HIGH-SPEED RAIL IN THE U.S. – MODE CHOICE DECISION AND IMPACT OF COVID-19

FINAL REPORT

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16. Abstract

While high-speed rail (HSR) has achieved success in major cities in Europe and Asia, it is a new phenomenon in the US, and few studies on HSR in the US are available, especially from the users' perspective. This study aims to fill the research gap by investigating the mode choice behavior in the Los Angeles and San Francisco corridor, where HSR may soon become a feasible option. The impact of COVID-19 was examined regarding how people view modes of domestic travel and how their views may change. The geographic locations of travelers and the possible HSR characteristics in the US were also explored. In addition, this study explored the meaningful segmentation of travelers, using transport culture, HSR prices, travel time, safety, and comfort jointly as the cluster variates. Survey data of US travelers was collected on MTurk, which was analyzed using logistics regression and two-way MANOVA. The results indicated that convenience in transport, travel frequency, income, gender, mobility issues, and total travel time were determinants in the choice between HSR and air service, while travel frequency and total travel time were important in the choice between HSR and car. Most US travelers changed their views following COVID-19 regarding domestic travel and exhibited a higher intention to travel by trains and HSR.

Geographic patterns were identified, such as people in the southern US were the most knowledgeable of HSR and had the greatest intention to use HSR, while people in the northeast exhibited the lowest intention. Four HSR user segments were identified, including Balanced, Comfort First, Price Sensitive, and Traditional Traveler segments, each with different characteristics regarding the use of HSR in the US. The findings indicate potential interest in HSR among US travelers and offer much-needed empirical evidence for the potential success of HSR in the US.

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Executive Summary

High-speed rail (HSR) is a type of rail transport that operates at significantly higher speeds than conventional rail, often involving specialized trains and dedicated tracks to support fast and efficient travel between major cities or regions. With the maturation of HSR technologies, HSR has succeeded in various countries worldwide, especially in European and Asian countries. In the US, however, HSR is still a new phenomenon, and few studies on HSR in the US are available, especially from the users' perspective. This study aims to fill the research gap by examining potential HSR users in the US, focusing on mode choice behaviors, HSR users' composition, the impact of COVID-19 on how people view modes of domestic travel and how their views may change, and the impact of geographic locations of travelers on the possible HSR use in the US.

This study adopted a non-experimental survey design. A survey instrument was developed to collect data from 1,033 US travelers on Amazon Mechanical Turk (MTurk). The questionnaire was based on the Los Angeles-San Francisco corridor, considering the high travel demand and potential HSR operation in this market. Three questions were used to guide the research in the context of HSR development in the US, including 1) What factors were important in the intermodal choice for domestic travel in a highly competitive market following the introduction of HSR, 2) What is the impact of COVID-19 on HSR use, considering geographic locations of travelers, and 3) What user segments can be identified within the survey data to describe the unique characteristics of potential HSR travelers in the US.

Three sets of statistical analyses were performed to answer the research questions.

In the first analysis, logistic regression was performed, focusing on the effect of seven demographic, travel, and HSR factors (gender, age, income, travel frequency, mobility issue, total travel time, and convenience in transport) on the intermodal decision in the Los Angeles-San Francisco market. Two analyses were conducted, including 1) multinomial logistic regression (MLR) to investigate travelers' choice from air, HSR, and car transport, and 2) binary logit regression (BLR) analyses between air and HSR and between cars and HSR to verify the first analysis due to the small sample size for some mode choice categories. Results indicated that convenience in transport, travel frequency, gender, mobility issues, income, and total travel time were important determinants of choosing between air, HSR, and cars in the Los Angeles-San Francisco market. However, they affected the choice differently due to the specific mode characteristics. Convenience in transport and travel frequency were major factors in the decision between air and HSR, while the choice between cars and HSR was influenced mainly by travel frequency and total travel time.

To answer the second question, a two-way MANOVA was performed to identify the effect of two independent variables (IVs) - view change on mode use for domestic travel following COVID-19 (View_Change) and geographic locations of participants (Geo_Location) - on four travel- and HSR- related dependent variables (DVs) including knowledge of HSR, travel habits, the likelihood of using the train, and the intention to use HSR in the post-pandemic era. Both the main and interaction effects of the two IVs were identified. Most travelers had changed their views about which transport mode to use for domestic travel because of COVID-19, and they were more likely to travel by trains and had a greater intention to use HSR in the post-pandemic era. In addition, travelers from the Northeast region demonstrated significantly less intention to use either trains or HSR than travelers from the southern or western US. Finally, neither change in view nor geographic locations could individually affect the travelers' knowledge level of HSR; instead, the knowledge level is determined by both factors. Travelers from the southern US reported the highest level of HSR knowledge, while travelers from the Northeast and Midwest regions were least knowledgeable of HSR.

The third question was answered by cluster analysis, using hierarchical and non-hierarchical techniques to identify meaningful clusters based on the joint use of five transport and HSR attributes, including consideration of transport culture, price, travel time, safety, and comfort of HSR. Results suggested that the collective use of five HSR and transport attributes allowed for identifying four segments of HSR users, namely Balanced, Comfort First, Price Sensitive, and Traditional Traveler segments. The Balanced group tended to provide a comprehensive evaluation of all five transport and HSR attributes and to strike a balanced view toward using HSR as a new transport mode in the US. The Comfort First group focused almost exclusively on comfort in travel, likely due to mobility issues reported by the members of this segment, among other reasons. The Price Sensitive group attached the greatest importance to HSR prices and was open to accepting HSR as a new addition to the transport system in the US. Lastly, the Traditional Traveler group primarily focused on the air and car culture in the US. Given the unique transport culture in the US, this group is likely to exhibit some doubt about public acceptance of HSR.

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1. RESEARCH INTRODUCTION

In an increasingly interconnected world, the need for efficient, rapid, and sustainable transportation options has become paramount. High-speed rail (HSR) has emerged as a significant contender in addressing this need, mostly in Europe and Asia. HSR combines cutting-edge technologies, infrastructural advancement, and a vision of sustainable mobility, making it a compelling alternative to other modes of transport. The transportation system has become more strained in recent years because of expanding cities and population growth. The US population is expected to surpass 400 million by 2058, with the highest percentage increase expected in the 65 and over age group (Vespa et al., 2018). The rapid increase in population and the aging of the population will require new forms of transportation and innovative solutions that can enhance connectivity, reduce congestion, and minimize environmental impact.

HSR is broadly defined as a railway system with an average commercial speed of 155 mph on newly constructed dedicated HSR lines and 125 miles per hour (mph) on existing upgraded lines (International Union of Railways [UIC], 2018). Japan pioneered HSR with the introduction of the Shinkansen in 1964. With its initial speed of 130 mph, the Shinkansen heralded a new era of rapid rail travel, evolving over the years to reach speeds of 200 mph (Cohen, 2022; Perl & Goetz, 2015). The original Shinkansen line took only 4 hours from Tokyo to Osaka, reducing the previous travel time by 3 hours and 10 minutes. The line transported an average of 60,000 passengers daily in 1964 (Taniguchi, 1993). The success of the Shinkansen line in Japan led to a global expansion of HSR, with countries such as France (TVG), Germany (ICE), South Korea (KTX and SRT), and eventually China constructing their own HSR lines. Over the years, HSR has become faster and more reliable because of technological innovations encompassing aerodynamics, propulsion systems, track design, and materials science. Today, around 35,000 miles of HSR lines are in operation globally, transporting over three billion passengers a year (UIC, 2021). With its extensive HSR network encompassing around two-thirds of global HSR lines, China stands as the frontrunner in HSR development (Cao & Zhu, 2017). The HSR network is constructed out of four horizontal and four vertical lines that create a grid serving 29 of the 33 provinces in China (Li et al., 2019). With trains operating with speeds over 200 mph and high frequencies of operations, the Chinese HSR network was able to transport 2.29 billion passengers in 2019 (Yi et al., 2023).

Despite the successful international experience, HSR has achieved little progress in the US. Currently, Amtrak Acela Express, serving the Northeast Corridor (NEC), is arguably the only HSR in the US. Although the train can reach a maximum speed of 150 mph on some sections, the average speed remains below the HSR criterion due to infrastructure constraints (Amtrak, 2022). New HSR lines will open in the US in the coming years, such as the Miami–Orlando International Airport Brightline and the Los Angeles–San Francisco HSR line. The first part of the Florida Brightline is expected to open in 2023, connecting Orlando International Airport with Miami (High Speed Rail Alliance, n.d.). A further expansion connecting Orlando International Airport with Walt Disney World and Tampa is still in its planning phase. The California High-Speed Rail Authority hopes to operate passenger service between Merced and Bakersfield between 2030 and 2033 (California High-Speed Rail Authority, 2023). Other parts of the line will open in the years after. More HSR lines across the US are still in the planning phase.

Likely due to the low HSR penetration in the US, literature that addresses HSR in the US is almost exclusively at the policy level, focusing primarily on the advantages and disadvantages of HSR development in the country. Opponents of HSR often cite low population density, long distances between major cities, and inadequate investment in rail infrastructure as concerns for the economic viability of HSR in the US (Ashiabor & Wei, 2012). Only a few corridors in the US come near the population density required for the success of HSR. Additionally, due to lower population density compared to other countries with thriving HSR systems, travelers in the US are more likely to need to resort to alternative modes of transportation for starting or completing their journeys. Compared to other countries with HSR, the use of public transit is far behind, implicating the convince of HSR (Kamga, 2015; United States Census Bureau, 2021). Furthermore, the building of HSR lines in the US and other countries has experienced major cost overruns (O’Toole, 2021). Maintenance cost for HSR is higher than conventional rail, making opponents of HSR believe that HSR cannot be financially sustainable without major governmental subsidies. The country's strong car and airplane culture, driven partially by the prevalence of individualism, antistatism, and car-centric transportation policies, is also argued to hinder HSR acceptance in the US (Chen, 2015; Kamga & Yazici, 2014).

However, there has been renewed discussion of HSR in the US recently. Evolving urbanization trends, changing mobility preferences, economic potentials, and environmental imperatives present new opportunities for HSR in the US. The introduction of HSR in the US is poised to foster a more balanced, multimodal transportation system marked by heightened service quality and efficiency. Integrating public transportation with HSR becomes pivotal in creating a mutually reinforcing loop for both modes and overall success in the US (Kamga, 2015).

In the last decade, the population density in the US has increased, showing a clear trend in urbanization (United States Census Bureau, 2022a). Urbanization is most prone in the Southern parts of the US (Bounoua et al., 2018). Younger people leading this trend tend to obtain their driver's licenses later when living in a large city (Foundation for Traffic Safety, 2019). This trend, in combination with the increasing urbanization, causes a decrease in car purchases among young Americans (Thompson & Weismann, 2012). This, coupled with the trend of relocation to urban areas where travelers of different ages can easily find mobility alternatives, may re-stimulate the interest in HSR (Kamga, 2015).

Supporters of HSR state that amid growing environmental concerns, HSR presents itself as a more sustainable alternative to conventional modes of transportation such as cars and airplanes. HSR's efficiency, coupled with the potential to operate on renewable energy sources, holds the promise of reducing greenhouse gas emissions and mitigating the environmental impact of the transportation system (California High-Speed Authority, 2022a; Kamga & Yazici, 2014). An additional benefit of HSR is that HSR can also provide the opportunity to significantly reduce the dependency on foreign oil when HSR uses renewable energy. This transition to domestically generated electricity for powering HSR operations can substantially mitigate the nation's exposure to the volatility of global oil markets. The environmental benefits HSR, however, are not without debate. To reduce emissions produced by the transportation sector, France substituted all domestic flights shorter than 2.5 hours between cities with HSR if HSR connects the two cities. Although it is a step toward a more sustainable transportation sector, the positive effects are up for debate. Shorter flights (shorter than 500 km) account for 27.9% of departures, but only 5.9% of the aviation fuel burned (Dobruszkes, Mattioli, and Mathieu, 2022). It is said that these departures will now be substituted by long-distance flights (more than 4,000 km) that account for 47.0% of the total aviation fuel burned. Furthermore, the construction process of HSR networks has prompted debates regarding their initial carbon footprint and the extent to which emission reductions during operations offset these impacts (Lin et al., 2019; Wang et al., 2022).

HSR’s impact extends beyond infrastructure and sustainability, having the ability to impact the socio-economic landscape of the regions connected to the HSR network. One notable consequence is the bolstering of urban connectivity. By reducing travel times between cities, HSR enhances accessibility and creates closer economic ties between urban centers. It can enhance the knowledge economy caused by significant regional developments and shorter commuting times (Miwa et al., 2022). The largest positive effects of HSR on regional development are found in China. Chen and Haynes (2017) found that HSR in China promoted regional economic convergence and decreased regional economic disparity. In the United Kingdom and France, the introduction of HSR has economically strengthened the capitals of the regions connected to the nation's capital (Chen & Hall, 2012). However, the sub-regions around the region's capital experienced less of this economic growth. The economic growth in the regional capitals is often related to the operations of HSR stations, which often serve as economic activity hubs, attracting businesses and tourism, and fostering job creation (Chen & Hall, 2012). Furthermore, the planning, designing, and building of HSR lines also creates job opportunities for the surrounding communities (Lynch, 2002; Peterman et al., 2009).

Traffic congestion has long plagued major urban centers and key transportation corridors across the US. In major cities such as San Francisco, New York, and Boston, the average peak travel speed has decreased in the past few years (Roy et al., 2020). Road and highway congestion is expected to become even more substantial in and around major cities in the coming decades with the increasing population and the urbanization trend. A similar congestion trend is seen in the aviation sector. With the air traffic numbers per month in 2023 exceeding pre-COVID-19, the relative number of delays has also increased compared to 2019 (Bureau of Transportation Statistics [BTS], 2023a). Because of the capacity of HSR, it can swiftly transport a substantial number of passengers between densely populated areas. HSR caters to intercity and regional travel, making it an attractive alternative for short to medium distances, diverting passengers from overburdened highways, roadways, and airports.

The long-term vision to find an efficient, rapid, and sustainable transportation mode has set the stage for meaningful development of HSR in the US. Encouraging progress has already been made, thanks to recent political and financial commitments to accelerate HSR development. Federal support for HSR dates back to 1965, with the High-Speed Ground Transportation Act of 1965 investing $90 million to develop and demonstrate HSR technologies (Federal Railroad Administration, 2019a). In 2008, President Obama granted $8 billion to intercity rail projects with a priority for HSR (Federal Railroad Administration, 2009). President Biden announced a $66 billion investment in US rail, of which $36 billion is allocated for new intercity passenger rail lines and expansions of existing lines outside the North-East corridor (The White House, 2023). The HSR project in California, for example, has drawn billions of dollars in state and federal investment over the past five years, contributing significantly to the HSR progress and the local economy (California High-Speed Rail Authority, 2021; 2022b; United States Department of Transportation, 2022).

Although most research of HSR in the US has been conducted at the policy level, few studies discuss the user’s choice toward HSR. The current literature has identified factors that underlie the choice of HSR in matured HSR countries, citing travel time and convenience, among others, as the main motivators in the short- and medium-haul markets (Behrens & Pels, 2012; Lee et al., 2016; Valeri, 2014; Yao et al., 2013). Only one early study investigated HSR in the US from the passengers' perspective, but the focus was on the behavioral intention to use HSR rather than on the choice of HSR over alternative transport modes (Gehrt et al., 2007). In the US, the transport market is characterized by well-established car and air services, and travelers' selection of HSR should be understood in the context of intermodal choice, where travelers evaluate all possible transport options. Research focusing on intermodal choice involving HSR is therefore needed in the US to not only fill the research gap but also to provide empirical evidence for HSR development in busy transport corridors.

Another meaningful topic in the research of HSR is the impact of COVID-19. Unlike in some countries where HSR is a well-accepted travel option, HSR has only received limited attention in the US for the last couple of years. In these years, the US, like much of the world, navigated a series of pandemic waves, each characterized by varying intensities of mitigation measures. Mitigation measures such as social distancing, wearing face masks, and the general advice to avoid public transport directly affected the public image of public transport. The initial stage of HSR development in the US means the market entry of HSR could be affected by COVID-19, which fundamentally changed domestic transport and travel behaviors. An important question to ask is whether or not COVID-19 presents an opportunity for the success of HSR. Specifically, do travelers in the US view HSR differently, given their COVID-19 experience, and have the travel- and HSR-related characteristics in the US changed in the post-pandemic era? To bridge the research gaps, this study attempts to answer two research questions: 1) What demographic, travel, and HSR factors are important for travelers to choose HSR over air and car in high-demand markets in the US if HSR becomes a feasible travel option; and 2) Do travelers view domestic travel differently following the COVID-19 pandemic, and if so, does their new view and their habitual residence affect their travel habits, knowledge of HSR, likelihood to use train, and intention to use HSR in the post-pandemic era, and 3) what user segments can be identified within the survey data to describe the unique characteristics of potential HSR travelers in the US.

