering that respondents were assigned randomly to different information treatments; these findings suggest that the randomization process was effective in ensuring that the treatment groups were comparable and suitable for conducting subsequent analyses.

Table 3 Descriptive Statistics (N=2,250)

		Control Group	Treatment 1	Treatment 2	Treatment 3
N		557	514	583	596
Gender	Man	259	219	277	280
	Woman	298	295	306	316
Age	18-24	35	32	35	47
	25-34	89	72	65	76
	35-44	76	84	92	89
	45-65	224	194	233	243
	65+	133	132	158	141
Race	Asian	5	8	5	9
	Black or African American	71	72	79	79
	Hispanic / Latino	11	6	5	13
	Other	13	16	21	12
	White	457	412	473	483
Income	Less than $25,000	103	113	109	125
	$25,000 to $49,999	166	150	156	167
	$50,000 to $74,999	128	122	129	128
	$75,000 to $99,999	70	49	86	81
	Greater than $100,000	90	80	103	95
Education	Less than high school degree	21	23	16	23
	High school degree	264	254	248	261

Associates Degree	74	68	109	107
Bachelors' degree	121	99	131	124
Postgraduate	77	70	79	81

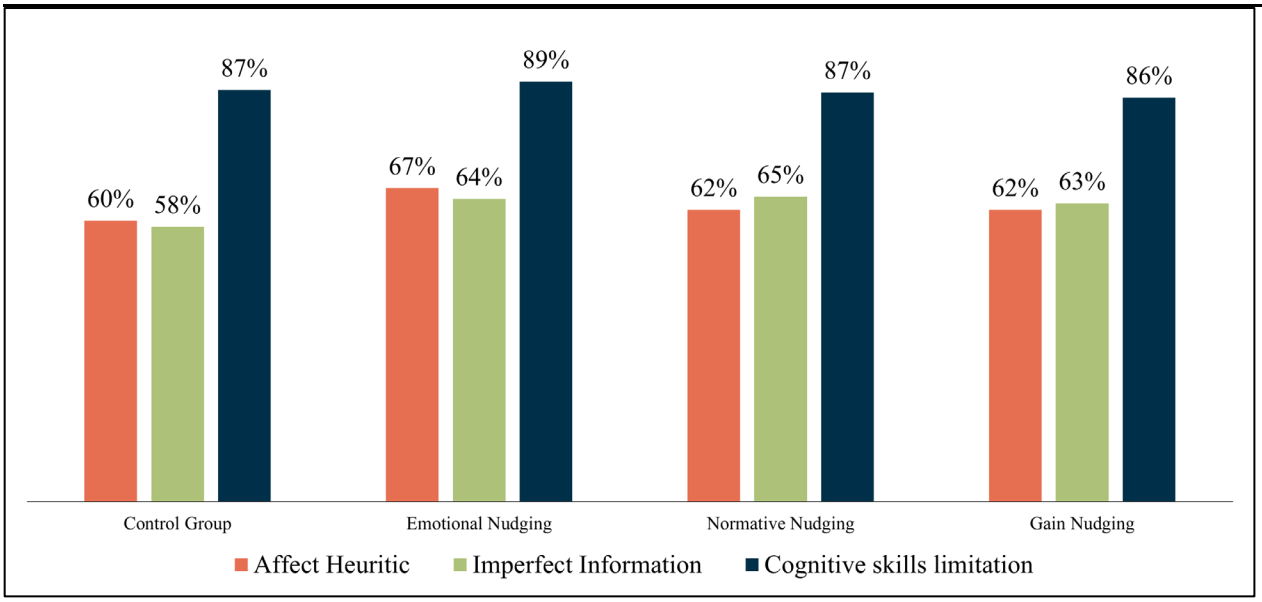


Figure 23 Percentage of respondents passing the Manipulation Checks for different Treatment Groups

Before delving into the assessment of treatment effects, the MCs used in the study were analyzed. Figure 23 displays the percentage of people passing each of the MCs. It is evident from the figure that a significant proportion, exceeding 86% of the participants successfully cleared the MC for cognitive skills limitation across all the treatment groups and the control group. This indicates that above 86% of the respondents were able to assess the benefits or gains and did not have cognitive skill limitations. Conversely, the MC that focused on imperfect information yielded the lowest pass rate among the control group, with 58%. Interestingly, the normative nudging group exhibited the highest pass rate 67% and it is plausible that for the remaining 33%, either the information was inadequately conveyed, or their responses were a product of deliberate decision-making processes. The specific query posed inquired whether individuals believed that single-occupancy vehicles contribute to increased air pollution and detrimentally affect sustainability. It is possible that despite exposure to the messaging, either the communication was not adequately conveyed, or the respondents remained unconvinced by its content. Examining the impact of affect heuristics on the respondents revealed that a significant majority, greater than 60 % in all groups, were influenced by the visual stimuli. Remarkably, the emotional nudging group achieved the most noteworthy pass rate for this MC with 68%. This outcome could serve as an indicator that employing such evocative messages, as demonstrated by emotional nudging, holds promise in effectively steering a shift towards public transit modes.