The remainder of this report is structured as the follows. Section 2 proposes the related studies and factor selection based on the literature review. Section 3 describes the study method, which is followed by the presentation of results in Section 4. Section 5 discusses the findings in relation to the HSR literature. Conclusions, contributions, and policy implications are provided in Section 6.

2. LITERATURE REVIEW

2.1 HSR – A Global Perspective

Since the first HSR operation in 1964, HSR has become a global phenomenon with rapid development, primarily in Europe and Asia (Albalate & Bel, 2012a). The first HSR line was opened in Japan and was called the Shinkansen. With the success of the Shinkansen line, other countries such as France (TGV), Germany (ICE), and South Korea (KTX and SRT) also started building HSR (Albalate & Bel, 2012a). However, despite its relatively delayed initiation, China has surged ahead to become the frontrunner in HSR development, having the largest amount of HSR lines in the world (Zhou & Shen, 2011). Although China opened its first HSR line in 2007, the total HSR mileage in China accounts for nearly two-thirds of the world's HSR lines and is planned to increase further in the coming years to 44,000 mi in 2035 (Cao & Zhu, 2017; Yi et al., 2023). This already extensive network served 2.29 billion passengers in 2019 (Yi et al., 2023).

Throughout the years, countries have upgraded their HSR lines to increase operational speed. Especially in 1980, HSR speed capabilities took a significant leap with dedicated HSR lines, advanced track designs, streamlined trains, and technological advancements. The operational speed of the TVG in France was 124 mph in 1981 and has increased to 200 mph (Momenitabar et al., 2021). Most countries with HSR have lines with speeds above 187 mph. China now operates the fasted trains with an average speed of 217 mph on the Wuhan–Guangzhou line (Albalate & Bel, 2012b).

Besides increases in speeds, these advancements also aimed to improve the efficiency, capacity, and sustainability of HSR. One of these research innovations is magnetic levitation (MAGLEV), which allows the train to use magnetic fields to suspend, glide, and propel onto the track (Qadir et al., 2021). The magnetic field ensures that the train cannot derail, increasing safety. It also eliminates the rolling friction, resulting in more efficient operations and reduced maintenance costs. However, while MAGLEV has a lower operating cost, MAGLEV tracks are more expensive than conventional rail, making this option financially inviable until a solution is found to reduce construction costs (Liu et al., 2015). Furthermore, research has been conducted on application of Artificial Intelligence to HSR (Yin et al., 2020; Zhong et al., 2021). By embracing these innovations, the HSR industry aims to usher in a new era of enhanced convenience, operations, and sustainability.

With the advancements made in HSR, the discussion turns towards the broader context, and a pivotal consideration arises – the prospect of replacing air travel routes with HSR, thereby curbing the environmental impact of the aviation sector. If HSR can replace air transport is highly dependent on the distance and travel time between the two destinations (Givoni, 2006). There are examples of routes of around 185 miles where HSR becomes the primary mode of transport instead of air travel (as was the case between Brussels and Paris). For distances of 625 miles or longer, HSR is no longer a viable alternative to air travel as HSR travel times exceed the travel time of air travel. Between 188 and 625 miles, HSR and air travel are in direct competition. When there is an HSR station at a major hub airport, it is possible to complement air travel with HSR to reach the final destination (Givoni, 2006).

While the discussion of HSR in the US can be traced back to the 1960s, it has yet to materialize into meaningful progress. The federal and state governments have tried to realize HSR in the US by subsidizing HSR initiatives. In 2009, the Obama Administration dedicated $8 billion to HSR development with a proposal to construct 8,600 miles of HSR (Federal Railroad Administration, 2009; Perl & Goetz, 2015). The Biden administration announced $36 billion in grants to improve conventual railways and fund HSR developments (The White House, 2023). State governments like California have invested billions of dollars in realizing HSR projects.

At the time of writing this article, Amtrak's Acela Express connects Washington DC and Boston, averaging 66 mph with a top speed of 150 mph along some parts of the route (Amtrak, 2022; Ashiabor & Wei, 2013). The Acela Express remains the only rail service in the US closest to a functioning HSR service. During the second half of 2023, a part of the Florida Brightline will be operational between Orlando International Airport and Miami (High Speed Rail Alliance, n.d.). Although the train will drive a part of the route with a speed of 125 mph, it does not qualify as HSR as it will drive on a newly constructed line that requires a speed of 155 mph to qualify for HSR. An extension of the Florida Brightline from Orlando International Airport to Tampa is still in the planning phase. California is underway with the construction of the Los Angeles–San Francisco HSR line with an average speed of 200 mph (California High-Speed Rail Authority, 2023). After constructing the first part, the line will be extended South to San Diego. Phase one is expected to be operational between 2030 and 2033 (California High-Speed Rail Authority, 2023). Other HSR routes that are still in their planning phase are the Brightline West (Las

Vegas–Los Angeles), Texas (connecting Houston, Dallas, and Fort Worth), the Southeast line (connecting Atlanta, Savannah, and Charlotte), and the Cascadia line (Portland–Vancouver BC).

HSR has long been a controversial topic in the US due to its unique characteristics. HSR performs the best on short- and medium-distance routes, which typically go through densely populated, high-demand economic centers. Opponents of HSR argue that metropolitan area of this type is uncommon in the US, as cities typically grow in a sprawling pattern in the country and do not have the required population density to make HSR a success (Ashiabor & Wei, 2012; Chen, 2015; Peterman et al., 2009).

Only limited corridors in the US, such as the North-East Corridor and Los Angeles-San Francisco Corridor, have a high enough population density to create a possible success for HSR (Peterman et al., 2009). Because of the lesser population density, it is more likely that passengers will require additional modes of transport to start and complete their travels. Therefore, to make HSR work, HSR must be fully integrated with the broader transportation system where the HSR station functions as a transportation hub (Kamga, 2015). However, transit usage in large US metro areas is well below that of cities in Europe and Asia (Kamga, 2015; United States Census Bureau, 2021).

Another common reason for not favoring HSR is economic viability. HSR often experiences cost overruns no matter the country in which the HSR line is built. This is also the case in California, where the construction cost went up from $63 million per mile to $190 million per mile (O'Toole, 2021). The $190 million per mile estimate is around 17 times the cost of constructing a highway in the exact same location (O'Toole, 2021). In addition, the maintenance cost for HSR is more expensive than conventional rail. The revenue should be able to cover the expenses of operating and maintaining the HSR. However, so far, Amtrak has shown that profitability in rail is difficult in the US, as Amtrak currently has $200 billion in maintenance backlogs (O'Toole, 2021). It can take decades before an HSR line is financially sustainable, and that is if only the projections do not fall short.

A different reason for not favoring HSR is that the US history and government policies stimulate car usage. As the US was mostly built after the rise of the car, the influence of the car can be found in almost all cities. During the construction of cities across the US, few alternative transport modes were implemented (Kamga, 2015). Low gas taxes (on average $0.41 per gallon) in the US also stimulate car usage compared to Europe, where taxes are between $1.55 and $3.25 per gallon (Hoffer, 2023; United States Energy Information Administration, 2023a). The low price of gas and the convenience of car usage caused 87% of all trips in the US to be done by car (BTS, 2017).

Having an HSR alternative will also not necessarily reduce the number of highway users. Because most highway traffic is local, it is estimated that rail improvements only divert 3%–6% of intercity automobile trips to HSR (Peterman et al., 2009). For the HSR planned between Orlando and Tampa in Florida, the planners only expect a 2% reduction in traffic (Peterman et al., 2009). Social norms may also play a role in HSR stagnation in the US. Many American travelers prefer to rely on cars and airplanes for transportation, and cultural factors may influence this preference. This may lead to a lack of interest in exploring alternative travel options, as Chen (2015) noted.

Recent years, however, have seen new opportunities for HSR In the US, driven primarily by rapid urbanization, changing mobility habits, economic potentials, reducing congestion for other modes of transport, and environmental benefits of HSR. The ongoing urbanization in the US results from urban population expansion, a phenomenon witnessed in many countries worldwide (Perl & Goetz, 2015). Currently, 80% of the US population lives in urban areas, with an increase in population density in these urban areas from 2,343 in 2010 to 2,553 people per square mile in 2020 (United States Census Bureau, 2022a). From 2001 to 2011, the US experienced a growth rate of 11% in urbanization, with the Southern and Western parts of the country leading the population growth (Bounoua et al., 2018).

Continuous growth in population, economic activities, and inter-city mobility provide a foundation for HSR success, which in turn can reshape the urban transportation systems (Yin et al., 2015). The past decade in the US has also seen changing mobility patterns. Young and older demographic groups have shown greater interest in settling in urban areas where they can depend less on cars and use public transport more often (Kamga, 2015). This is visible in the trend showing that the younger people who live in large cities obtain their driver's licenses at a later age compared to a decade ago as they prefer alternative transport modes (Foundation for Traffic Safety, 2019). The decline in car usage in metropolitan cities is most substantial in cities with a sound transit system (Kamga, 2015). The success of HSR highly depends on the integration of transit systems. Besides increasing the convenience for passengers using HSR, local transit can feed ridership to HSR. The introduction of HSR can also increase urban density, demand, and the development of new transit systems, creating a mutually beneficial feedback loop (Kamga, 2015). The change in mobility patterns could make HSR a preferred option for these people.

The implementation of HSR also creates economic development. In the short term, the planning, designing, and building of HSR creates jobs. In the long term, it creates maintenance and operating jobs and spurs economic development around the HSR stations. The Californian High-Speed Rail Authority expects that the build of the HSR line will create 160,000 short-term jobs and 450,000 long-term jobs (Peterman et al., 2009). Furthermore, significant regional developments caused by the introduction of HSR can increase the knowledge economy in cities connected and decrease the commute time, therefore increasing the availability of skilled labor (Miwa et al., 2022). The number of tourists traveling between two or more cities also increases with the introduction of HSR (Albalate & Bel, 2012b). Although the number of tourists increases, overnight stays decrease as HSR makes single-day trips more favorable.

Finally, HSR is considered a less polluted way to travel than cars and airplanes. There are different approaches for the propulsion of the trains, and they have different effects on reducing the pollution of HSR. Brightline in Florida will operate with a diesel-electric locomotive that runs on clean biodiesel (Brightline, 2022), while the California HSR is planned to run on fully sustainable solar energy (California High-Speed Rail Authority, 2022a). The build of the HSR is often argued as a very pollutant process that nullifies the emission reduction during the operational lifetime (Lin et al., 2019; Wang et al., 2022). However, current HSR lines are built with a focus on sustainability, offsetting emissions, and Net-Zero Energy goals. The California High-Speed Rail Authority (2022a) estimates to reduce the carbon dioxide emissions between 84 and 102 $MMTCO_2e$ during the 50-year lifetime of the HSR. This is a yearly reduction of between 0.80% and 0.97% of California's total transport CO_2 emissions. The environmental benefits of HSR align with the long-term goal of establishing a sustainable transportation system in the US, which can further promote HSR development.

2.2 The Choice of HSR for Domestic Travel

Much has been studied regarding air-rail competition and coping strategies in the changing transport markets (Albalate et al., 2015; Jiang et al., 2017; Zhang et al., 2017). At the micro level, passenger behaviors in the HSR context have been frequently examined, focusing primarily on the choice between HSR and full-service carriers (FSCs) (Behrens & Pels, 2012;

Pagliara et al., 2012), HSR and low-cost carriers (LCCs) (Chantruthai et al., 2014), and HSR and private cars (Kuo et al., 2013), with findings indicating that travel time, travel cost, convenience, safety, and demographic characteristics, among other factors, were important in passengers' intermodal choices. In this study, respondents were given a scenario of traveling between Los Angeles–San Francisco, a busy corridor potentially served by HSR (UIC, 2021). As HSR remains a new phenomenon in the US, this study selected relevant factors in the context of mode choice based on the HSR literature. Specifically, this study examined whether total travel time, convenience in transport, travel frequency, mobility issues, and traveler demographics would influence travelers' mode choice of air, car, and HSR in the Los Angeles–San Fransisco market. The remainder of Section 2.2. justifies the factor selection for this study.

Travel time is a crucial motivator to choose one transport mode over the other (Garmendia et al., 2012; Koppelman & Wen, 2000; Sinha & Labi, 2007). Studies showed that travel time was essential in increasing HSR ridership and for travelers to choose HSR over other transport modes (Celikkol-Kocak et al., 2017; Lee et al., 2016). In this study, the medium-distance Los Angeles–San Francisco corridor was used as the travel scenario, based on which respondents were asked to choose from air service (1.5 hours airport-to-airport time), HSR (less than 3 hours station-to-station time), and car (about 6 hours) for the trip.

Although time spent in the vehicle is important, it is only reasonable to consider ground access and egress when the impact of travel time is examined (total travel time). Access and egress time are important for an HSR journey, as 35%–55% of the total travel time can be spent towards and from the rail station (Moyano et al., 2018). Access and egress time can differ significantly during the day as it is influenced by traffic congestion and the frequency of public transport (Moyano et al., 2018). Fu et al. (2012) argued that, compared to air service, HSR enjoys an advantage in total travel time because airline passengers often need a much longer time for airport procedures, which can increase the total time these passengers spend on the entire trip. Furthermore, the centrally located rail stations and easy ground access can reduce the total travel time of HSR, bringing benefits to HSR passengers (Fu et al., 2012). Behrens and Pels (2012) show that HSR also has a better on-time performance than air travel. In 2009, the Eurostar between London and Paris had an on-time performance of 95%, compared to British Airways and Air France, which had an on-time performance of 84 and 77%, respectively.

Studies in Europe have shown that total travel time affected the market share of HSR and significantly influenced passengers' choice of HSR (Behrens & Pels, 2012; Valeri, 2014). The total travel time is a more weighing factor for business passengers choosing a transport mode than leisure passengers (Behrens & Pels, 2012; Román et al., 2007).

HSR is typically located near the city center with well-connected surface transport, allowing quick access to the train station (Fu et al., 2012). When looking at the average distance between the city center and an HSR station or airport, HSR stations are often closer. A majority of the HSR stations are located within 10 miles of the city center, while airports are often between 6 and 20 miles (Wang et al., 2015). Reducing the HSR station access and egress time substantially impacts the HSR market share (Givoni & Banister, 2012; Talebian & Zou, 2016). Even when the travel time is faster, HSR becomes less attractive compared to other modes of transport when the station is located outside the city center (Givoni & Banister, 2012).

Compared to station-to-station time, total travel time can better reflect the time-saving benefit of HSR, and the consideration of total travel time can be essential in the US, given its geographic characteristics (Zhao & Yu, 2018). Noticeably, when total travel time is considered, the three transport modes, especially HSR and air service, offer competitive travel time for passenger evaluation. This study thus included total travel time as a predictor of the intermodal choice in the Los Angeles–San Francisco market.

The convenience of using HSR can increase passenger satisfaction and influence the decision to choose HSR (Chan & Yuan, 2017). Studies showed that travelers might be more concerned about convenience, reliability, and door-to-door time than station-to-station time in deciding to use HSR (Givoni & Banister, 2012). Similar findings were made in the US, suggesting that the growth in ridership of Amtrak may be partially driven by convenience in train transport (Kamga, 2015).

As convenience is such an important parameter, it is said that it would be more effective to increase HSR ridership by improving accessibility to and from the stations than by improving HSR travel times (Moyano et al., 2018). To improve accessibility for passengers, the HSR station must function as a hub for different types of transport to reduce the access and egress time (Nash, 2015). HSR can also serve as an access mode for air travel when connected to large hub airports. When rail and air travel are fully integrated, HSR can even complement air travel instead of competing with it by carrying out some routes, increasing passenger convenience (Givoni & Banister, 2007). This is already done in some European countries, such as in Germany at Frankfurt International Airport in Germany, where Lufthansa offers a rail substitute to Stuttgart and Cologne (Sharp, 2003). The integration of rail and air travel can be beneficial for both the airport and the train operator. Rail can relieve congestion around and at the airport, while hub airports create enough demand for rail to make the airport a viable stop along the route (Givoni & Banister, 2007).

The convenience of using train transport stands in sharp contrast to the mixed experience in air travel. As air travel has been increasingly affected by inconvenient airport access, traffic congestion, and tightened security at airports, airlines may lose passengers to other transport modes, including HSR (Kamga, 2015). On the other hand, car usage has the most considerable convenience in that the car is often located close to the passenger, making the access and egress time the smallest of all modes of transport. The convenience of car usage can be reduced if there is congestion along the route or the passenger must search for a parking spot at the destination, increasing the total travel time (Kowalski, 2023). Because of the potential influence of convenience on HSR ridership, this study thus added convenience in transport to the study model.

Traveler demographics and travel characteristics were added to the model, given their possible influence on the mode choice decision. Studies show that demographic characteristics such as gender, income, and education can determine the choice of HSR (Chan & Yuan, 2017; Chantruthai et al., 2014; Jing et al., 2014). Gender appears to be a particularly relevant factor in the selection of transport modes. Bhat (1998) concluded that females are more likely to use common carriers, especially trains, as a mode of transportation over air travel than males. Similar results were found by Ren et al. (2019) and Shakibaei et al. (2021), who concluded that females are more likely to use public transportation, including rail and HSR, compared to their male counterparts. However, different results were found by Hong and Najmi (2022) and Su et al. (2019), who concluded males more often use HSR over air travel than females. Regarding car usage, Shakibaei et al. (2021) concluded that males use private vehicles significantly more than females.

The visible trend within the age demographic can also benefit HSR operations. The number of younger people with driver's licenses living in the city has decreased during the past decade, which increased the use of alternative transport (Foundation for Traffic Safety, 2019). Su et al. (2019) found that in the age range of 18 to 29, there is no big difference between the preference for HSR or air travel, while for the age range between 30 and 39, people prefer air travel over HSR. People over 40, however, prefer HSR over air travel (Su et al., 2019).

Income can also influence transport mode choice. Mid- to high-income travelers tend to choose air travel over HSR, while lower-income travelers will use HSR over air travel (Dargay & Clark, 2012; Llorca et al., 2018). Paulley et al. (2006) also found a strong positive correlation between income and car ownership and a strong negative correlation between car ownership and rail demand. This can be explained by the fact that people with a higher income often own a private vehicle, creating an alternative mode of transport. Higher-income travelers who already use rail as a mode of transport are more likely to switch to using HSR than lower-income travelers (Mahardika et al., 2022). Lower-income travelers will keep using existing train connections due to lower fares. Mahardika et al. (2022) also state that providing a high level of service is crucial to ensure that people with a higher income are willing to use HSR.

Finally, the passengers' educational level can influence the transport mode choice. It was found that cities with a higher student population see an increase in the use of all modes of transport except cars (Santos et al., 2013). Dobruszkes et al. (2022) show that there are relatively more people with a university degree using HSR compared to the share of people with a university degree in the population.

Travel frequency is often a determinant of intermodal choice (Nurhidayat et al., 2023; Zhang et al., 2017; Zhang et al., 2019). It was found that increasing the frequency of HSR can make HSR more favorable compared to air travel for routes up to 4 hours (Li et al., 2019). The increased frequency of HSR is only viable when there is enough demand (Albalate et al., 2015). Airlines will try to increase the frequency of routes served by HSR to compete with the higher frequency that HSR can operate at. However, airlines will stop servicing these routes when the frequency is limited by, for example, slot allocations at an airport (Dobruszkes, 2011). Business travelers prefer a higher frequency, as this gives them more flexibility (Pagliara et al., 2012). Hong and Najmi (2022) showed that the frequency of operations is a significant attribute for passengers choosing between HSR and air travel. Leisure passengers give less importance to frequency (Behrens & Pels, 2012). This aligns with the general belief that leisure passengers value time less than business passengers (Adler et al., 2010; Behrens & Pels, 2012).

However, the impact of travel frequency on the mode decision involving HSR and car has not been fully investigated. If the passenger owns a car, car usage is not subjected to frequency limitation, as is HSR and air travel. Frequency is an interesting predictor for the mode choice behavior in this study and is therefore added to the model.

A factor that can be important in HSR use in the US is the mobility issue of travelers, given that one in four adults in the United States has some type of disability (Centers for Disease Control and Prevention [CDC], 2020). Around 30% of people with disabilities have a travel-limiting disability, of which 14% do not leave their homes at all because of their disability (BTS, 2022a). It is likely that travelers who are disabled or have limited mobility may prefer certain types of transport modes. The primary mode of transport for people with a disability is their own personal vehicle, either as a driver or as a passenger, attributing to 74.8% of the trips (BTS, 2022a). Recent studies showed that disabled people are more likely to use buses and taxis, whereas non-disabled people use rail more often (Mackett, 2021). Schmöcker et al. (2008) concluded that the preference for taxi use increases with the increasing age of disabled people. One of the reasons for a lower share of rail by disabled people is the lack of accessibility. Disabled people, even after the passage of the Americans With Disabilities ACT in 1990, reported inaccessible stations and train cars, no level-entry boarding, problems with reservations, and a lack of dual-mode communication (National Council on Disability, 2015). For longer distances, disabled people may prefer air travel over trains. With an aging population and the increase in people with a disability, the mobility issue predictor was added to the model.

2.3 HSR and the Impact of COVID-19

The COVID-19 pandemic has had a profound impact on the transport industry. The World Health Organization (WHO) declared COVID-19 a global pandemic on March 11, 2020, ending the global Public Health Emergency on May 5, 2023 (Pfizer, 2023; WHO, 2020). During these three years, the federal government and state governments in the US have used different intensity measures to reduce the spread of COVID-19. These measures have come in waves following the mutation of the COVID-19 virus and the number of infected people. One of the first measures in the US was a travel ban for non-US citizens from China and Europe (CDC, 2023). This was followed by the implementation of wearing face masks in public, social distancing, school closings, and workplace shutdowns.

During the COVID-19 pandemic, significant emphasis has been placed on understanding its economic implications. Moreover, researchers have increasingly recognized the behavioral shifts in transport due to the pandemic. These shifts include travel avoidance (Morar et al., 2021), bus-users compliance with COVID-19 measures (Dzisi & Dei, 2020), mask-wearing behaviors onboard airplanes (Pan & Liu, 2022), and transport mode shifts (Abdullah et al., 2020; Meister et al., 2022).

Viruses causing diseases such as COVID-19 are highly contagious and can spread through respiratory fluids (United States Environmental Protection Agency, 2023). The fact that a person can be infected through respiratory fluids increases the chance of infection in crowded places such as train stations, airports, and public transport. A significant relationship is found between the use of public transport and the spread of the COVID-19 virus (Ando et al., 2021). Gaskin et al. (2021) found that a percentage point increase in public transport to get to work in a county increases the number of COVID-19 cases by a factor of 1.056 and the number of COVID-19 deaths by 1.096 compared to working from home. Also, the frequency of air travel and HSR are significantly associated with the speed of the COVID-19 spread at the destination (Zhang et al., 2020).

Because of the higher risk of COVID-19 infection in public transport, many governments advised against using public transport. In the US, companies were advised to incentivize employees to minimize contact with others (CDC, 2021). In the Netherlands, the government advised minimizing the use of public transport (Rijksoverheid, n.d.). In the United Kingdom, people were advised to avoid public transport (United Kingdom Department of Transportation, 2020). The higher risk for contamination and the discouragement of public transportation led to a major decline in ridership.

During the COVID-19 pandemic, the number of trips taken, both leisure and work-related, reduced. In the US, Canada, Europe, China, South Korea, and Japan, public activities such as school, cultural and sports events, amusement, and restaurants were prohibited or closed (Zhang et al., 2021). Furthermore, shopping was restricted to the absolute necessities. In the Netherlands, 80% of the people reduced their outdoor activities, and the number of trips and distances decreased by 55 and 68%, respectively (Haas et al., 2020). In Istanbul, social, recreational, and leisure trips dropped by 77.8%, and shopping trips by 23.6% (Shakibaei et al., 2021).

The reduction in overall trips undertaken by people reduced public transport frequency. Preventive measures, travel anxiety, and fear of infection heavily affected public transport ridership worldwide during the COVID-19 pandemic. In a survey conducted by Kopsidas et al. (2021), it was found that 43.6% of travelers feared a COVID-19 infection, and 84.3% of the travelers did not or, to an average extent, trusted their fellow travelers to follow the COVID-19 safety rules. The number of people stated to be moderately and extremely concerned about the cleanliness and hygiene of public transport increased drastically compared to before the COVID-19 pandemic (Beck et al., 2020). Females and younger people were the most concerned about cleanliness and hygiene.

In Germany, Australia, Indonesia, Thailand, and Japan, public transport ridership decreased by more than 50% (Abdullah et al., 2020; Eisenmann et al., 2021). In the Netherlands, public transport decreased by 90% (Haas et al., 2020). However, car usage dropped by 80%. In the US, rail ridership decreased by 71.2%, while bus ridership decreased by 53.8% (Ziedan et al., 2023). The more considerable reduction in rail ridership can be explained by the decreasing travel distance of passengers to minimize infection chances (BTS, 2023b). Public transport usage decreased even more in larger cities such as Seattle, where public transport usage dropped by 79%, and New York, where subway ridership dropped by 91% (Gao et al., 2020). Besides rail, air travel also took a hit during the COVID-19 pandemic. Sokadjo and Atchadé (2020) found a positive relationship between the number of infections and the global passenger air traffic level. The travel bans to other countries and discouragement of domestic air travel within the US resulted in a 96% drop in April 2020 compared to December 2019 (BTS, 2023c).

There was a noticeable behavioral change in transport modes during the COVID-19 pandemic. In the US, the largest shift was from public transport to car usage, with 63.2% (Zhang et al., 2021). This is less than the same shift in Europe, which equaled 68.0%. Other shifts in transport modes were from public transport to walking (39.5%) and from public transport to cycling 39.5% (Zhang et al., 2021). In the Netherlands, 88% of the people indicated that they prefer individual transport modes (like car or bicycle) during the pandemic over public or shared transport (Haas et al., 2020). He et al. (2022) found that people who had access to a private vehicle were more likely to reduce or stop the use of public transport than those who did not. This is because people who do not have access to a private vehicle do not have an alternative form of transport and, therefore, must continue using public transport.

While the shift in transport mode has been universally witnessed, how long it would sustain in the post-pandemic era remains to be seen. Recent studies have suggested that lasting COVID-19 effects can be expected (van Wee & Witlox, 2021). In the Netherlands, where the population widely uses public transport, around 80% of survey respondents have stated they will return to public transport after the pandemic (Haas et al., 2020). In Scotland, around a third of the people expect to use buses and trains less in the future (Downey et al., 2022). From a survey performed by Kopsidas et al. (2021), it can be concluded that more than half the people (61.85%) expect to use public transport within one month after the COVID-19 pandemic ends. A trend throughout the pandemic showed that the number of people who would return to public transport increased throughout the pandemic (Beck et al., 2020).

Studies show that travelers' demographics influence the recovery of public transport (Kopsidas et al., 2021). Travelers may have varied responses to the COVID-19 effect in the long term due to different levels of perceived health risks (Ren et al., 2022). A study by Hotle et al. (2020) showed that men are less likely to change their travel behavior than females. People who are self-employed or are aged 46–65 years are respectively 41.8 and 24.9% less likely to use public transport again compared to other professions and age groups (Kopsidas et al., 2021). Furthermore, Kopsidas et al. (2021) found that 33.6% of the people who use a private car will take longer to return to public transport.

At the time of writing, public transport is gradually recovering from the pandemic. In September 2022, public transport ridership was, on average, 72% compared to the average ridership in 2019 (American Public Transportation Association, 2022). In some cities, such as Tampa and Tucson, rail ridership in 2022 exceeded the 2019 ridership (Ziedan et al., 2023). It is meaningful to keep monitoring behavioral changes in the post-pandemic era, as people may be more capable of adapting their travel behaviors to new environments than usually expected following COVID-19 (Marsden & Docherty, 2021).

It is important to consider the impact of the pandemic in the study of HSR in the US, as HSR in the US has gained renewed attention only in recent years. During this time, the country has experienced and emerged from the COVID-19 pandemic. Given the significant change in travel and mode choice behaviors due to COVID-19 (Abdullah et al., 2020), it is reasonable to assume that the catastrophic impact of the pandemic may have changed the public view of what transport mode to use for domestic travel. Travelers may view HSR more favorably following COVID-19, given its convenience and controllable health risks compared to other transport modes, especially air travel. In other words, there could be a wider public acceptance of HSR in the post-pandemic era because of the impact of COVID-19. Yet, the relationship between COVID-19 and HSR in the US remains unexamined, especially from the user perspective, which is a research gap this study aims to bridge.

2.4 Studies of HSR in the US

Although HSR is a relatively new phenomenon in the US, different studies have been done regarding the benefits (Levinson, 2012), disadvantages (O'Toole, 2021), environmental effects (Chester & Ryerson, 2014; Kamga & Yazici, 2014), and economic viability (Button, 2012; Peterman et al., 2009), for building HSR in the US. Some studies use the North-East Corridor as a case study as this line comes close to an actual HSR (Button, 2012; Kamga, 2015). Other studies used the Brightline in Florida or the proposed HSR line in California as case studies or discussed the lessons learned from HSR in Europe and Asia and applied this to the US (Albalate & Bel, 2012b; Ashiabor & Wei, 2013; Chang & Kendall, 2011; Eidlin, 2015; Schorung, 2022).

Sudies suggested that the ridership share of HSR is one of the essential parameters to make HSR environmentally and economically beneficial (Chester & Horvath, 2010; Givoni, 2006; Krishnan et al., 2015; O'Toole, 2008). Studies show that the low population density and more widely spaced urban areas in the US, in combination with the highly integrated use of car and air travel, decreases the potential success of HSR (Chen, 2015; Kamga, 2015). To make HSR succeed in the US, it needs to attract new passengers and passengers that previously used car, air, or conventional rail.

To compete with other US transport modes, increasing HSR's operating speed and service frequency is essential (Sperry, 2017). Eidlin (2015) states that for HSR to succeed, it needs to satisfy several conditions: urban centers of considerable size situated along the HSR corridor, significant economic activity along the corridor, concentrated activity hubs within a walkable distance of the HSR station, and a solid public transit network. Teng et al. (2022) concluded from studying HSR in other countries that for the California HSR to do well, it is important to make the HSR stations transit-orientated, have an integrated ticketing system between rail and transit modes, and coordinate arrivals and departures with other transit options to reduce egress and access times.

The proposed downtown locations for the Dallas–Houston HSR stations benefit passengers in terms of shorter egress and access times, increasing competitiveness with other modes of transport (Zhao, 2018). It is therefore expected that with the introduction of the Dallas–Houston HSR line, around 29% of travelers will use HSR between the two cities (Federal Railroad Administration, 2019b, Appendix J). Travelers between the two cities mostly switch from car usage to HSR, followed by air, while bus usage between the two cities ceases to exist. The California High-Speed Rail Authority is building new stations in dense city centers close to public transport to maximize the utilization of HSR (Eidlin, 2015). Research performed by the California High-Speed Rail Authority (2023) showed that because of the region's lower socio-economic growth, the forecasted ridership needed to be reduced from 38.58 million to 31.28 million passengers in 2040.

In the US, passengers can make use of the extensive and well-developed interstate highway network, with traffic congestion mainly found at the origin and destination cities instead of along the route (Ashiabor & Wei, 2013). In the ten cities with the most extensive delays, a decrease in delay times can be seen for seven cities in 2022 compared to 2019 (Inrix, 2023). However, with the increasing demand for highway usage because of population growth, legislators acknowledge the requirement for additional capacity (Ashiabor & Wei, 2013). Research investigating the effects of building an HSR line in the Appalachian Region has shown that without introducing a new form of transport, accessibility of five major cities in that region will reduce because of the increasing highway demand (Chandra & Vadali, 2014). The accessibility can be improved when a new HSR line is constructed between the five cities.

When certain economic and geographical conditions are met, HSR can be an essential economic and social function (Button, 2012). However, these conditions that suit HSR are rare, as shown when looking at HSR abroad. Ashiabor and Wei (2012) argue that the US has no corridors with high-density and high economic activity centers. However, this is expected to change in the coming years with the rapidly increasing urbanization (Ross, 2011). By 2050, it is expected that the US will have a population of over 389 million people (Vespa et al., 2018), and two-thirds of the economic growth will occur in several megaregions across the US. Currently, there are seven megaregions consisting of metropolitan centers and surrounding areas of influence across the country, but that is expected to increase to 10 by 2040 (Ross, 2011). It is estimated that two-thirds of the US population will live in these 10 megaregions. The seven current megaregions each have a population of more than 10 million people and combined represent 80% of the economy. Ross (2011) argues that these and future megaregions are suitable locations for a successful HSR network.

Button (2012) and O'Toole (2022) state that economic development due to HSR can be disappointing because of the high fares required to compensate for the high developing and building costs, leading to a decrease in ridership. Intercity rail and Amtrak in the US have the highest fares, equaling 41.7 cents per passenger mile compared to 18.6 cents for air travel and 25 cents for car usage (O'Toole, 2021; BTS, 2023d). To make the fare competitive with air travel and car usage, it is estimated that the HSR in California requires around $590 million FY1997 ($ 1.12 billion when adjusted for inflation) in public subsidies a year (Levinson et al., 1997). Without subsidies, HSR would not be financially sustainable.