Use of Public Transit

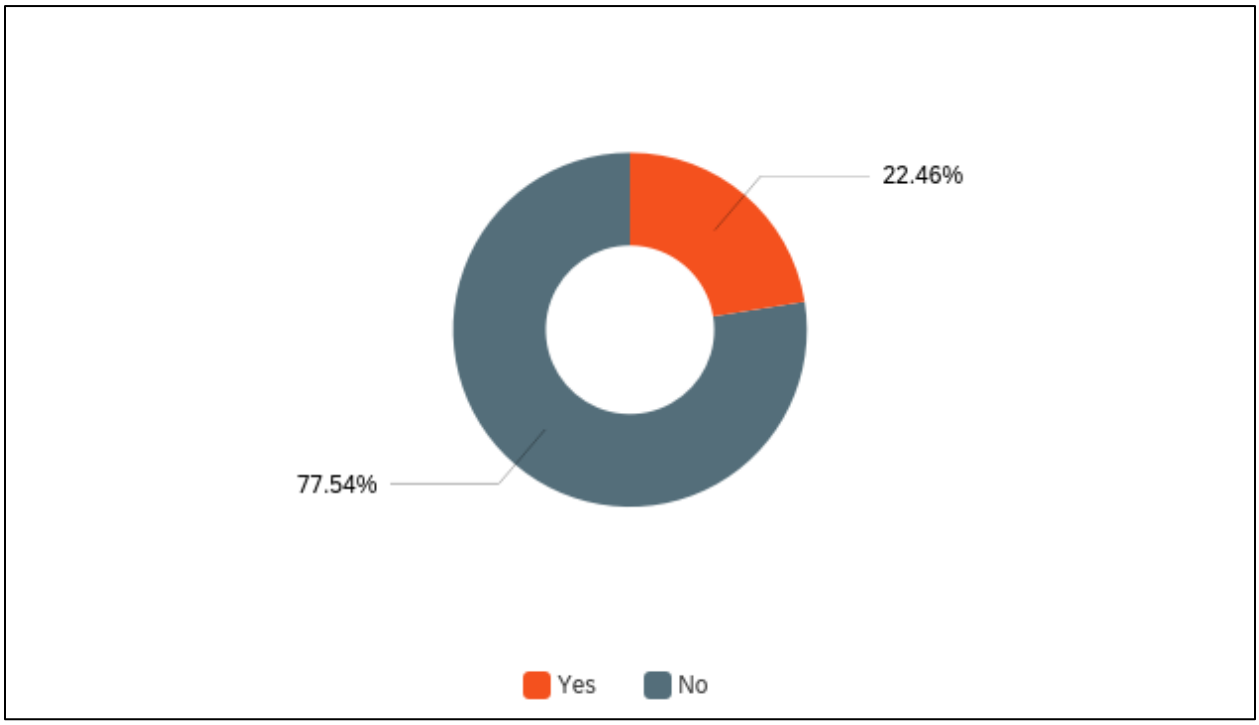


Figure 24 Percentage of People Who Use Public Transit

According to Figure 24, that says the percentage of people who use public transit, a substantial portion of respondents, comprising 77.54%, indicated a preference against utilizing public transportation modes for their travel needs. Among those who do opt for public transit, the bus emerges as the prevailing mode of choice (Figure 25). This observation underscores the prevalence of bus transportation among individuals who opt for public transit options, suggesting its significance as a commonly utilized mode within the surveyed population.

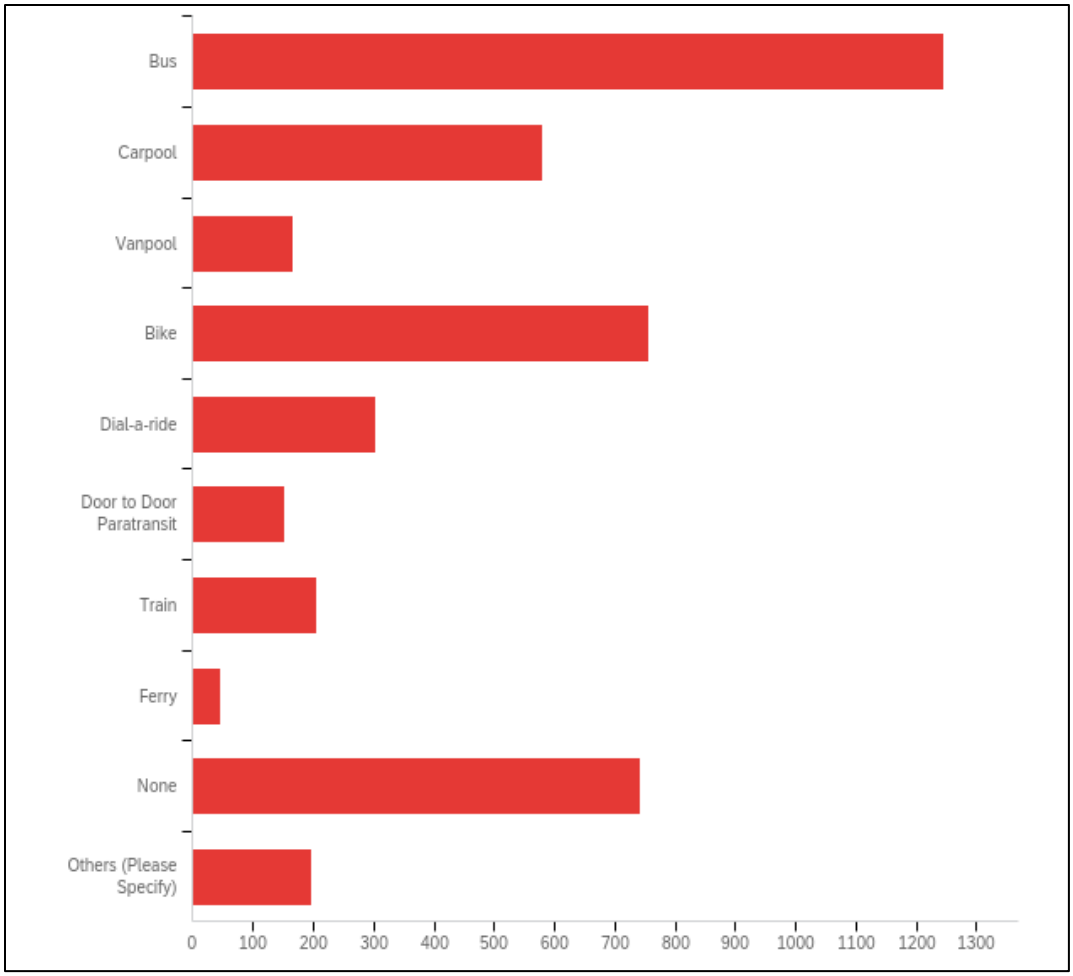


Figure 25 Percentage Use of Public Transit Modes

Treatment Effects

Based on the assertions articulated, we anticipate that the treatments under examination will yield a favorable impact on respondents' likelihood to choose public transit modes. We also do not anticipate any of the treatments to diminish the probability of respondents selecting public transit since our interventions do not entail providing any information that could induce negative perceptions of public transit modes. This assumption is validated by the respondents' stated choices, as Figure 26 provides statistical data illustrating the percentage of respondents within each treatment group who expressed a preference for Public Transportation-Bus and Multimodal Transit. In the no-treatment control group, 8% of respondents choose Public Transit-Bus, and 3% Multimodal Transit. In contrast, the Emotional Nudging with the "Color Scale" treatment demonstrated more favorable outcomes, as 36% of respondents selected Public Transit-Bus, and 8% chose Multimodal Transit. The Normative Nudging: "Nation Building" treatment resulted in 31% of respondents favoring Public Transit-Bus and 11% choosing Multimodal Transit.