Murakami and Cervero (2010) state that the economic development expected in California will be more redistributive than generative with the introduction of HSR. This is because there will be higher economic development around train stations, but economic development will slow down in cities that are not connected (O’Toole, 2021). Especially mid-size cities will notice that companies will move to the bigger cities connected to HSR lines. Economic development and industrial productivity can be improved when the new HSR lines are used by passengers and freight, increasing connectivity between logistical areas, airports, and seaports (Albalate & Bel, 2012b).

Ross (2011) shows more promising effects for HSR in the United States, stating that HSR can increase property value, enhance mobility, and improve employment and economic activity. Furthermore, HSR can improve the flow of information and boost the knowledge economy in connected cities (Chen & Hall, 2012). This can be achieved through substantial regional advancements and reduced commute times, leading to greater availability of skilled labor (Miwa et al., 2022). Eidlin (2015) states that the HSR line in California can bring economic development because of the large California economy, which is mainly concentrated along the proposed HSR line, and eight of the ten highest-density populations in California are along the HSR line. Furthermore, areas around HSR stations will notice economic, commercial, and employment growth because of the increased activity introduced by HSR. The effects of HSR will be most notable in smaller cities such as Fresno and Bakersfield in California, as these smaller cities will be better connected to the state’s major economies (Eidlin, 2015).

Research done by the University of Florida before the construction of Brightline showed that the introduction of HSR in Florida could have a benefit-cost ratio between 1.34 and 3.02 (Lynch, 2002). Furthermore, the line was expected to create between 21,520 and 165,069 new jobs in Florida. Similar job creations are found for the California HSR. In the short term, it will result in 160,000 jobs; in the long term, it can create around 450,000 jobs (3% of the entire California workforce) (Peterman et al., 2009).

Most passenger and freight transport involves fossil-fuel-dependent cars, aircraft, and boats. This caused the transport sector to use around 67% of its daily petroleum consumption in 2019 (United States Energy Information Administration, 2023b). Environmental improvements have been made both in the car sector and in the aircraft sector. The average car fuel consumption was 25.4 miles per gallon, reducing CO_2 emissions by 25% compared to 2004 (United States Environmental Protection Agency, 2022). In addition, there has been a large increase in hybrid electric and electric car sales in the last couple of years (BTS. 2022b). Although the transport sector is advancing to a more sustainable future, radical steps must be taken to speed up this process. Different studies stated that HSR could be a step towards a more sustainable transportation system in the US (Chester & Horvath, 2012; Kamga & Yazici, 2014).

Studies are mixed about the environmental gains of HSR compared to other modes of transport. The environmental effects depend on the passenger shift from other modes of transport to HSR and the overall ridership (Givoni, 2006). Studies suggested that HSR is more environmentally friendly than air travel as HSR requires 240% less energy (Albalate & Bel, 2012b). However, HSR requires more energy when compared to gasoline cars (12.8%), diesel cars (55.9%), and intercity trains (140.9%). Therefore, Albalate and Bel (2012b) suggest that building a dedicated HSR line in the US does not reduce emissions enough to justify the cost. However, this study assumes that HSR will use electricity drawn from the national grid, generated mainly by natural gas and coal. However, both the Brightline in Florida and the HSR line in California will run on more sustainable sources, with the HSR line in California running fully on solar power (Brightline, 2022; California High-Speed Rail Authority, 2022a).

Chang and Kendall (2011) stated that the production of construction materials is the most pollutant part of building HSR, followed by transporting the materials. Furthermore, although tunnels and bridges only account for 15% of the entire California HSR line, they contribute to 60% of overall emissions. The overall emissions are estimated to be 5,120 tons of CO_2-equivalent per mile of the HSR line. Building an HSR line is concrete intensive, creating significantly more greenhouse gas emissions than constructing infrastructure for other modes of transport (Chester & Horvath, 2010). With the emission savings estimation of the California Air Resources Board (1.15 million metric tons of CO_2-equivalent), which assumes the use of sustainable energy, it is estimated that the emissions produced during the building phase can be recuperated within two years of operations (eight years after the start of construction) (Chang & Kendall, 2011). Chang and Kendall (2011) also estimated that it would take around six years after the operations start for the global warming effects to be compensated for.

Krishnan et al. (2015) performed an environmental analysis on a US-wide integrated HSR network. It was concluded that with a 30% penetration, the gasoline and jet fuel consumption for interstate passenger trips could be reduced by approximately 34%. Over a 40-year lifespan of HSR, this would result in a total CO_2 reduction of 0.8 billion short tons. In this model, it is estimated that the HSR will use renewable energy.

2.5 Research Gap

Clear research gaps can be seen regarding HSR in the US. First, prior studies of HSR in the US focused almost exclusively on the economic viability, challenges, and opportunities of developing HSR, with few studies considering the perspective of US travelers. The success of HSR depends not only on HSR infrastructures and operations but, perhaps more importantly, on public acceptance and the decision to use HSR. Research at a micro level focusing on individual

US travelers and their interest and choice regarding HSR is therefore needed to fill the research gap. Second, unlike many other countries, transport in the US is supported primarily by cars (for short distances) and airplanes (for long distances). The mode decision of travelers must be examined when multiple travel options, including HSR, are available, and the factors that are important in their intermodal choice need to be considered, especially in high-demand markets like San Francisco (SA) and Los Angeles (LA) where different travel options are available. While Gehrt et al. (2007) investigated HSR use in the US, the study was conducted when policy and the economic environment for HSR development were vastly different. The study focused only on the intention to use HSR, which ignored the fact that the mode decision is based on an evaluation of all available transport modes. To the best of our knowledge, no prior study has examined travelers' intermodal choices involving HSR in the US. The findings of this study will provide much-needed empirical evidence for the viability of HSR service in the country. Moreover, with the renewed discussion of HSR in the US, the potential impact of COVID-19 should be examined for its effect on views about domestic travel, including the use of new transport modes like HSR. For example, has the COVID-19 experience led to an increased interest and intention toward HSR, especially when the geographic factor is considered? Empirical research on the impact of COVID-19 and the use of HSR in the US is needed to answer this important question.

3. 3. Methods

3.1. Sampling and Data Collection

This study followed a convenience sampling strategy to collect survey data from Amazon Mechanical Turk (MTurk). Given the COVID-19 situation, an online survey provided a feasible and efficient way for data collection. Three qualification checks were applied to ensure data quality from survey participants, including 1) participants must have successfully completed at least 100 tasks on MTurk, 2) participants must have received over 98% of the approval rates, and 3) participants in the pilot study were not eligible to participate in the main survey. Data was collected in June 2022, which was considered an ideal time for data collection for the purpose of this study. After years of limited progress in HSR development, there has been discussion of HSR development in the busy corridors across the country. The timeline for the HSR development coincides with the country's experience and re-emergence from the COVID-19 pandemic. It is reasonable to assume that the pandemic may have changed how people view and use transport modes in the US, and this change is likely to sustain for some time in the future. It is also likely that travelers have developed different views of HSR following the COVID-19. The survey data (N =1,033) collected at this time allowed the researcher to better capture travelers' opinions toward this new transport mode in the US.

3.2 Survey Questionnaire

A survey questionnaire containing four major sections was developed for data collection. The first two sections collect information on participants' demographics and travel experience. Section 3 measures the factors that can be important to the choice of HSR. Likert scale questions were developed for respondents' evaluation of these factors, from 1 (strongly disagree) to 5 (strongly agree). Most scale items were adopted from validated scales in the literature to increase the validity of the measurement (Bösehans & Walker, 2020; Chou & Yeh, 2013; Hou et al., 2021; Sagoe et al., 2021; Verplanken & Orbell, 2003). Section 4 collects data of mode choice behaviors by providing a future scenario of traveling from LA to SF, for which respondents were asked to choose air, HSR, or cars for the trip. The use of the LA-SF scenario in the survey considered high travel demand and potential HSR operations in this market, which presented a real-life scenario that respondents can easily understand. In addition, the mid-distance trip (around 350 miles) in this corridor makes air, HSR, and cars competitive transport modes, allowing participants to realistically assess the mode choice behavior if HSR becomes a viable travel option. The survey scale and mode choice scenario are provided in Appendix A.

3.3 Treatment of Data

This study aimed to answer three research questions about travelers in the US, including 1) What factors were important in the intermodal choice for domestic trips in a highly competitive market following the introduction of HSR, 2) What is the impact of COVID-19 on HSR use, considering the possible view change and geographic locations of travelers, and 3) What user segments can be identified within the survey data to describe the unique characteristics of potential HSR travelers in the US .

Logistic regression was performed to answer the first question, focusing on the effect of seven demographic, travel, and HSR factors (gender, age, income, travel frequency, mobility issue, total travel time, and convenience in transport) on the intermodal decision in the LA-SF market. Two sets of analysis were conducted, including 1) multinomial logistic regression (MLR) to investigate travelers’ choice from air, HSR, and car transport, and 2) binary logit regression (BLR) analyses between air and HSR and between cars and HSR to verify the first analysis due to the small sample size in some categories of the mode choice. To answer the second question, a two-way MANOVA was performed to identify the effect of two independent variables (IVs) – the view change on mode use for domestic travel following COVID-19 (View_Change) and geographic locations of participants (Geo_Location) - on four travel- and HSR- related dependent variables (DVs) including knowledge of HSR, travel habits, the likelihood of using the train, and the intention to use HSR in the post-pandemic era in the US. Both the main and interaction effects of the two IVs were identified. The third question was answered by cluster analysis, using hierarchical and non-hierarchical clustering to identify meaningful clusters based on the joint use of five transport and HSR attributes (consideration of transport culture, and price, travel time, safety, and comfort of HSR). The selection of transport culture as a clustering variable considers the unique transport culture in the US. Travelers rely on air transport for long-distance travel and automobiles for short trips, creating a unique *air and car culture* in the US (Kamga & Yazici, 2014). Adding the culture factor to the cluster analysis can generate deeper insights into the potential users of HSR in the US.

4. Results

4.1 Logistic Regression – Multinomial and Binary Analyses

Logistic regression analyses were performed to investigate the intermodal choice among air, HSR, and cars in the LA-SF corridor if HSR becomes a viable travel option in this high-demand market. The total sample size, after data cleaning to remove invalid questionnaires (e.g., those who failed to provide MTurk worker's ID), was N = 1,033. Section 4.1 presents the results of descriptive statistics and logistic regression analyses.

4.1.1. Respondents' Demographics

Table 1 summarizes the major characteristics of the survey respondents in this study.

Table 1

Respondents' Profile

Variables	Category	Frequency	Percentage
Gender	Male	576	55.8
	Female	448	43.4
	Others	2	0.2
	Missing	7	0.7
Age	< 20	8	0.8
	20-30	343	33.2
	31-40	289	28.0
	41-50	203	19.7
	51-60	140	13.6
	> 60	46	4.5
	Missing	4	0.4
Education	Completed some high school	7	0.7
	High school	122	11.8
	Bachelor's degree or equivalent	646	62.5
	Master's degree	236	22.8
	Higher than master's degree	19	1.8
	Missing	3	0.3
Personal Income	< $25,000	114	11.0
	$25,000 - $50,000	385	37.3
	$50,000 - $75,000	219	21.2
	$75,001 - $100,000	218	21.1
	$100,001 - $125,000	68	6.6
	> $125,000	27	2.6
	Missing	2	0.2
Ethnicity	Black or African American	59	5.7
	Asian	59	5.7
	Hispanic or Latino	44	4.3
	Pacific islander	4	0.4
	White	843	81.6
	Native American	18	1.7
	Missing	6	0.6

Variables	Category	Frequency	Percentage
Employment Status	Employed, working 40 or more hours per week	837	81
	Not employed, not looking for work	22	2.1
	Employed, working 1-39 hours per week	122	11.8
	Retired	16	1.5
	Not employed, looking for work	26	2.5
	Disabled, not able to work	1	0.1
	Missing	9	0.9
Purpose of Travel	Leisure/Vacation	341	33
	Business	441	42.7
	Visiting Family/Friends	206	19.9
	Study	28	2.7
	Others	11	1.1
	Missing	6	0.6

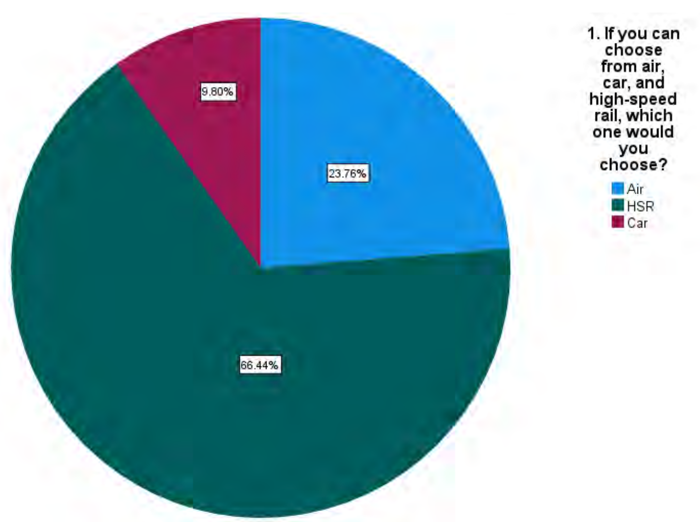
Respondents' demographic characteristics including gender, age, educational level, personal income, ethnicity, employment status, travel frequency, and travel purposes were collected in this survey. As shown in Table 1, slightly more male (55.8%) than female (43.4%) respondents participated in the survey. The gender ratio differed slightly from the national average, which indicated a similar size of male and female categories in the general population of the US. Most respondents (80.9%) were between the ages of 20 and 50. Within this age range, those between the ages of 20 and 30 formed the largest category, accounting for 33.2% of the total respondents, followed by those between the ages of 31 and 40 (28%), and then between the ages of 41 and 50 (19.7%). The difference in the age profile between the sample and the national population is particularly noticeable in the group of 60 years or older, indicating that in this age group only a small percentage of the population is capable of or interested in participating in online surveys. With respect to educational attainment, the percentage of the respondents with a bachelor's degree or equivalent was 62.5%, representing the largest category of the respondents in this survey. This was followed by the category of master's degree, which represented 22.8% of the respondents. Collectively, respondents possessing bachelor's and master's degrees accounted for a major portion of the total respondents (85.3%). This differed substantially from the national population in the US, which indicated much less of the US population received higher than bachelor's degree (US Census, 2022b). In terms of personal income, 58.5% of the respondents reported annual income between $25,000 to 75,000, followed by 21.1% between $75,001–$100,000, and 11% below $25,000. Only a small portion (9.2%) of the respondents earned annual incomes above $100,000. An overwhelming majority of respondents (81.6%) reported their ethnic background as White. An identical portion of the respondents (5.7%) identified themselves as Asian and Black/African American. Hispanic or Latino accounted for 4.3% of the total respondents, while only 2.1% self-reported as Native American and pacific Islander in this survey. The dominant category of White respondents in this survey mirrors that in the US population, in which White population constitutes the racial majority in the general population living in the US. However, the percentages associated with Asian, Black or African American, and Hispanic or Latino in this survey were lower than that observed in the US population (US Census, 2022c). The employment status of the respondents varied. Most of the respondents (81%) worked full-time while 11.8% took part time jobs. About 4.6% of respondents were not employed at the time of the survey. The remaining respondents were either retired or not able to work due to disability. Regarding the main purpose of travel, 42.7% of the respondents traveled for business purposes, while 33% and 19.9% identified leisure/vacation and visiting family/friends as their main purposes for traveling domestically. Collectively, these three categories accounted for nearly 96% of the total respondents.

4.2 Descriptive Statistics – Vulnerable Population

In Section 4.2, the choice among air, HSR, and cars were examined based on specific demographic groups. Focus was placed on vulnerable populations and their choice of the three modes. Vulnerable populations are defined by socio-economic status, geography, gender, age, disability status, risk status related to sex and gender, and among other populations identified to be at-risk for health disparities (University of North Dakota, n.d.). Three demographic characteristics, namely gender, age, and income were examined in relation to the intermodal choice of air, HSR, and cars for domestic travel in the LA-SF market. Figure 1 illustrates the choice decision of the entire sample (N=1,033) when the three transport modes were presented for selection.

Figure 1

Choice Decision Among Air, HSR, and Car – Survey Summary



As shown in Figure 1, most respondents (66.44%) indicated HSR as their first choice if it became available in the LA-SF market, followed by air (23.76%), and then by car (9.8%). The result demonstrated the popularity of HSR among the participants in this study. The respondents in the sample were then grouped by gender, age, and income to further examine the choice of the three modes, which can provide deeper insights into the choice behaviors especially regarding the vulnerable populations. The results (based on gender, age, and income) are presented in the remainder of Section 4.2.

Figure 2

Gender Distribution of the Respondents

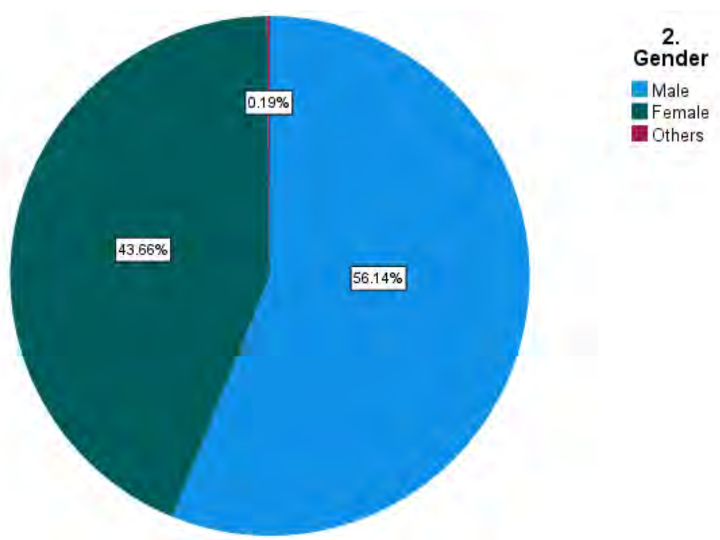


Figure 3

Intermodal Choice based on Gender

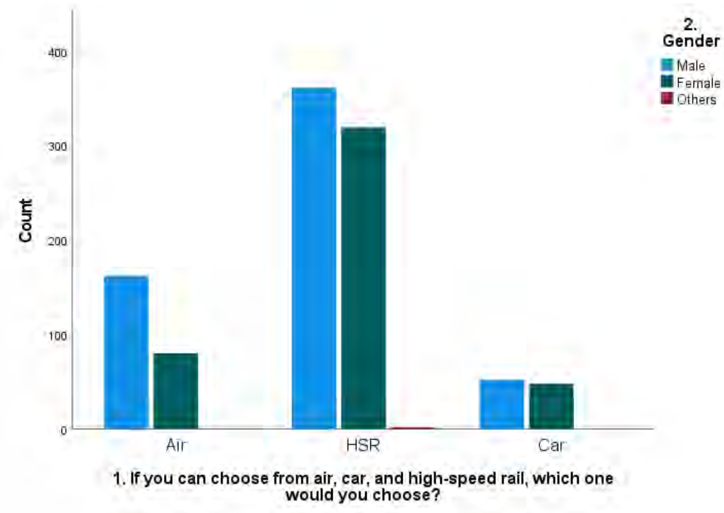


Figure 2 visualizes the gender distribution of the respondents, which indicates more males than females in participating in this study (56.14% and 43.66%, respectively). Figure 3 compares the intermodal choices between male and female respondents when three transport modes - air, HSR, and cars - were available in the LA-SF market. As only less than 0.2% of the respondents selected “Others” when providing the gender information, this analysis focused only on male and female comparison for the purpose of simplicity. While similar numbers of male and female respondents selected cars for the trip, male respondents appeared to be more likely to choose either HSR or air in this market compared to female respondents. This pattern is particularly clear in the choice of air transport.

Figure 4

Age Distribution of the Respondents

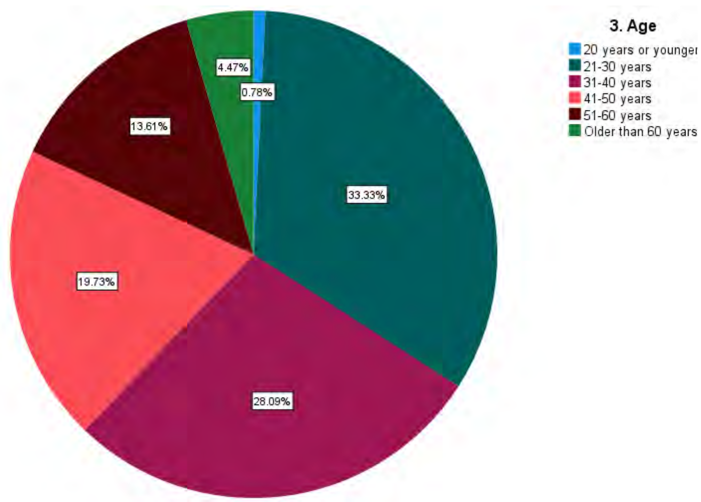


Figure 5

Intermodal Choice by Age Groups

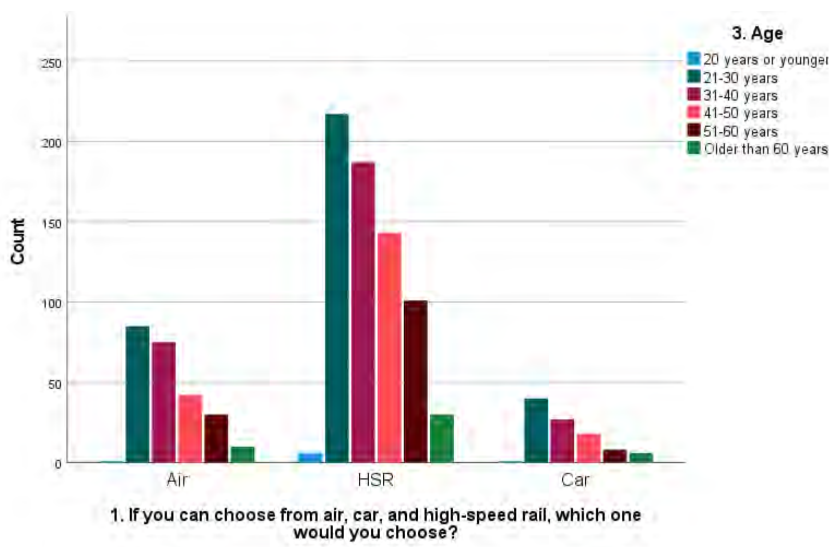


Figure 4 shows that age group of 21 to 30 years old (33.33%) was the largest in this study, followed by the 31 to 40 (28.09%), and 41 to 50 (19.73%) age groups. The choice decision by age group in Figure 5 illustrated the similar patterns; that is, for each transport mode category, the age group of 21-30 years old was the largest in number, followed by 31-40 and 41-50 age groups. The senior group (age 60 or older) showed the highest percentage of choosing cars (13%) compared with the other age groups, which may reflect the mobility needs of vulnerable travelers in this group.

Figure 6

Income Distribution of the Respondents

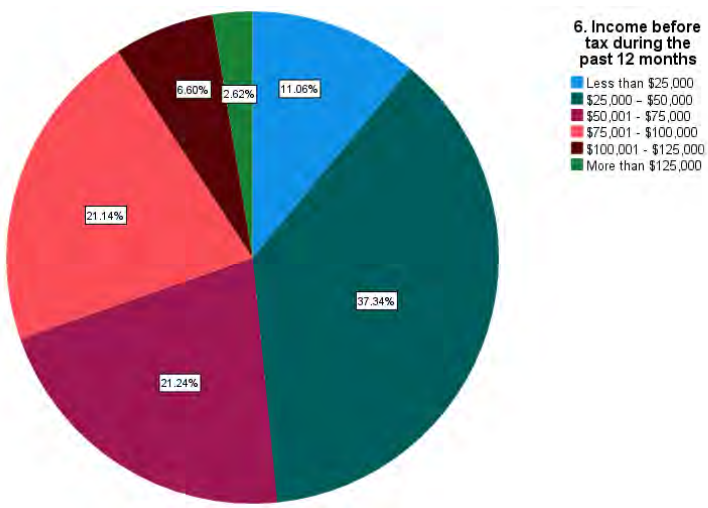
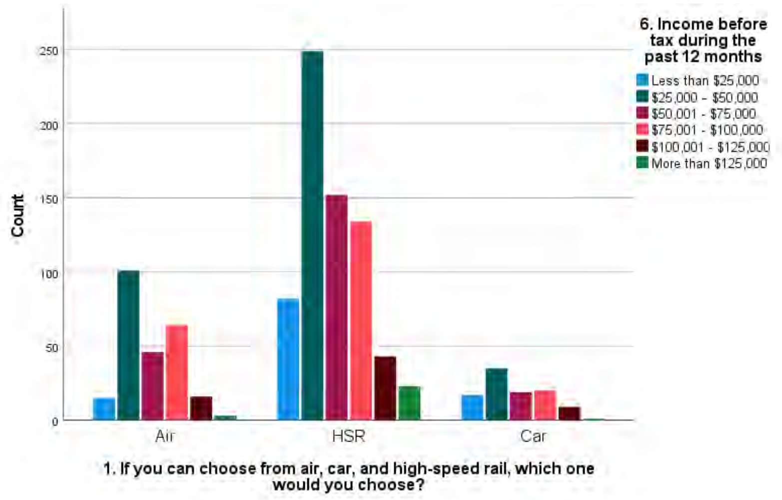


Figure 6 illustrates the income distribution of the respondents, indicating that respondents with low to moderate incomes ($25,000–$100,000) account for the major portion of the total respondents (80%). Figure 7 breaks down the incomes based on the choices of the respondents of the three transport modes. It demonstrated that the low-income group (respondents earning lower than $25,000 annually) was most likely to choose car transport (14.9%%) compared to other income groups; the moderate-income group (respondents with moderate to high incomes, $75,001-$100,000) was most likely to choose air (29.4%), and the high-income group (those with high incomes, >$125,000) was most likely to choose HSR (85.2%).

Figure 7

Intermodal Choice by Income



4.3 Logistic Regression Analyses – Multinomial and Binary Regression

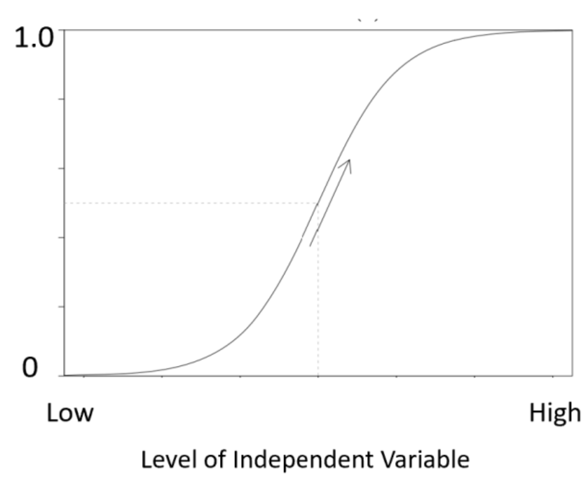
4.3.1 Logistic Regression – An Overview

In this study, a logistic regression analysis was performed to predict the impact of demographic, travel, and HSR factors on the choice among air, HSR, and cars for the trip between LA and SF. While logistic regression shares some similarities with multiple linear regression, it differs in the type of the dependent variable (DV) in the analysis. The DV should be categorical, and the independent variable(s) can be metric or nonmetric variables. It's considered a suitable analysis for the first research question in this study, because the question was about finding significant predictor(s) of the mode choice of travelers. The mode choice (dependent variable) was a categorical variable comprising the choice of transport modes (air, HSR, cars). The independent variables were gender, age, income, mobility issue, travel frequency, total travel time, and convenience in transport, all of which were nominal or ordinal variables. An advantage of logistic regression is that it does not require the data to meet the major assumptions typically required in parametric statistics, including linear relationships between independent and dependent variables, normal distribution of error terms, and homoscedasticity (constant variance). It is a preferred method also because it is unlikely that a linear relationship can be observed between the predictor variables and the outcome variable in this study.

A commonly used logistic regression is binary logistic regression, where DV is dichotomous, and the independent variables are either continuous or categorical. A binary DV has two levels, represented by the values of 0 and 1, respectively. As such, the predicted value (probability) must fall within the range between these two values (Hair et al., 2019). The logistic curve is often used to graphically illustrate the relationship between the IV and DV in binary logistic regression, as shown in Figure 8

Figure 8

Form of Logistic Relationship Between Independent and Dependent Variables



Note: Source: Hair et al. (2019).

The S shape curve in Figure 8 represents the change in the predicted value with the change in the IV. At the very low levels of the IV, the predicted values approach 0, but never reach it. As the IV increases, the predicted value also increases, but at any level of the IV the predicted value will approach 1, but never exceed it (Hair et al., 2019). This type of relationship is nonlinear, and therefore cannot be addressed by traditional regression analysis such as multiple linear regression.

Another important concept in logistic regression is the odds of an event, which refer to the ratio of the probability that an event will occur to the probability that the event will not occur. In logistic regression analysis, the impact of the IV is typically explained in terms of odds (Park, 2013). The maximum likelihood method is used to estimate coefficients for the independent variables. Estimation using the logit value is shown below (Park, 2013).

$$logit(y)=\ln (p/(1-p)) =a + \beta_1 \chi_1 + ... +\beta_k\chi_k$$

where p is the probability of outcome occurrence,

x is the explanatory variable,

α and β are the parameters of logistic regression.

When the dependent variable comprises more than two categories, a multinomial logistic regression can be used. Multinomial logistic regression works in the same way as binary logistic regression; however, since multinomial logistic regression predicts membership of more than two categories, it breaks the outcome variable down into a series of comparisons between two categories. This means that the researcher must select a baseline category, against which the other categories are compared (Field, 2009). In Sections 4.3.2 and 4.3.3, both multinomial and binary logistic regression were employed to predict the choice when three transport modes (air, HSR, cars) were presented, as well as when participants were asked to choose between air and HSR, and between cars and HSR.

4.3.2 Multinomial Logistic Regression

Multinomial logistic regression was conducted to exam whether gender, age, income, mobility issue, travel frequency, total travel time, and convenience in transport would affect the choice of air, cars, and HSR in the LA-SF market. As gender, age, income, and travel frequency were ordinal or categorical variables with more than two levels, dummy coding was performed to make these variables suitable for logistic regression analysis. An important assumption of logistic regression is absence of multicollinearity among the explanatory variables. All the variance inflation factor (VIF) values were less than 3 (Table 2), indicating minimum concern of multicollinearity. Regarding sample size, Hair et al. (2019) recommended a sample of 400 or more for logistic regression analysis, with at least 10 observations for each category of the dependent variable (DV), which was satisfied in this study. Both the total sample size and observations for each category of the DV (n=243, n=101, and n=681 for the choice of air, cars, and HSR, respectively) met the sample size requirement.

Table 2 shows the results of the MLR analysis. Most respondents (681, or 66.4%) selected HSR as the preferred mode to travel from LA to SF, suggesting that HSR was the most popular travel option in this study. Model estimation showed that the final model containing all the predictors represented a significant improvement in model fit over the null model (X^2 (38) = 156.82, $p < .001$). The test of goodness-of-fit yielded similar results, further suggesting that the model fit the data adequately (X^2 (2004) = 2036.271, $p = .302$). To investigate the mode preference in this study, HSR was used as the reference group (represented by R in Table 2) against which the other two modes were compared. The comparison between air and HSR indicated that six factors (total travel time, convenience in transport, gender, income, travel frequency, and mobility issue) were significant predictors. For these factors, the interpretation was based on the sign of the coefficient (negative or positive) and the value of odds ratio. Annual income ($25,001-50,000 and $75,001-100,000) and convenience in transport had positive coefficients. With their odds ratios, the interpretation was that, in general, participants who earned moderate annual incomes ($25,001-$50,000 and $75,001-$100,000) had greater odds of selecting air (versus HSR) by factors of 2.021 and 2.743, compared to those who earned low incomes (less than $25,000), and when transport convenience increased, the participants were

Table 2

Multinomial Logistic Regression – Choice of Air, HSR, and Car in the LA-SF Market

	HSR n = 681	Air n=243	Car n=101	VIF
Model Factor	Odds Ratio	Odds Ratio	Odds Ratio	
Gender	R			<3
Female		.562**	1.11	
Others		7.173E-8	6.082E-8	
Age	R			<3
21-30		.923	.561	
31-40		1.355	.544	
41-50		.815	.407	
51-60		.949	.292	
>60		1.544	.930	
Income	R			<3
$25,001-50,000		2.021**	.662	
$50,001-75,000		1.544	.705	
$75,001-100,000		2.743**	.949	
$100,001-125,000		2.131	1.32	
>$125,000		1.08	.379	
Travel Frequency	R			<3
Once		.694	.939	
2-3 times		.506**	.644	
4-5 times		.455**	.331**	
>5 times		.385**	.521	
Mobility Issue	R	.498***	.747	<3
Total Travel Time	R	.143***	.189**	<3
Convenience	R	1.992**	.944	<3
Model Assessment				
2*LL*	1564.951***			
Pearson χ2	2036.271 (*p*=.302)			
Nagalkerke R^2	0.174			
Classification[a]	95.30%	17.30%	3%	

Note: ***=*p* < .001, **=*p* <.05
R=Reference Category
[a]: Overall Classification Accuracy=67.7%

more likely to choose air travel over HSR. Gender, mobility issue, travel frequency (travel 2 times or more annually), and total travel time had negative coefficients. The interpretation was that female participants' odds of choosing air (versus HSR) was smaller by a factor of .562 compared to that of male participants; participants who traveled 2-3 times, 4-5 times, and more than 5 times annually had smaller odds of selecting air (versus HSR) by factors of .506, .455, and .385, compared to that of participants who traveled less than once a year; participants with mobility issues had smaller odds of selecting air (versus HSR) by a factor of .498, compared to those without mobility issues; and when total travel time increased, participants were less likely to select air over HSR. Only two factors - total travel time and travel frequency (4-5 times annually) - were found to be significant in the choice between cars and HSR, both with negative coefficients. This indicated that participants were more likely to choose HSR over cars when total travel time increased, and in general, participants who traveled 4-5 times annually had smaller odds of choosing car (versus HSR) by a factor of .331 compared to those traveled less than once a year.