As for the Gain Nudging: "Health Gain" treatment, 43% of respondents preferred Public Transit-Bus, and 8% favored Multimodal Transit. Notably, this treatment was particularly effective in reducing the preference for Personal Car. There is an observable difference in the mode choice of people after the stated preference survey. These findings suggest that compared to the control group, the treatments are likely to have a positive effect on respondents choosing public transit.

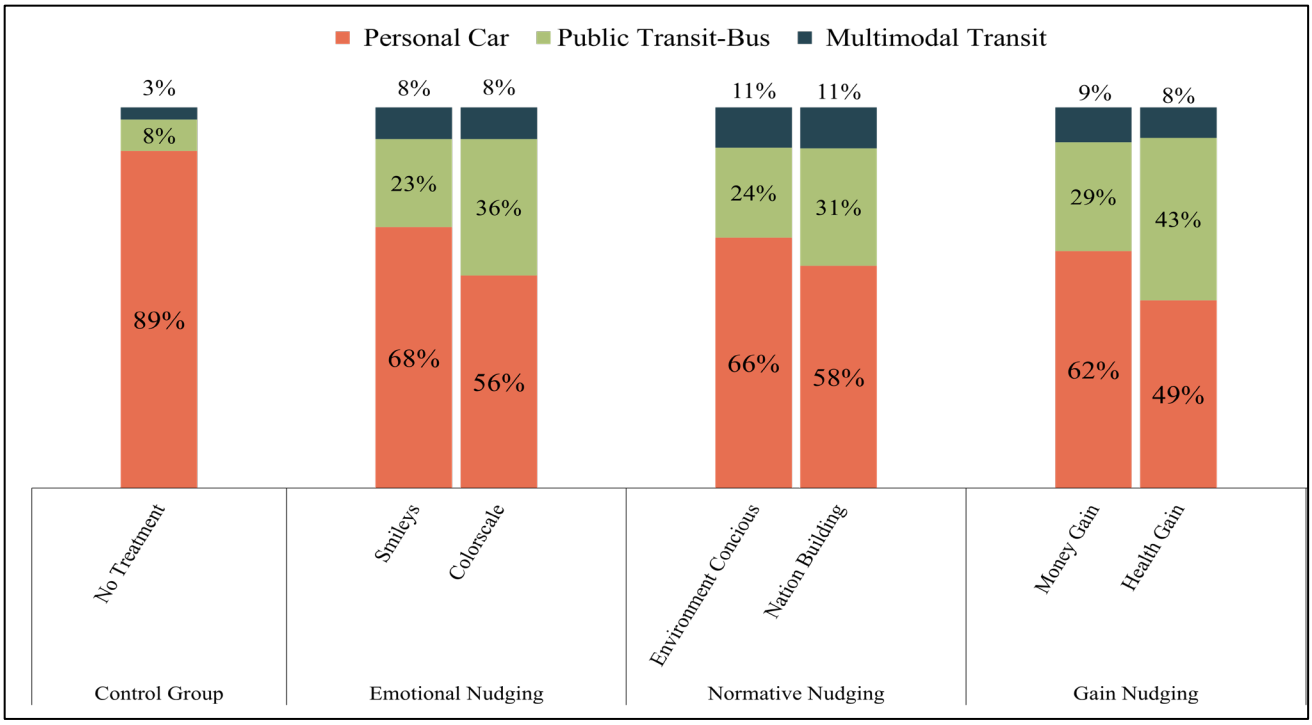


Figure 26 Stated Mode Choice across Treatments

4.3 Visualization Dashboard

In the subsequent phase of the project, the survey results were visualized to facilitate comprehension and analysis. The visual representations depict the utilization of various transportation modes across different zip codes in Tennessee, showcasing the percentage distribution of usage. These visualizations are equipped with filters allowing sorting by demographic variables such as age, gender, city, income level, and education. Each zip code is selectable, enabling users to access specific details pertaining to that region. The dashboard interface is designed to provide an intuitive and easily navigable platform for users to interpret the survey findings effectively. Below, presented are screenshots (Figure 27, 28) exemplifying the layout and functionality of the dashboard, aimed at enhancing accessibility and understanding of the survey results.