4.3.3 Binary Logistic Regression

The prediction accuracy of the model was further quantified by the classification statistics. While the model had an overall prediction accuracy of 67.7%, the predictive ability of the choice of air (17.3%) and cars (3%) was low. This may be related to the relatively small sample size especially for the car mode. As the survey also collected separate data for the choice between air and HSR, and between cars and HSR, the data, with larger sample size for the car and air choices, was then used to estimate two binary logistic regression (BLR) models to verify the significant predictors identified in the MLR. The results are presented in Table 3. The BLR analyses showed that total travel time, convenience in transport, gender, mobility issue, and age

Table 3

Binary Logistic Regression –Choice between Air and HSR and Choice between Car and HSR

		Air (370) vs. HSR (654)	Car (201) vs. HSR (823)
Model Factor		(Odds Ratio)	(Odds Ratio)
Gender			
	Female	.739**	NS
	Others	NS	NS
Age			
	21-30	NS	NS
	31-40	1.448**	NS
	41-50	NS	NS
	51-60	NS	NS
	>60	NS	NS
Income			
	$25,001-50,000	NS	NS
	$50,001-75,000	NS	NS
	$75,001-100,000	NS	NS
	$100,001-125,000	NS	NS
	>$125,000		
Travel Frequency			
	Once	NS	2.094***
	2-3 times	NS	NS
	4-5 times	NS	NS
	>5 times	NS	NS
Mobility Issue		.270***	NS
Total Travel Time		.141***	.128***
Convenience		2.093**	NS
Model fit measurement			
2*LL*		1189.188(Δ 41.343)	911.967(Δ 20.224)
Hosmer & Lemeshow X^2		.060 (Δ .009)	.739 (Δ .602)
Nagelkerk R^2		.187 (Δ .048)	.151 (Δ .029)
Classification[a]		69.4% (Δ 3.9%)	80.8%

Note:
Δ = Change from base model; NS=Not Significant ***: p < 0.001
**: p < .05
*: p < 0.1
a : Group Classification 82.4% and 46.5% for HSR and Air, 97.9% and 10.4% for HSR and Car.

(31-40 years old) were significant in the choice between air and HSR, while total travel time and travel frequency (once a year) were significant in the choice between cars and HSR. While the BLR analysis identified age (31-40 years old) as an additional significant factor in the choice between air and HSR, the results generally supported the MLR findings that total travel time, convenience in transport, gender, travel frequency, and mobility issue were important predictors of travelers choosing from air, HSR, and cars in the LA-SF market. Classification accuracy was 69.4% for the air-HSR choice (82.4% for HSR and 46.5% for air) and 80.8% for car-HSR choice (97.9% for HSR and 10.4% for cars), representing improvement in predictive accuracy from the MLR analysis.

4.4 Two-Way MANOVA

4.4.1. Two-Way MANOVA – An Overview

Multivariate analysis of variance (MANOVA) is a dependence technique that measures the differences for two or more dependent variables based on a set of categorical (nonmetric) independent variables (Hair et al., 2019). MANOVA is termed a multivariate procedure because it assesses group differences across multiple metric dependent variables simultaneously. In other words, MANOVA is used to assess whether an overall difference is identified between groups on the combination of the dependent variables, and then separate univariate tests are performed to address the individual dependent variables (Hair et al., 2019). MANOVA was selected to answer the second question in this study because the question aimed to find out whether the two independent variables (the view change regarding transport mode for domestic travel following COVID-19 and geographic locations of the respondents), each containing multiple categories, would differ across the categories when multiple dependent variables (knowledge level of HSR, travel habits, the likelihood of using train, and behavioral intention to use HSR following the pandemic) were considered in combination or separately. As the current analysis had two independent variables and multiple dependent variables and aimed to identify group differences, a two-way MANOVA was deemed appropriate.

MANOVA is unique in that the variate optimally combines the multiple dependent measures into a single value that maximizes the difference across groups (Hair et al., 2019). As such, there need to be multiple null hypotheses for a two-way MANOVA to test group differences on a combination of the dependent variables, on individual dependent variables, and on an interaction effect between the independent variables. For the current study, three sets of null hypothesis statements were stated including (1) all group mean vectors are equal *(*omnibus test), (2) group means are equal on individual dependent variables, and (3) no interaction effect is observed between the two independent variables.

4.4.2. Two-Way MANOVA Analysis

Different from the logistic regression analysis in Section 4.3, the focus of Section 4.4 is on multivariate analysis for group comparison involving travel, HSR, and COVID-19 factors. Table 4 shows the respondents' characteristics related to these factors. About half of the respondents self-reported having mobility issues regarding themselves or their family members. Regarding train experience over the past five years, the largest category traveled between two to three times per year (37.3%), followed by once per year (24.8%), and then no train experience (20.5%). This indicates a considerable level of familiarity with train transportation among the respondents. Regarding the impact of COVID-19 on mode preference, most respondents (70.5%) indicated that the COVID-19 pandemic had changed their view of what transport mode to use for domestic travel. In comparison, less than 30% of the responders stated that the pandemic did not impact their view of domestic transport modes. Concerning the source of information on HSR, social media appeared to be the most popular source for HSR information, with 29.2% of the respondents reporting obtaining HSR information from social media. This was followed by

Table 4

Characteristics of Respondents Related to Travel, HSR, and COVID-19 Factors

Variables	Category	Frequency	Percentage
Mobility issue	Yes	513	49.7
	No	514	49.8
	Missing	6	0.6
Travel Frequency by Train in Last Five years	Less than once	212	20.5
	1 time	256	24.8
	2-3 times	385	37.3
	More than 3 times	178	17.2
	Missing	2	0.2
COVID-19 changed my view of transport mode to use for domestic travel	Yes	728	70.5
	No	296	28.7
	Missing	9	0.9
Main Source of Information of HSR	Social media	302	29.2
	family/friends/co-workers	248	24.0
	National News (including website)	212	20.5
	International News (including website)	94	9.1
	Government Agency	50	4.8
	Other Sources	30	2.9
	I don’t get any information of HSR	93	9.0
	Missing	4	0.4

sources of family, friends, and coworkers (24%), and international news (20.5%). Noticeably, HSR information given by government sources only accounted for less than 5% of all the information sources, likely indicating insufficient HSR information provided by the government.

One question in the survey asked the respondents to provide the city and state they lived in. With this information, the researcher was able to develop a clear understanding of the sample distribution across the country. There were 999 valid answers with identifiable city and state names, while in the other 34 cases, the city and state names were either invalid or the respondents failed to provide any information. Table 5 summarizes the sample distribution based on respondents' geographic locations. It shows that slightly less than 45% of the respondents came from the South region of the country. The remaining respondents were roughly equally distributed across the country's Northeast, Midwest, and South regions. The sample distribution across the four geographical locations showed a pattern similar to that observed in the US. Both consisted of the largest percentage of individuals from the South region, with the remaining individuals roughly evenly distributed across the Northeast, Midwest, and West regions (US Census, 2022d).

Table 5.

Sample Distribution Based on Respondents' Geographic Locations.

Geographic location	Frequency	Percentage
Northeast	182	17.6
Midwest	182	17.6
South	461	44.6
West	174	16.8
Total	999	96.7

The goal of the two-way MANOVA in this study was to identify the impact of COVID-19 and geographic locations of the respondents on several HSR and travel factors. For this analysis, the impact of COVID-19 was defined as whether COVID-19 has changed the view of what transport mode to use for domestic travel, or View_Change (travelers choose between change or not change). The geographic locations of respondents (Geo_Location) were represented by the four geographical regions defined by the US Census (Northeast, Midwest, South, and West). A two-way MANOVA was performed to test whether four HSR and travel characteristics (dependent variables, or DVs), namely knowledge level of HSR, travel habits, the likelihood of using the train, and behavioral intention to use HSR following the pandemic, differed across the levels of the two independent variables (View_Change and Geo_Location). Noticeably, most of the respondents reported that COVID-19 had changed their view of what transport mode to use for domestic travel, demonstrating a large impact of COVID-19 on domestic travel and potential mode shifts following the COVID-19 crisis.

For the MANOVA analysis, a sample size of 20 or more was recommended for each level of IV, which was satisfied in this study (Hair et al., 2019). The four DVs showed moderate correlations, with Pearson's coefficient between .218 and .634, indicating minimal concern about multicollinearity. Box 's Test of Covariance matrices was statistically significant, indicating that equal variance at the multivariate level was not satisfied. Due to the partial violation of the assumptions, Pillai's Trace was used for interpreting multivariate test results, given its robustness to departures from assumptions. Table 6 shows the two-way MANOVA results.

The Pillai's Trace statistic was significant at $p < .001$. Therefore, the four DVs, when considered collectively, differed significantly across the levels of the two IVs - View_Change and Geo_Location (Pillai's Trace = .143, $F(4, 979) = 40.933$, $p <.001$, partial $\eta^2 = .143$, observed value = 1.00, and Pillai's Trace = .036, $F(12, 2943) = 2.937$, $p <.001$, partial $\eta^2 = .012$, observed value = .992). View_Change had a large effect on the linear combination of the DVs, while Geo_Location had a small effect, as indicated by the partial η^2. There was a significant interaction effect between View_Change and Geo_Location on the combination of the DVs (Pillai's Trace = .022, $F(12, 2943) = 1.785$, p=.045, partial η^2 = .007, observed value = .892), although the effect size was marginal. At the univariate level, both IVs demonstrated significant main effects on the individual DVs (when the DVs were tested separately).

Table 6

Two-Way MANOVA – Multivariate, Main Effect, and Interaction Effect

	F	df1	df2	*p*	η^2
Box 's Test of Covariance matrices	6.418	70	284497.98	***	-
Multivariate Test - Pillai's Trace					
Geo	2.937	12	2943	***	.012
View	40.933	4	979	***	.143
Interaction	1.785	12	2934	**	.007
Univariate Test (Main Effect)					
Geo - KN	5.986	3		***	.018
Geo - LU	4.188	3		**	.013
Geo - HA	4.372	3		**	.013
Geo - BI	8.426	3		***	.025
View - KN	162.178	1		***	.142
View - LU	56.523	1		***	.054
View - HA	12.675	1		***	.013
View - BI	28.332	1		***	.028
Geo*View (Interaction Effect)					
View*Geo - KN	3.523	3		**	.011
View*Geo - LU	1.889	3		NS	
View*Geo - HA	2.125	3		NS	
View*Geo - BI	1.599	3		NS	

Notes: KN=Knowledge of HSR; LU=Likelihood to use train after COVID-19; HA: Travel habit; BI=Intention to use HSR after COVID-19; : ***=p < .001, **=p <.05.

Therefore, the respondents who changed their view on transport mode due to COVID-19 differed significantly in HSR knowledge, travel habits, the likelihood to use trains, and behavioral intention to travel by HSR, compared to respondents whose view on mode use was unaffected by COVID-19. The mean estimates (Table 7) further showed that those reporting changed views in domestic travel due to COVID-19 scored higher on all the DVs, indicating that this traveler group had more HSR knowledge and higher intention to use both train and HSR in the post-pandemic era.

Similarly, respondents from the four geographical regions of the US (Northeast, Midwest, South, and West) differed significantly in HSR knowledge, travel habits, the likelihood to use trains, and the intention to use HSR. Close examination of the results revealed a pattern indicating generally higher scores from South and West regions than from Northeast and Midwest regions. To further identify which pair(s) of the geographic regions produced the significant difference(s), a post hoc analysis was performed. Table 8 shows the pairs of regions that differ significantly, supported by the mean differences. Consistent with the patterns observed in the univariate tests, the Northeast region (which had the lowest mean scores on all the DVs in the univariate test) differed significantly from the South and West regions (the regions with the highest mean scores in the univariate test), while the other pairs of the geographic regions showed no significantly different mean scores. This suggested that travelers coming from the Northeast region of the country have a significantly lower level of knowledge of HSR, the likelihood to use the train, and the intention to use HSR following COVID-19 compared to travelers from the South and West regions of the country.

Of the four DVs, only knowledge of HSR was significantly affected by the interaction effect of View_Change and Geo_Location. This suggested that the respondents' HSR knowledge level was determined by the combined effect of the IVs rather than any of them individually. In other words, the effect of View_Change (travelers changed their views on transport mode due to COVID-19) on the knowledge level of HSR depends on the geographic

Table 7

Mean Estimates - Univariate Test and Interaction Effect

Univariate Test		Geo				View	
		NE	MW	SO	WE	Yes	No
	KN	5.629	6.11	6.483	6.251	7.135	5.102
	LU	5.679	6.284	6.470	6.430	6.888	5.544
	HA	3.280	3.430	3.423	3.433	3.452	3.331
	BI	3.262	3.508	3.510	3.524	3.562	3.340
Interaction Effect[a]		Yes	No				
View and Geo on KN	NE	7.032	4.226				
	MW	6.777	5.443				
	SO	7.392	5.575				
	WE	7.339	5.163				

[a] : Only Significant Interaction Effect was Included; NE=Northeast; MW=Midwest; SO=South; WE=West.

Table 8

Post Hoc Analysis - Geo_Location with Mean Difference

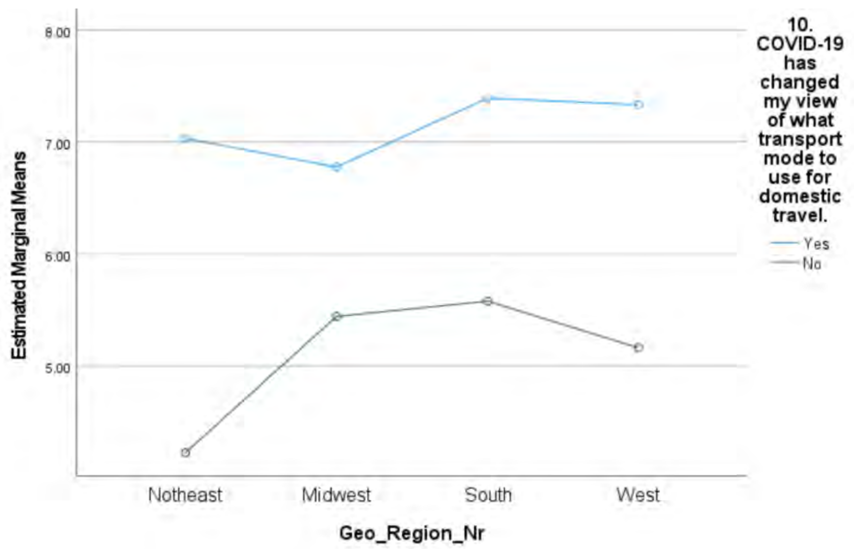
	NE/MW	NE/SO	NE/WE	MW/SO	SO/WE	MW/WE
KN	-.0626	-.6848**	-5.966	-.6222**	.0883	-.5340
LU	-.3291	-.7976**	-.7295**	-.4685	.0681	-.4004
HA	-.1031	-.1156**	-.1502**	-.0125	-.0346	-.0471
BI	-.1887**	-.2146***	-.2623***	-.0260	-.0477	-.0737

Notes: NE=Northeast; MW=Midwest; SO=South; WE=West.

locations of the travelers. Respondents who changed their views on what mode to use for domestic trips and lived in the South region of the country had the highest knowledge level of HSR, whereas those from the Northeast region with unchanged views of mode use for domestic travel (views not affected by COVID-19) had the lowest level of knowledge of HSR. Figure 9 shows the interaction effect of view change and geographic location factors on the HSR knowledge level of the respondents. An interaction effect between the two independent variables can be observed, with the South region in the view change group and the Northeast region in the no view change group representing the highest and the lowest mean values.