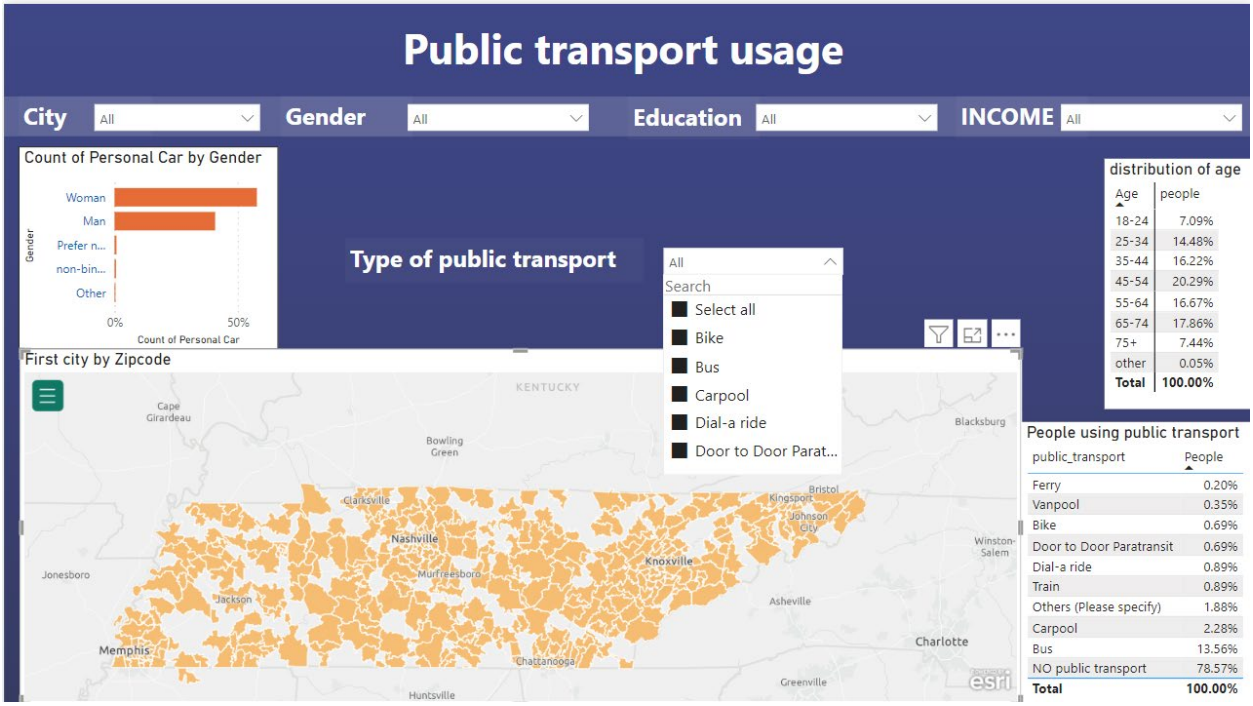


Figure 27 Snippet of Visualization Dashboard: Different Modes

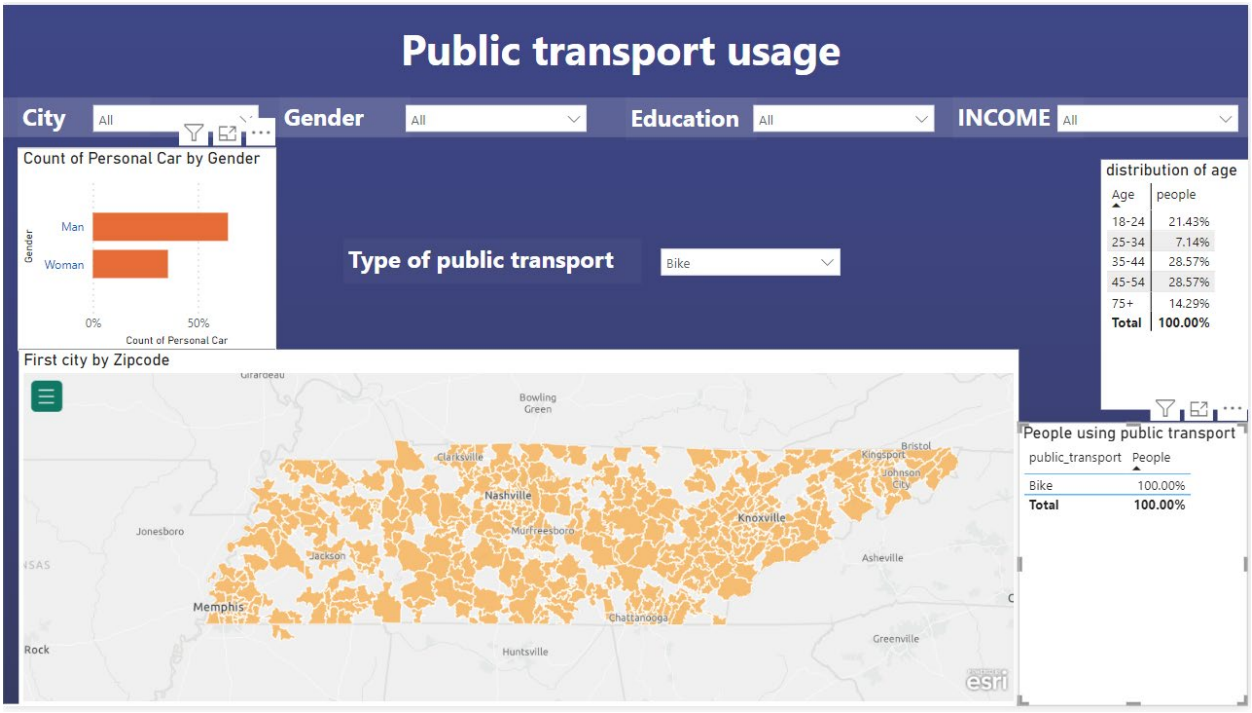


Figure 28 Snippet of Visualization Dashboard: Bike

5. Conclusion

5.1 Addressing Transportation Challenges:

This project has illuminated the pressing transportation challenges faced by Tennessee, particularly the over-reliance on Single Occupant Vehicles (SOVs) leading to significant congestion in urban areas. Despite efforts to promote sustainable alternatives through TDM initiatives, there has been a discernible lack of public response and participation. Our study's comprehensive examination of effective TDM strategies from literature and case studies, alongside evaluations of current TDM practices in Tennessee, underscores the need for continuous improvement and innovation in addressing these issues.

5.2 Enhancing TDM Initiatives:

Stakeholder analysis revealed both successes and areas for improvement within Tennessee's TDM initiatives. While some stakeholders have developed strategic plans and shown a willingness to promote alternative transportation modes, gaps such as the absence of long-range strategic plans and regional TDM committees remain. TDM organizations face challenges, including the need for mobile applications and improved data collection practices. Addressing these gaps is essential for refining TDM initiatives and fostering a more coordinated approach to sustainable transportation.

5.3 Effectiveness of Nudging Strategies:

Experimental results demonstrated that nudging strategies provide valuable insights and actionable recommendations for TDOT and other stakeholders to refine and enhance TDM initiatives. By leveraging behavioral psychology and effective nudging techniques, Tennessee can encourage a shift towards more sustainable transportation options. Emotional nudging, normative nudging, and gain nudging each show unique strengths in promoting public transit, with health gain treatments showing the most significant impact on encouraging a modal shift.

5.4 Considering Individual Values and Norms:

This study also highlights the importance of considering individual values and norms when designing policies and communication strategies. The findings emphasize addressing individual beliefs also the prevailing social norms to promote environmentally conscious decision-making. Insights from the study can guide policymakers in crafting targeted interventions that align with individuals' values and aspirations, ensuring a more effective and resonant approach to promoting sustainable transportation options.

5.5 Targeting Specific Demographics:

Demographic factors such as age, race, income, and education play a role in individuals' mode choices. Interestingly, gender did not significantly impact decision-making in the study. Older individuals and higher-income individuals showed a preference for personal cars, while younger individuals indicated potential as target groups for promoting sustainable transportation options. Policymakers should focus on these demographics to maximize the effectiveness of nudging strategies and promote broader adoption of public transit.

5.6 Robust Analysis through Experimental Studies:

The use of experimental studies with randomized groups allowed for a robust analysis of the effects of nudging treatments, providing evidence beyond traditional survey methodologies. This approach enhances our understanding of how information framing can influence policy attitudes and behavior change. Policymakers can draw on insights from behavioral economics to design more efficient and targeted communication strategies, maximizing public receptiveness to sustainable transportation initiatives. By integrating these findings and recommendations, Tennessee can develop more effective TDM strategies that promote sustainable transportation options, alleviate congestion, and enhance mobility across the state.

5.7 Study Limitations and Future Research Directions:

This study, while comprehensive, has certain limitations that must be acknowledged. One primary limitation is the reliance on stated choice data, which, although valuable for understanding preferences and potential behaviors, may not fully capture actual behavior in real-world settings. The hypothetical scenarios presented in the surveys might not translate directly to real-life decision-making, as respondents' choices could be influenced by factors not accounted for in the survey. Additionally, the study's focus on nudging strategies within a controlled experimental framework may not fully encompass the complexities and variabilities of daily commuting decisions. The demographic diversity of the sample, while robust, might not perfectly represent all segments of the Tennessee population, potentially limiting the generalizability of the findings.

Future research should aim to address these limitations by incorporating longitudinal studies and real-world pilot projects that track actual changes in commuter behavior over time. Investigating the long-term impacts of nudging interventions in naturalistic settings would provide a more accurate assessment of their effectiveness. Furthermore, expanding the scope of research to include a broader range of demographic variables and geographic regions would enhance the generalizability of the results. Exploring the interactions between different nudging techniques and their combined effects on various subgroups could yield deeper insights into tailored intervention strategies.

Additionally, future studies could delve into the integration of technological advancements, such as mobile applications and real-time data analytics, to enhance the precision and efficacy of TDM initiatives. By addressing these areas, future research can build on the findings of this study, contributing to the development of more effective and sustainable transportation solutions.

6. References

(18) (PDF) Belief, attitude, intention and behaviour: An introduction to theory and research. (n.d.). Retrieved January 26, 2023, from https://www.researchgate.net/publication/233897090_Belief_attitude_intention_and_behaviour_An_introduction_to_theory_and_research

Adjei, E., & Behrens, R. (2012). *Travel behaviour change theories and experiments: a review and synthesis*.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, *50*(2), 179–211. https://doi.org/10.1016/0749-5978(91)90020-T

Alta Planning. (2018). *Applying Behavioural Insights to Transportation Demand Management*.

Anable, J. (2005). 'Complacent Car Addicts' or 'Aspiring Environmentalists'? Identifying travel behaviour segments using attitude theory. *Transport Policy*, *12*(1), 65–78. https://doi.org/10.1016/J.TRANPOL.2004.11.004

Applying Behavioural Insights to Transportation Demand Management A report by Alta Planning + Design and the Behavioural Insights Team (BIT). (n.d.).

Arnott, B., Rehackova, L., Errington, L., Sniehotta, F. F., Roberts, J., & Araujo-Soares, V. (2014). Efficacy of behavioural interventions for transport behaviour change: Systematic review, meta-analysis and intervention coding. *International Journal of Behavioral Nutrition and Physical Activity*, *11*(1), 1–23. https://doi.org/10.1186/S12966-014-0133-9/TABLES/8

Avineri, E. (2012). On the use and potential of behavioural economics from the perspective of transport and climate change. *Journal of Transport Geography*, *24*, 512–521. https://doi.org/10.1016/J.JTRANGEO.2012.03.003

Bamberg, S. (2006). Is a Residential Relocation a Good Opportunity to Change People's Travel Behavior? Results From a Theory-Driven Intervention Study. *Environment and Behavior*, *38*(6), 820–840. https://doi.org/10.1177/0013916505285091

Bamberg, S. (2013a). Applying the stage model of self-regulated behavioral change in a car use reduction intervention. *Journal of Environmental Psychology*, *33*, 68–75. https://doi.org/10.1016/J.JENVP.2012.10.001

Bamberg, S. (2013b). Applying the stage model of self-regulated behavioral change in a car use reduction intervention. *Journal of Environmental Psychology*, *33*, 68–75. https://doi.org/10.1016/j.jenvp.2012.10.001

Bamberg, S., Fujii, S., Friman, M., & Gärling, T. (2011). Behaviour theory and soft transport policy measures. *Transport Policy*, *18*(1), 228–235. https://doi.org/10.1016/J.TRANPOL.2010.08.006

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, *27*(1), 14–25. https://doi.org/10.1016/j.jenvp.2006.12.002

Barr, S., Shaw, G., & Coles, T. (2011). Times for (Un)sustainability? Challenges and opportunities for developing behaviour change policy. A case-study of consumers at home and away. *Global Environmental Change*, *21*(4), 1234–1244. https://doi.org/10.1016/J.GLOENVCHA.2011.07.011

Bauer, J., Bedsole, L. K., Snyder, K., Neuner, M., & Smith, M. C. (2018). *Expanding Traveler Choices through the Use of Incentives: A Compendium of Examples*.

Beale, J. R., & Bonsall, P. W. (2007a). Marketing in the bus industry: A psychological interpretation of some attitudinal and behavioural outcomes. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10*(4), 271–287. https://doi.org/10.1016/J.TRF.2006.11.001

Beale, J. R., & Bonsall, P. W. (2007b). Marketing in the bus industry: A psychological interpretation of some attitudinal and behavioural outcomes. *Transportation Research Part F: Traffic Psychology and Behaviour*, *10*(4), 271–287. https://doi.org/10.1016/j.trf.2006.11.001

Becker, G. S. (1976). *The Economic Approach to Human Behavior. Chicago University Press: Chicago*. 314.

Brazil, W., Kallbekken, S., Sælen, H., & Carroll, J. (2019). The role of fuel cost information in new car sales. *Transportation Research Part D: Transport and Environment*, *74*, 93–103. https://doi.org/10.1016/J.TRD.2019.07.022

Brög, W., Erl, E., Ker, I., Ryle, J., & Wall, R. (2009). Evaluation of voluntary travel behaviour change: Experiences from three continents. *Transport Policy*, *16*(6), 281–292. https://doi.org/10.1016/J.TRANPOL.2009.10.003

Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A., & Goodwin, P. (2008a). Smarter Choices: Assessing the Potential to Achieve Traffic Reduction Using 'Soft Measures".' *Transport Reviews*, *28*(5), 593–618. https://doi.org/10.1080/01441640801892504

Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A., & Goodwin, P. (2008b). Smarter Choices: Assessing the Potential to Achieve Traffic Reduction Using 'Soft Measures.'

Http://Dx.Doi.Org/10.1080/01441640801892504, *28*(5), 593–618. https://doi.org/10.1080/01441640801892504

Chatterjee, K., Chng, S., Clark, B., Davis, A., De Vos, J., Ettema, D., Handy, S., Martin, A., & Reardon, L. (2019). Commuting and wellbeing: a critical overview of the literature with implications for policy and future research. *Https://Doi.Org/10.1080/01441647.2019.1649317*, *40*(1), 5–34. https://doi.org/10.1080/01441647.2019.1649317

Cochran, W. G. (1977). *Sampling techniques*. John Wiley & Sons, Ltd.