Figure 9

Interaction Effect of the Two Independent Variables on the Knowledge Level of HSR.



4.4. Segmentation of HSR Users – Cluster Analysis

4.4.1. Cluster Analysis – An Overview and Data Suitability

Cluster analysis is a grouping technique used to make sense of the data, especially for large datasets. The primary purpose of cluster analysis is to group objects based on their characteristics. This technique is data-driven, meaning the data is classified as suggested by natural groupings of the data themselves. The goal of the analysis is to group objects – e.g., products, survey respondents, or other entities – based on a set of preselected user characteristics to identify and assess the natural structure within the data (Hair et al., 2019). Indeed, cluster analysis is a form of exploratory data analysis to divide observations into meaningful groups that share common characteristics among each other. The group should be formed such that all members of a group are similar to one another, and at the same time, they are distinctively different from members outside of this group.

The two widely used clustering techniques are hierarchical clustering and non-hierarchical clustering. Hierarchical clustering generates classifications in a bottom-up manner to combine observations into a hierarchy or a tree-like structure. On the other hand, non-hierarchical procedures assign objects into clusters once the number of clusters is specified (Hair et al., 2019). As both hierarchical and non-hierarchical techniques have advantages and disadvantages, it is recommended that an approach combining both should be employed. This study adopted this strategy by (1) using a hierarchical technique to determine the optimal cluster solution and (2) using a non-hierarchical method to group the observations based on the selected clustering solution.

In this study, the purpose of the cluster analysis was to better understand the characteristics of HSR users in the US. This can be achieved by grouping potential HSR travelers into meaningful segments based on some important features of HSR users. Before starting the analysis, it is important to check data suitability for cluster analysis. There should not be missing data in the dataset, as missing data can complicate the application of clustering algorithms, leading to inaccurate clustering results. Also, the data should be collected from observations measured on similar scales. In addition, cluster analysis generally requires a large sample size. The issue of sample size in cluster analysis is not related to inferential statistics; instead, it is required because a large sample size is essential to provide a sufficient representation of small groups within the population, allowing the researcher to uncover the underlying structure of the data effectively (Hair et al., 2019). This study fully satisfied these data requirements, as the variables used for cluster analysis showed no missing values, the variables were measured using the same scale, and the sample size was large enough to provide meaningful representations of the groups identified within the data. Another data requirement for cluster analysis is the absence of multicollinearity, meaning the variables in cluster analysis should not be highly correlated. This data requirement was tested in Section 4.4.2..

4.4.2. Clustering Results – A Two-Stage Approach

Cluster analysis was performed to classify the survey respondents with similar characteristics. The focus was on finding clusters based on the HSR variables; that is, how did the respondents evaluate the use of HSR based on some key attributes of HSR? These attributes were measured in the survey and represented by five variables - perception of culture (CU), price (PR), total travel time (TT), safety (SA), and comfort (CO). Specifically, they represented respondents' evaluation of whether it's easy to change the air and car culture in the US (Culture), whether the price was an important consideration in choosing HSR (Price), whether the respondents value the time saving of HSR when total travel time, namely access time, pre-boarding time, train time, and egress time, were considered (Total Travel Time), whether safety record of train travel can motivate the use of HSR (Safety), and whether HSR travel was perceived as comfortable given large seats and leg room on the train (Comfort). These five variables were used collectively as the clustering variables in this study. Table 9 shows the descriptive statistics of these variables.

Table 9

Descriptive Statistics of the Clustering Variables

	CU	PR	TT	SA	CO
Mean	3.81	4.10	4.00	4.03	3.91
SD	0.95	0.83	.083	.082	.072
Min.	1	1	1	1	1
Max.	5	5	5	5	5
N	1033	1033	1033	1033	1033

Notes: CU=Culture (car and air); PR=Price; TT=Total Travel Time; SA=Safety; CO=Comfort; SD= Standard Deviation.

The mean and standard deviation scores in Table 9 indicated respondents' overall evaluation of the five HSR attributes on a five-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). The mean values can be described as moderately high, with the evaluation of the Price factor showing the highest mean score while that of the Culture factor showed the lowest mean score. Noticeably, the evaluation of the Culture factor demonstrated the highest standard deviation (0.95), indicating diverse perceptions of HSR in a country with a strong air and car culture. The evaluation of comfort showed the smallest standard deviation, indicating a relatively consistent evaluation of the perceived comfort of using HSR.

A two-stage cluster analysis was performed using both hierarchical and non-hierarchical techniques. Hierarchical clustering aims to find out previously undetected relationships within the dataset. This is achieved by repeatedly linking pairs of clusters until all the data values are included in the hierarchy. The final goal of this analysis stage is to identify a small subset of possible cluster solutions. Following these steps, the researcher selected the optimal cluster solution (the number of clusters to use) to organize the respondents into efficient segments that characterized the entire HSR users based on the collective use of five clustering variables – perception of culture (CU), price (PR), total travel time (TT), safety (SA), and the comfort (CO) in assessing the use of HSR. The SPSS output of the hierarchical clustering analysis was obtained in two forms - a dendrogram and an agglomeration schedule; both can be used to determine the optimal cluster solution given the data. The dendrogram, shown in Appendix B, shows the hierarchical relationship between the observations based on the joint use of the five clustering variables. From left to right, it appears reasonable to allocate the observations into three or four clusters. A similar pattern was observed when evaluating the agglomeration schedule, which is basically a numerical summary of the possible cluster solution. Focus should be given to the agglomeration coefficient in the schedule, which can be used to group observations based on similarity and dissimilarity between these observations. As a rule, a small coefficient increase indicates the merging of homogeneous clusters, and a large one indicates the joining of two very different clusters. As such, focus should be given to large percentage change across the coefficients to determine the optimal cluster solution (Hair et al., 2019). Table 10 shows the last six rows of the agglomeration schedule with the percentage change.

Table 10

Cluster Solution Comparison – Hierarchical Cluster Analysis

Stage	Number of Clusters	Coefficient	Increase in %
1027	6	1965.689	7.5%
1028	5	2113.799	8.3
1029	4	2288.856	10.2
1030	3	2521.195	13.4
1031	2	2858.335	25.3
1032	1	3581.789	

The largest percentage increase in agglomerative coefficient (25.3%) occurred when moving from Stage 1031 to Stage 1032 (the last two rows indicating moving from two clusters to one cluster), which appeared to suggest adopting a two-cluster solution. However, a two-cluster solution could not produce meaningful classification, as the cluster center for each cluster variable showed a similar score, as shown in Figure 10. The second largest percentage increase (13.4%) occurred when moving from Stage 1030 to Stage 1031 (moving from three clusters to two clusters). While this seemed viable, the three-cluster solution again produced homogeneous clusters (except for Cluster 2), as shown in Figure 11. It should be noted that the cluster analysis in this study aimed to group respondents with similar traits (in terms of the perception of transport culture, and price, safety, travel time, and comfort associated with HSR). Therefore, the chosen cluster solution must be able to produce traveler segments that demonstrate the unique characteristics of the travelers in each segment. Clearly, both the two-cluster and the three-cluster solutions failed to differentiate between the clusters when the five cluster variables were considered collectively, indicating that they lacked the capacity to capture the five variates' combined effect. A four-cluster solution, with a 10.2% value increase in agglomerative coefficient (moving from four clusters to three clusters), was then considered. The cluster center illustrated in Figure 12 indicates heterogeneous clusters, which aligned with the goal of identifying distinct clusters in this study. Because the four-cluster solution can better identify the structure in the data, it was accepted as the final cluster solution.

The researcher then performed non-hierarchical clustering (Stage Two of cluster analysis), using the K-means optimizing algorithm to re-assign observations to the four clusters until maximum homogeneity within clusters was achieved (Hair et al., 2019). An important data requirement for cluster analysis is the lack of multicollinearity, meaning the cluster variables should not be linearly and strongly correlated. The multicollinearity check was performed to obtain the Variance Inflation Factor (VIF*)* values. Since the VIF values for all the cluster variables (CU, PR, TT, SA, and CO) were lower than the recommended threshold of 5 (Hair et al., 2019), there was minimal concern about multicollinearity for the cluster analysis in this study.

Figure 10

Two-Cluster Solution – Cluster Center Illustration

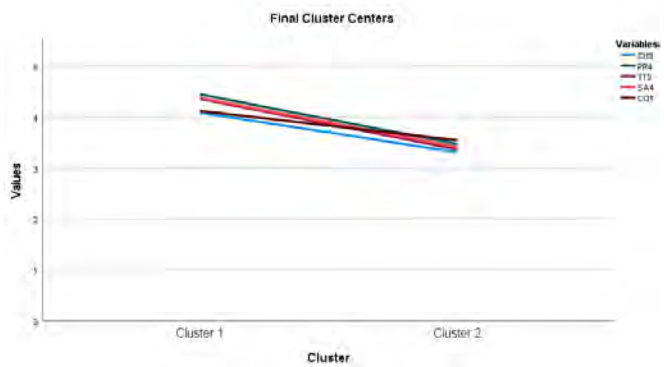


Figure 11

Three-Cluster Solution – Cluster Center Illustration

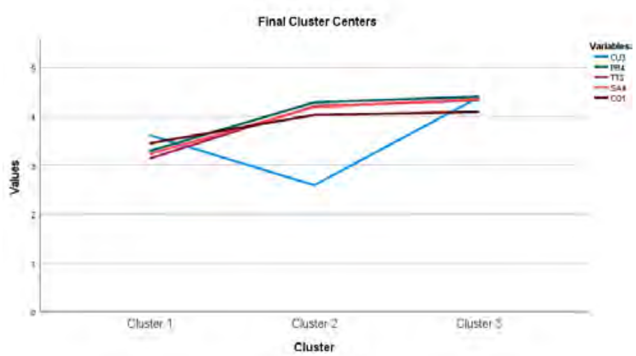


Figure 12

Four-Cluster Solution – Cluster Center Illustration

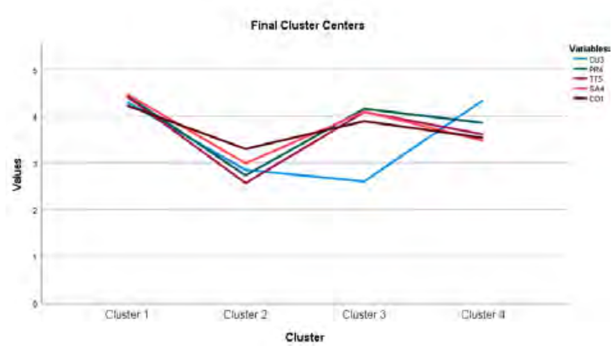


Table 11 shows the mean scores of the cluster variables across the four clusters. The values mirrored the illustration in Figure 12, indicating that the cluster solution can adequately discriminate between observations. The patterns observed in the cluster means were used to label the clusters.

Table 11

Four Clusters Based on Five Cluster Variables - Perception of Culture, Price, Travel Time, Safety, and Comfort

	Cluster One Balanced Group	Cluster Two Comfort First	Cluster Three Price Sensitive	Cluster Four Traditional Travelers	ANOVA	
Variables	n=482	n=85	n=230	n=236	F-ratio	Sig.
	47%	8%	22%	23%		
Culture	4.3	2.85	2.6	4.33	594.213	***
Price	4.43	2.73	4.15	3.85	163.059	***
Travel Time	4.41	2.56	4.08	3.61	245.667	***
Safety	4.47	2.99	4.09	3.47	205.263	***
Comfort	4.22	3.29	3.89	3.53	92.229	***

Note: *** = $p < .001$

Cluster One was the largest group, containing 482, 47% of the total respondents. It was the only group in which respondents assigned high values (> 4) to all the five cluster variables, suggesting a high level of perception (recognition) regarding price, travel time, safety, comfort, and transport culture associated with the use of HSR. As such, the name “Balanced Group” was used to label this cluster. Cluster Two was the smallest group, composing only 85 respondents (8%). It showed almost the opposite side of “Balanced Group” in that it assigned the lowest values to all the five cluster variables (at the 2-level on average except for the Comfort factor), indicating a relatively low perception (recognition) regarding price, travel time, safety, comfort, and transport culture associated with the use of HSR. The comfort of HSR was the only factor that was given a value at the 3-level, suggesting this cluster paid attention to comfort during an

HSR trip. Hence, the name “Comfort First” was used to label this cluster. Cluster Three (230 respondents, or 22% of the total sample) was similar to Cluster One (Balanced Group) because respondents assigned a high level of perception (recognition) to HSR features (with price being given the highest value), but different from Cluster One in that the score assigned to transport culture was only at the 2-level, the lowest among all clusters. Given the emphasis on the price factor of HSR, the name “Price Sensitive” can be used to describe Cluster Three. In Cluster Four, 236 respondents (23%) showed a moderate level of perception (recognition) concerning the four features (price, travel time, safety, and comfort) in the use of HSR. This cluster was unique in that respondents demonstrated a high level of perception (recognition) regarding the traditional transport culture in the US (the highest of all the clusters). This cluster is thus labeled “Traditional Travelers”. As shown in Table 11, the ANOVA tests were statistically significant, supporting the differences across the four clusters.

4.2. Validating and Profiling the Clusters

Given the exploratory nature of clustering analysis, cluster validation was used to evaluate the goodness of clustering algorithm results, using the demographic, travel, and HSR variables that were not involved in the clustering process. Twelve ordinal-categorical variables were selected for the crosstabs procedure to test the differences across the four clusters, shown in Table 12. The Chi-square analysis was performed on the relationship between these variables and the cluster membership. Significant Chi-Square values were obtained in eight of the twelve profile variables, generally supporting the differences between the clusters.

The Balanced group composed more males than females, with one-third of the respondents falling into the 21-30 years old category (33%). While this traveler segment contained more respondents between the ages of 51 and 60 compared with the other clusters, the

Table 12

Profiling the Clusters with Demographic, Travel Experience, and HSR Factors

Category	Cluster 1: Balanced Group (n= 482, 47 %)	Cluster 2: Comfort First (n= 85, 8%)	Cluster 3: Price Sensitive (n= 230, 22%)	Cluster 4: Traditional Traveler (n=236, 23%)	Chi-square X2	df	sig.
Gender							
Male	56%	62%	54%	55%	3.929	6	0.686
Female	43%	38%	46%	45%			
Age							
20 years or younger	1%	2%	0%	0%			
21-30 years	33%	48%	30%	32%			
31-40 years	27%	25%	28%	32%	27.68	15	0.024
41-50 years	19%	17%	26%	17%			
51-60 years	16%	6%	11%	15%			
Older than 60	4%	2%	5%	4%			
Education							
Lower than High School	1%	4%	0%	1%			
High School	13%	11%	12%	10%	26.896	12	0.008
Bachelor	59%	68%	70%	61%			
Master	25%	15%	16%	27%			
Higher than Master	2%	2%	2%	1%			
Income							
Less than $25,000	9%	12%	14%	13%			
$25,000 to 50,000	37%	40%	39%	35%			
$50,001 to 75,000	22%	25%	21%	19%	15.494	15	0.416
$75,001 to 100,000	22%	14%	18%	25%			
$100,001 to 125,000	7%	9%	5%	5%			
More than $125,000	3%	0%	3%	3%			
Ethnicity							
Black or African American	5%	5%	9%	4%			
Asian	6%	3%	6%	7%			
Hispanic or Latino	5%	1%	3%	4%	19.727	15	0.183
Pacific Islander	1%	0%	0%	1%			
White	81%	90%	80%	82%			
Native American	2%	1%	2%	2%			
Travel Frequency/Year Before COVID-19							
Less than 1 time	8%	21%	6%	13%			
1 time	19%	37%	18%	26%	49.668	12	***
2-3 times	32%	13%	30%	26%			
4-5 times	26%	21%	29%	26%			
Over 5 times	15%	8%	17%	9%			

Category	Cluster 1: Balanced Group (n= 482, 47 %)	Cluster 2: Comfort First (n= 85, 8%)	Cluster 3: Price Sensitive (n= 230, 22%)	Cluster 4: Traditional Traveler (n=236, 23%)	Chi-square X2	df	sig.
Travel Frequency/Year Since COVID-19							
Less than 1 time	12%	8%	10%	13%			
1 time	26%	54%	33%	33%	31.27	12	0.002
2-3 times	37%	17%	35%	31%			
4-5 times	17%	17%	14%	16%			
Over 5 times	8%	4%	8%	7%			
Purpose of Trip							
Leisure/Vacation	35%	26%	33%	32%			
Business	42%	52%	42%	43%	15.053	12	0.239
Visiting Family/Friends	20%	15%	22%	20%			
Study	3%	4%	2%	3%			
Others	0%	3%	1%	2%			
Mobility issue							
Yes	50%	72%	44%	47%	19.817	3	***
No	50%	28%	56%	53%			
Where are you from in the US							
Northeast	15%	36%	18%	19%			
Midwest	16%	14%	21%	21%	31.8	9	***
South	48%	36%	49%	42%			
West	21%	14%	12%	18%			
Source of HSR Information							
Social Media	31%	22%	31%	27%			
Visiting Family/Friend	24%	33%	23%	22%			
National News	20%	9%	25%	20%	39.292	21	0.009
International News	10%	17%	7%	7%			
Government	4%	6%	4%	7%			
Other Sources	3%	4%	4%	2%			
Not Getting HSR Info	8%	9%	6%	15%			
Intermodal Choice							
Air	22%	29%	21%	28%	20.666	6	0.002
HSR	70%	53%	71%	59%			
CAR	8%	18%	8%	13%			

age distribution was overall more balanced. Similarly, while most respondents possessed a bachelor's degree and earned between $25,000 and $50,000 (59% and 37%, respectively), the overall educational and income characteristics were more balanced compared with other segments in this study. Eighty-one percent of the respondents were White in the balanced group, and the portion of Hispanic or Latino (5%) was slightly higher compared to other segments. Exactly half of the respondents reported having mobility issues for themselves or their family members. The balanced group had the lowest percentage of respondents from Northeast (15%) and the highest percentage (21%) from West of the country. For the two travel-related questions, the balanced group indicated two to three times as the highest travel frequency before and after the COVID-19 pandemic (32% and 37%, respectively). More respondents traveled for non-business purposes (58%) than business purposes. More respondents reported obtaining HSR information from social media, followed by family and friends, and then national news. A large portion of the respondents in this group selected HSR to travel between LA and SF (70%), while only 8% chose a car as the transport mode.