Crim, S., McMahon, M., & LDA Consulting and Simple Solutions Planning and Design LLC. (2016). *OFFICE BUILDING STUDY: Analysis of 16 Transportation Performance Monitoring Studies in Arlington's Rosslyn-Ballston Corridor, June 2016*.

Daziano, R. (2018). Increasing the influence of CO2 emissions information on car purchases. *Charging and Infrastructure Symposium 2018, Held at AABC Europe 2018*, 81–93.

De Groot, J. I. M., & Steg, L. (2009). Morality and Prosocial Behavior: The Role of Awareness, Responsibility, and Norms in the Norm Activation Model. *The Journal of Social Psychology*, *149*(4), 425–449. https://doi.org/10.3200/SOCP.149.4.425-449

Derefeldt, G., Swartling, T., … U. B.-C. R. &, & 2004, undefined. (2004). Cognitive color. *Wiley Online Library*, *29*(1), 7–19. https://doi.org/10.1002/col.10209

Donald, I. J., Cooper, S. R., & Conchie, S. M. (2014). An extended theory of planned behaviour model of the psychological factors affecting commuters' transport mode use. *Journal of Environmental Psychology*, *40*, 39–48. https://doi.org/10.1016/j.jenvp.2014.03.003

EDRG. (2020). *Economic Impact of Public Transportation Investment, 2020 Update*.

Elliot, A. J. (2015). Color and psychological functioning: A review of theoretical and empirical work. *Frontiers in Psychology*, *6*(APR). https://doi.org/10.3389/FPSYG.2015.00368/FULL

Energy Technology Perspectives 2017 – Analysis - IEA. (n.d.). Retrieved January 25, 2023, from https://www.iea.org/reports/energy-technology-perspectives-2017

Eriksson, L., Garvill, J., & Nordlund, A. M. (2006). Acceptability of travel demand management measures: The importance of problem awareness, personal norm, freedom, and fairness. *Journal of Environmental Psychology*, *26*(1), 15–26. https://doi.org/10.1016/j.jenvp.2006.05.003

Esfahani, M. D., Nilashi, M., Rahman, A. A., Ghapanchi, A. H., & Zakaria, N. H. (2015). Psychological Factors Influencing the Managers' Intention to Adopt Green IS.

International Journal of Strategic Decision Sciences, *6*(2), 28–56. https://doi.org/10.4018/ijsds.2015040103

Esztergár-Kiss, D., Shulha, Y., Aba, A., & Tettamanti, T. (2021). Promoting sustainable mode choice for commuting supported by persuasive strategies. *Sustainable Cities and Society*, *74*, 103264. https://doi.org/10.1016/j.scs.2021.103264

Finucane, M. L., Alhakami, A., Slovic, P., & Johnson, S. M. (2000). The affect heuristic in judgments of risks and benefits. *Journal of Behavioral Decision Making*, *13*(1), 1–17. https://doi.org/10.1002/(SICI)1099-0771(200001/03)13:1<1::AID-BDM333>3.0.CO;2-S

Fishbein & Ajzen (1975). (n.d.). Retrieved January 26, 2023, from https://people.umass.edu/aizen/f&a1975.html

Franssens, S., Botchway, E., de Swart, W., & Dewitte, S. (2021). Nudging Commuters to Increase Public Transport Use: A Field Experiment in Rotterdam. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.633865

Friman, M., & Fellesson, M. (2009). Service Supply and Customer Satisfaction in Public Transportation: The Quality Paradox. *Journal of Public Transportation*, *12*(4), 57–69. https://doi.org/10.5038/2375-0901.12.4.4

Friman, M., & Gärling, T. (2001). Frequency of negative critical incidents and satisfaction with public transport services. II. *Journal of Retailing and Consumer Services*, *8*(2), 105–114. https://doi.org/10.1016/S0969-6989(00)00004-7

Fujii, S., Bamberg, S., Friman, M., & Gärling, T. (2009). Are effects of travel feedback programs correctly assessed? *Http://Dx.Doi.Org/10.1080/18128600802591277*, *5*(1), 43–57. https://doi.org/10.1080/18128600802591277

Fujii, S., & Kitamura, R. (2003). What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation*, *30*, 81–95. https://doi.org/10.1023/A:1021234607980

Fujii, S., & Taniguchi, A. (2005a). Reducing family car-use by providing travel advice or requesting behavioral plans: An experimental analysis of travel feedback programs. *Transportation Research Part D: Transport and Environment*, *10*(5), 385–393. https://doi.org/10.1016/J.TRD.2005.04.010

Fujii, S., & Taniguchi, A. (2005b). Reducing family car-use by providing travel advice or requesting behavioral plans: An experimental analysis of travel feedback programs. *Transportation Research Part D: Transport and Environment*, *10*(5), 385–393. https://doi.org/10.1016/j.trd.2005.04.010

Garcia-Sierra, M., van den Bergh, J. C. J. M., & Miralles-Guasch, C. (2015). Behavioural economics, travel behaviour and environmental-transport policy. *Transportation Research Part D: Transport and Environment*, *41*(December), 288–305. https://doi.org/10.1016/J.TRD.2015.09.023

Gärling, T., Eek, D., Loukopoulos, P., Fujii, S., Johansson-Stenman, O., Kitamura, R., Pendyala, R., & Vilhelmson, B. (2002). A conceptual analysis of the impact of travel demand management on private car use. *Transport Policy*, *9*(1), 59–70.

Gärling, T., Fujii, S., & Boe, O. (2001). Empirical tests of a model of determinants of script-based driving choice. *Transportation Research Part F: Traffic Psychology and Behaviour*, *4*(2), 89–102. https://doi.org/10.1016/S1369-8478(01)00016-X

Graham-Rowe, E., Skippon, S., Gardner, B., & Abraham, C. (2011). Can we reduce car use and, if so, how? A review of available evidence. *Transportation Research Part A: Policy and Practice*, *45*(5), 401–418. https://doi.org/10.1016/j.tra.2011.02.001

Haynes, L., Service, O., Goldacre, B., & Torgerson, D. (2012). Test, Learn, Adapt: Developing Public Policy with Randomised Controlled Trials. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2131581

Hilbrecht, M., Smale, B., & Mock, S. E. (2014). Highway to health? Commute time and well-being among Canadian adults. *Https://Doi.Org/10.1080/16078055.2014.903723*, *56*(2), 151–163. https://doi.org/10.1080/16078055.2014.903723

Hoehner, C. M., Barlow, C. E., Allen, P., & Schootman, M. (2012). Commuting distance, cardiorespiratory fitness, and metabolic risk. *American Journal of Preventive Medicine*, *42*(6), 571–578. https://doi.org/10.1016/J.AMEPRE.2012.02.020

Jansson, J., Nordlund, A., & Westin, K. (2017). Examining drivers of sustainable consumption: The influence of norms and opinion leadership on electric vehicle adoption in Sweden. *Journal of Cleaner Production*, *154*, 176–187. https://doi.org/10.1016/j.jclepro.2017.03.186

Kahneman, D., Tversky, A., Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, *47*(2), 263–291.

Kane, J. V., & Barabas, J. (2019). No Harm in Checking: Using Factual Manipulation Checks to Assess Attentiveness in Experiments. *American Journal of Political Science*, *63*(1), 234–249. https://doi.org/10.1111/ajps.12396

Kauppinen-Räisänen, H., & Luomala, H. T. (2010). Exploring consumers' product-specific colour meanings. *Qualitative Market Research*, *13*(3), 287–308. https://doi.org/10.1108/13522751011053644/FULL/HTML

Kazhamiakin, R., Marconi, A., Perillo, M., Pistore, M., Valetto, G., Piras, L., Avesani, F., & Perri, N. (2015). Using gamification to incentivize sustainable urban mobility. *2015 IEEE First International Smart Cities Conference (ISC2)*, 1–6. https://doi.org/10.1109/ISC2.2015.7366196

KCATA. (n.d.). *Environmental Benefits of Public Transit | The Environment | About KCATA | KCATA*. https://www.kcata.org/about_kcata/entries/environmental_benefits_of_public_transit#:~:text=A single person who switches,adult%2C two-car household.

Kormos, C., Sussman, R., & Rosenberg, B. (n.d.). How cities can apply behavioral science to promote public transportation use. *Behavioral Science & Policy*, *7*(1), 95–115.

Kristal, A. S., & Whillans, A. v. (2019). What we can learn from five naturalistic field experiments that failed to shift commuter behaviour. *Nature Human Behaviour 2019 4:2*, *4*(2), 169–176. https://doi.org/10.1038/s41562-019-0795-z

Lane, B., & Potter, S. (2007). The adoption of cleaner vehicles in the UK: exploring the consumer attitude–action gap. *Journal of Cleaner Production*, *15*(11–12), 1085–1092. https://doi.org/10.1016/j.jclepro.2006.05.026

Lee, C., Winters, P., Pino, J., & Schultz, D. (2013a). *Improving the Cost Effectiveness of Financial Incentives in Managing Travel Demand Management (TDM)*.

Lee, C., Winters, P., Pino, J., & Schultz, D. (2013b). *Improving the Cost Effectiveness of Financial Incentives in Managing Travel Demand Management (TDM)*.

Lindenberg, S., & Steg, L. (2007). Normative, Gain and Hedonic Goal Frames Guiding Environmental Behavior. *Journal of Social Issues*, *63*(1), 117–137. https://doi.org/10.1111/j.1540-4560.2007.00499.x

Maki, A., Burns, R. J., Ha, L., & Rothman, A. J. (2016). Paying people to protect the environment: A meta-analysis of financial incentive interventions to promote proenvironmental behaviors. *Journal of Environmental Psychology*, *47*, 242–255. https://doi.org/10.1016/J.JENVP.2016.07.006

MAURO FERMARIELLO, & SCIENCE PHOTO LIBRARY. (n.d.). *Child by roadside wearing air pollution face mask*. Https://Www.Sciencephoto.Com/Media/183436/View/Child-by-Roadside-Wearing-Air-Pollution-Face-Mask.

Merlin, L. A., Freeman, K., Renne, J., & Hoermann, S. (2022). Clustered randomized controlled trial protocol of a Mobility-as-a-Service app for College campuses. *Transportation Research Interdisciplinary Perspectives*, *14*, 100572. https://doi.org/10.1016/j.trip.2022.100572

Milfont, T. L., Sibley, C. G., & Duckitt, J. (2010). Testing the Moderating Role of the Components of Norm Activation on the Relationship Between Values and Environmental Behavior. *Journal of Cross-Cultural Psychology*, *41*(1), 124–131. https://doi.org/10.1177/0022022109350506

Modal Shift in the Boulder Valley: 1990-2018. (2019a).

Modal Shift in the Boulder Valley: 1990-2018. (2019b).

Models of man: social and rational; mathematical essays on rational human behavior in society setting | WorldCat.org. (n.d.). Retrieved January 26, 2023, from https://www.worldcat.org/title/models-of-man-social-and-rational-mathematical-essays-on-rational-human-behavior-in-society-setting/oclc/165735

Morton, R. B., & Williams, K. C. (2010). *Experimental Political Science and the Study of Causality*. Cambridge University Press. https://doi.org/10.1017/CBO9780511762888

Möser, G., & Bamberg, S. (2008). The effectiveness of soft transport policy measures: A critical assessment and meta-analysis of empirical evidence. *Journal of Environmental Psychology*, *28*(1), 10–26. https://doi.org/10.1016/J.JENVP.2007.09.001

Nayum, A., & Klöckner, C. A. (2014). A comprehensive socio-psychological approach to car type choice. *Journal of Environmental Psychology*, *40*, 401–411. https://doi.org/10.1016/j.jenvp.2014.10.001

Nelson/Nygaard Consulting Associates Inc. (2018). *Arlington County Residential Building Study*.

Nordlund, A. M., & Garvill, J. (2002). Value Structures behind Proenvironmental Behavior. *Environment and Behavior*, *34*(6), 740–756. https://doi.org/10.1177/001391602237244

Nordlund, A., & Westin, K. (2013). Influence of values, beliefs, and age on intention to travel by a new railway line under construction in northern Sweden. *Transportation Research Part A: Policy and Practice*, *48*, 86–95. https://doi.org/10.1016/j.tra.2012.10.008

Ogilvie, D., Foster, C. E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C. F., & Mutrie, N. (2007). Interventions to promote walking: systematic review. *BMJ*, *334*(7605), 1204. https://doi.org/10.1136/bmj.39198.722720.BE

Ozaki, R., & Sevastyanova, K. (2011). Going hybrid: An analysis of consumer purchase motivations. *Energy Policy*, *39*(5), 2217–2227. https://doi.org/10.1016/j.enpol.2010.04.024

Pedersen, T., Friman, M., & Kristensson, P. (2011). Affective Forecasting: Predicting and Experiencing Satisfaction With Public Transportation1. *Journal of Applied Social Psychology*, *41*(8), 1926–1946. https://doi.org/10.1111/j.1559-1816.2011.00789.x

Pedersen, T., Kristensson, P., & Friman, M. (2012). Counteracting the focusing illusion: Effects of defocusing on car users' predicted satisfaction with public transport. *Journal of Environmental Psychology*, *32*(1), 30–36. https://doi.org/10.1016/j.jenvp.2011.10.004

Petrunoff, N., Rissel, C., Wen, L. M., & Martin, J. (2015). Carrots and sticks vs carrots: Comparing approaches to workplace travel plans using disincentives for driving and incentives for active travel. *Journal of Transport & Health*, *2*(4), 563–567. https://doi.org/10.1016/j.jth.2015.06.007

Public Transportation Facts - American Public Transportation Association. (n.d.). Retrieved January 25, 2023, from https://www.apta.com/news-publications/public-transportation-facts/

Richter, J., Friman, M., & Gärling, T. (2010). *Environmental Social Science Series Transportation: Theory and Application Review of Evaluations of Soft Transport Policy Measures*. *2*(1).

Schuitema, G., Steg, L., & Forward, S. (2010). Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm. *Transportation Research Part A: Policy and Practice*, *44*(2), 99–109. https://doi.org/10.1016/j.tra.2009.11.005

Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms: Research article. *Psychological Science*, *18*(5), 429–434. https://doi.org/10.1111/J.1467-9280.2007.01917.X

Schwartz, S. H. (1992). *Universals in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 Countries* (pp. 1–65). https://doi.org/10.1016/S0065-2601(08)60281-6

Simićević, J., Vukanović, S., & Milosavljević, N. (2013). The effect of parking charges and time limit to car usage and parking behaviour. *Transport Policy*, *30*, 125–131. https://doi.org/10.1016/j.tranpol.2013.09.007

Steg, L., Bolderdijk, J. W., Keizer, K., & Perlaviciute, G. (2014). An Integrated Framework for Encouraging Pro-environmental Behaviour: The role of values, situational factors and goals. *Journal of Environmental Psychology*, *38*, 104–115. https://doi.org/10.1016/j.jenvp.2014.01.002

Steg, L., Perlaviciute, G., van der Werff, E., & Lurvink, J. (2014). The Significance of Hedonic Values for Environmentally Relevant Attitudes, Preferences, and Actions. *Environment and Behavior*, *46*(2), 163–192. https://doi.org/10.1177/0013916512454730

Steg, L., & Vlek, C. (2009a). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, *29*(3), 309–317. https://doi.org/10.1016/J.JENVP.2008.10.004

Steg, L., & Vlek, C. (2009b). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, *29*(3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004

Stern, P., Dietz, T., Abel, T., Guagnano, G., & Kalof, L. (1999). A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism. *Human Ecology Review*, *6*(2).

Sussman, R., Tan, L. Q., & Kormos, C. E. (2020). Behavioral interventions for sustainable transportation: an overview of programs and guide for practitioners. *Transport and Energy Research: A Behavioral Perspective*, 315–371. https://doi.org/10.1016/B978-0-12-815965-1.00014-4

Taniguchi, A., & Fujii, S. (2007). Promoting Public Transport Using Marketing Techniques in Mobility Management and Verifying their Quantitative Effects. *Transportation*, *34*(1), 37–49. https://doi.org/10.1007/s11116-006-0003-7

Taniguchi, A., Suzuki, H., & Fujii, S. (2007). Mobility Management in Japan. *Https://Doi.Org/10.3141/2021-12*, *2021*, 100–109. https://doi.org/10.3141/2021-12

Trudel, R. (2019). Sustainable consumer behavior. *Consumer Psychology Review*, *2*(1), 85–96.

Valdez, P., & Mehrabian, A. (1994). Effects of Color on Emotions. *Journal of Experimental Psychology: General*, *123*(4), 394–409. https://doi.org/10.1037/0096-3445.123.4.394

Victoria Transport Policy Institute. (n.d.). Https://Www.Vtpi.Org/Tca/.

Wang, B., Waygood, E. O. D., Daziano, R. A., Patterson, Z., & Feinberg, M. (2021). Does hedonic framing improve people's willingness-to-pay for vehicle greenhouse gas emissions? *Transportation Research Part D: Transport and Environment*, *98*, 102973. https://doi.org/10.1016/j.trd.2021.102973

Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. *Transportation Research Part A: Policy and Practice*, *45*(8), 839–848. https://doi.org/10.1016/j.tra.2011.06.010

Wener, R. E., & Evans, G. W. (2011). Comparing stress of car and train commuters. *Transportation Research Part F: Traffic Psychology and Behaviour*, *14*(2), 111–116. https://doi.org/10.1016/J.TRF.2010.11.008

Westin, K., Nordlund, A., Jansson, J., & Nilsson, J. (2020). Goal Framing as a Tool for Changing People's Car Travel Behavior in Sweden. *Sustainability*, *12*(9), 3695. https://doi.org/10.3390/su12093695

Whillans, A., Sherlock, J., Roberts, J., O'Flaherty, S., Gavin, L., Dykstra, H., & Daly, M. (2021). Nudging the Commute: Using Behaviorally-Informed Interventions to Promote Sustainable Transportation. *BEHAVIORAL SCIENCE & POLICY (In Press)*.

White, K., Habib, R., & Hardisty, D. J. (2019). How to SHIFT consumer behaviors to be more sustainable: A literature review and guiding framework. *Journal of Marketing*, *83*(3), 22–49. https://doi.org/10.1177/0022242919825649/SUPPL_FILE/DS_10.1177_0022242919825649.DOCX

Yang, L., Sahlqvist, S., McMinn, A., Griffin, S. J., & Ogilvie, D. (2010). Interventions to promote cycling: systematic review. *BMJ*, *341*(oct18 2), c5293–c5293. https://doi.org/10.1136/bmj.c5293

Zhu, C., Yue, J. S., Mandayam, C. V., Merugu, D., Abadi, H. K., & Prabhakar, B. (2015). Reducing Road Congestion Through Incentives: A Case Study. *Transportation Research Board 94th Annual Meeting, Washington, D.C*.