Comfort first segment was most gender imbalanced, with the gender ratio of 62% males to 38% females. Almost half of the respondents were aged between 21 and 30 (48%), and the portion of respondents aged 51 or older was the lowest among all the segments. A bachelor's degree and a salary range of $25,000-$50,000 were the most selected categories, and the Comfort First segment also had the highest percentage of respondents earning salaries between $100,001 and $125,000. Regarding racial composition, this segment had the highest number of White respondents and the lowest number of Asian, Hispanic, Latino, Pacific Islander, and Native American respondents. Seventy-two percent of the respondents reported having mobility issues regarding themselves or their family members, much higher than those reporting no mobility issues. Unlike the Balanced Group, most respondents in the Comfort First group came from the Northeast (36%) and South (36%) regions of the country. These respondents appeared to be non-frequent travelers, with once a year being the most reported travel frequency both before and after the COVID-19 pandemic (37% and 54%, respectively). Over half of the respondents (52%) traveled for business purposes. Regarding the source of HSR information, 33% of the respondents obtained the information from friends, family, classmates, and coworkers, and 22% from social media, followed by international news (17%). Only slightly over half of the Comfort First Group (53%) chose HSR for the trip of LA-SF. This segment had the lowest number of respondents choosing HSR and the highest number of participants selecting air and car among all the clusters in this study (29% and 18%, respectively).

Price Sensitive segment consisted of more males than females (54% vs. 46%). There were similar numbers of respondents in the 21-30, 31-40, and 41-50 age categories, compared with the other segments in which respondents mostly fell within the 21-40 years old range. Seventy percent of the respondents possessed a bachelor’s degree, the highest among all the segments. While more respondents in this segment earned between $25,000 to $50,000 (39%), a similar pattern that was observed in the other segments; the Price Sensitive group had the highest percentage of respondents earning lower than $25,000 salaries among all segments. While most respondents were White (80%), 9% of respondents were Black or African American, the highest percentage among all segments. Unlike Balance Group and Comfort First Group, most Price Sensitive respondents reported no mobility issues regarding themselves and their families (56%). This segment also had the highest number of respondents from the South region (49%) and the lowest from the West region of the country (12%). Two to three times were the most reported travel frequency for respondents in the Price Sensitive segment (30%), and this group also had the highest percentage of respondents traveling four to five times (29%) and over five times (17%) before COVID-19 pandemic compared to the other segments. Price Sensitive Group obtained HSR information mainly from social media (31%), followed by national news (25%), and then family/friends/classmates/coworkers (23%). It had the highest portion of respondents choosing HSR for the trip between LA and SF (71%) among all segments and the lowest number of respondents selecting air and car (21% and 8%, respectively).

The Traditional Traveler segment contained more males than females (55% versus 45%). Nearly one-third of the respondents (32%) fell in the age groups of 21-30 and 31-40 years old, respectively. While 61% of the respondents had a bachelor's degree, which aligned with the patterns observed in the other segments, the Traditional Traveler segment showed the highest number of respondents who owned a master's degree (27%). Slightly more than one-third of the participants earned salaries between $25,000 and $50,000 (35%), while a quarter of the participants (25%) earned between $75,000 and $100,000, the highest percentage among all segments. Eighty-two percent of the respondents were White. Only 4% were black or African American, which was lower compared with the other segments. More respondents reported no mobility issues regarding themselves and their families compared to those who reported having mobility issues (53% versus 47%). Regarding the geographic location, 42% of the participants came from the South region of the country, while the rest were roughly evenly distributed among the Northeast, Midwest, and West regions. Again, more responders received HSR information from social media (27%), followed by family/friends/classmates/coworkers (22%), then by national news (20%). Noticeably, 15% of the respondents in the Traditional Traveler segment reported not receiving any HSR information, which was much higher compared with other segments. With respect to the intermodal choice, HSR was the most selected mode for the LA-SF trip, but there were relatively large numbers of participants choosing air and cars (28% and

13%), especially compared to the Balanced and the Price Sensitive segments. Table 13 summarizes the traveler characteristics of the four segments.

Table 13

Traveler Characteristics of the Four Clusters – Potential HSR Travelers

Cluster	Demographic Characteristics	Travel Characteristics	HSR-Related Characteristics
Cluster 1: Balanced Group	• More males than females, mostly young respondents • Mostly bachelor's degree, with low to moderate incomes • Predominantly White, and the highest number of Hispanic or Latino. • Highest number of respondents from South, and lowest number from Northeast of the country • Half respondents reported mobility issue in travel	• Moderate frequent travelers, with 2-3 times annually • Primarily non-business purposes	• Sources for HSR information in the order of importance – social media, family/friends/ classmates/coworker, national news. • Mostly selected HSR for LA-SA, followed by air, then car
Cluster 2: Comfort First	• The most gender imbalanced group – more males than females, and the youngest of all segments • Mostly bachelor's degree, with low to moderate incomes • The largest portion of Whites of all segments, and the lowest number of Asian, Hispanic or Latino, Pacific Islander, and Native American • More respondents reported mobility issue than those who did not • The highest number of respondents from Northeast	• Non-frequent travelers – mostly once a year • More for business than non-business purposes	• Sources for HSR information in the order of importance – family/friends/ classmates/ coworker, social media, international news • Slightly over half of the respondents selected HSR, the lowest of all segments. • The highest numbers of respondents selected air and car of all segments

Cluster	Demographic Characteristics	Travel Characteristics	HSR-Related Characteristics
Cluster 3: Price Sensitive	• More males than females, mostly young- and middle-age. • The highest number of bachelor's degree, and low-to moderate incomes. • Predominantly White, also the highest number of Black or African American. • More respondents reported no mobility issues than having mobility issues. • The highest number of respondents from South, and lowest number from West.	• Frequent travelers with mostly 2-3 trips annually. • Primarily for non-business purposes.	• Sources for HSR information in the order of importance – social media, national news family/friends/ classmates/coworker. • The highest number of respondents choosing HSR for LA-SA, and the lowest numbers for choosing air and car.
Cluster 4: Traditional Travelers	• More males than females, mostly young respondents. • Mostly bachelor's and master's degrees, with low to medium incomes. • Predominantly White, with lowest number of Black or African American respondents. • More respondents reported no mobility issues than having mobility issues. • More respondents from South than other regions.	• Low to moderate travel frequency. • Primarily for non-business purposes.	• Sources for HSR information in the order of importance – social media, family/friends/ classmates/coworker, national news. • HSR was the top choice for the LA-SF trip, but considerable respondents selected air and car.

5. Discussion

More males than females participated in the survey, and more respondents were White adults compared with other ethnic groups. The participants were generally younger, received more education, and earned less income than the national average (US Census, 2022b, c). Most traveled three times or less each year, primarily for personal purposes (leisure, vacation, and visiting family and friends). Surprisingly, 80% of the respondents traveled by train at least once over the past five years, and over half of them traveled two times or more, which differed from the general perception of lacking rail experience in the US. Noticeably, half of the respondents reported having mobility issues concerning themselves or their families, which aligned with the government statistics on mobility issues in the country (CDC, 2020). Respondents demonstrated a strong recognition of the impact of COVID-19, with nearly 70% claiming that COVID-19 changed their view of what transport mode to use for domestic travel. Respondents obtained HSR information mostly from social media, followed by sources of family, friends, and co-workers. Only one-third of the respondents received HSR information from national/international news or government agencies, and 9% indicated they had not received any information about HSR. This suggests HSR information is not widely available in the US, especially from formal government sources. This study performed three sets of analyses to understand the potential use of HSR from travelers' perspective. Sections 5.1, 5.2, and 5.3 discuss the findings.

5.1. Intermodal Choice – Logistic Regression Analysis

When choosing from air service, HSR, and cars to travel between LA and SF, two-thirds of the respondents preferred to use HSR, indicating potential interest in HSR service in the US. All factors except for age were significant in the intermodal choice, and more factors were found to impact HSR-air choices than HSR-car choices, likely indicating a stronger competition between air and HSR in the high-demand market. Convenience in transport and travel frequency were two major predictors in the choice between air transport and HSR. The importance of the convenience factor is supported by the HSR literature (Givoni & Banister, 2012). This suggested that travelers in mega metropolitan areas like LA and SF value the central location of HSR station, easy and quick access to HSR facilities, and flexible, well-connected public transport to the train station, which can become an important motivator in the choice between HSR and air service. Travel frequency was another significant factor, indicating that higher travel frequency (twice or more per year) was associated with a greater likelihood of choosing HSR over air. The finding could be related to the convenience of using HSR, which makes HSR a reasonable choice when travel frequency increases. Gender was another important factor in the intermodal choice, with female travelers being more likely to choose HSR over air service in the LA-SF market. The finding was consistent with the gender differences in mode choice identified in previous studies, suggesting that gender-based differences exist in mode choice, and females exhibited greater preference for HSR than males (Ren et al., 2019). Mobility issue was also a significant predictor of the intermodal choice. The findings indicated that travelers with mobility issues were more likely to choose HSR over air transport, which was not surprising due to the user-friendly nature of train transport. With easy access to the train station, simple station procedures, and spacious train cabins to move about freely, HSR can provide greater accessibility and simplicity over air transport, driving the mode choice of travelers with special needs. Finally, travelers' decision between air and HSR was affected by total travel time, which was supported by the literature (Behrens & Pels, 2012; Fu et al., 2012; Valeri, 2014). The finding of this study suggested that travelers in the US value the total time saving of HSR, which can drive the decision to choose HSR, especially on short- and medium-haul routes.

The choice between car and HSR was affected only by travel frequency and total travel time, making the comparison relatively straightforward. Only one category of travel frequency (4-5 times annually) significantly affected the intermodal choice. This suggested that, while travel frequency influenced the choice between air, HSR, and cars, it had less impact on the choice between cars and HSR than on the choice between air and HSR. Total travel time was the other significant predictor of the choice between car and HSR, which is well-expected. With the speed acceleration (less than three hours from station to station on the LA-SF route) and convenient locations, HSR can provide greater time-saving benefits than cars (six hours in driving), which can drive the mode shift from cars to HSR. Overall, the logistic regression analysis showed that travelers would focus on different factors when choosing from air, HSR, and cars to travel from LA to SA. While the decision-making between HSR and cars was relatively straightforward, the choice between air and HSR was affected by multiple factors, indicating potential strong competition between air service and HSR when HSR enters the LA-SF market.

5.5. Group Comparison – MANOVA Analysis

A MANOVA analysis was performed to test the main and interaction effects regarding two independent variables (View Change due to COVID-19 and Geographic locations of respondents) when four dependent variables (HSR knowledge, travel habits, the likelihood to travel by train, and the intention to use HSR) were considered collectively or individually. The survey revealed a great impact of COVID-19 on the perception of domestic travel, with over two-thirds of the respondents reporting a change in the view of what transport mode to use due to COVID-19. This implies opportunities for new transport modes, such as HSR, to gain success in the US market. The view change and the geographic location of travelers significantly influenced the travelers' HSR knowledge, travel habits, the likelihood to travel by train, and the intention to use HSR in the post-pandemic era. With respect to view change, the findings showed that the respondents who had changed their view of mode use due to COVID-19 were more knowledgeable of HSR, had different travel habits, were more likely to travel by train, and had higher intention to use HSR compared to respondents whose view of mode use was not affected by COVID-19. The findings were important and timely as they connected COVID-19, travel behaviors, and HSR to provide empirical evidence of how COVID-19 can reshape travelers' perceptions and intentions toward HSR in the US. It is likely that many travelers in the US feel strongly about the impact of COVID-19, and they have changed their view of what mode to use for domestic travel. These people are generally more curious and open-minded regarding HSR, as demonstrated by their greater knowledge level and intention toward HSR. Thus, this new traveler segment is likely to strongly support HSR in the US, as they may perceive HSR as a safer and more suitable transport mode to meet their travel needs domestically in the post-pandemic era.

Concerning the geographic location, the findings revealed clear geographic patterns regarding the travel and HSR characteristics across the four geographic regions (West, Midwest, South, and Northeast as defined by the US Census). While travelers in the four regions demonstrated similar travel habits, the Northeast and Midwest regions generally scored lower in HSR knowledge, likelihood to use trains, and the intention to use HSR, compared to the South and West regions. The major differences appeared between the Northeast, South, and West regions. Travelers from the Northeast region exhibited the lowest scores in all travel and HSR characteristics in this study. Specifically, its scores on the likelihood of using trains after COVID-19 and intention to use HSR were significantly lower than those from the South and West regions. It appeared that, while the Northeast corridor operates the fastest rail system in the US, travelers in this region had less HSR enthusiasm than travelers in the South and West regions. The finding may be partially explained by the more rapid population growth in the South and West compared to the Northeast and Midwest, which could increase the interest and intention regarding HSR (Bounoua et al., 2018). The mixed experience of the train ridership with

Amtrak in NEC may also explain the finding. Currently, train service in some sections of Amtrak's Acela line can reach 150 miles/hour, making it arguably the only HSR in the country. However, Acela's average speed was around 79 mph due to infrastructure constraints (Kamga, 2015). With the low average speed, the time benefit of using HSR diminishes, which could contribute to misunderstanding and lower interest in HSR. On the other hand, the HSR project in the West region has been built and promoted with a much-improved speed (217 mph/hour), allowing for travel between LA and SF in under three hours. This may have successfully enhanced HSR enthusiasm and anticipation in this region.

As indicated by the interaction effect between view change and geographic locations, travelers' knowledge level of HSR can be best explained by the combined effect of the two factors instead of individually. In other words, whether or not the view change in mode use affects the knowledge level of HSR depends on where the traveler comes from (geographic locations). The finding indicated that among travelers whose view of mode use has been changed by COVID-19, those from the South region reported the highest level of HSR knowledge. In contrast, those from the Midwest region showed the lowest level of HSR knowledge. This was consistent with the greater intention to use HSR in the South region, as identified earlier, indicating that travelers with greater intention to use HSR would exhibit greater interest in learning about HSR. Among respondents whose views were unaffected by COVID-19, respondents from the South region remained the most knowledgeable of HSR, while those from the Northeast region were the least knowledgeable. It appears that travelers from the South region have the highest level of HSR knowledge in the country. Unlike travel habits, the likelihood to travel by train, and intention to use HSR, the forming of HSR knowledge appears to be more complicated and influenced by a combination of different factors.

5.3. Potential Segments of HSR users – Cluster Analysis

To further understand potential HSR users in the US, a cluster analysis was performed to group HSR users into meaningful segments based on the collective use of five HSR and transport attributes, including consideration of transport culture in the US, HSR price, travel time, safety, and comfort characteristics. The results uncovered four distinct segments within the data set – Balanced Group, Comfort First, Price Sensitive, and Traditional Travelers. The segmentation enabled the researcher to identify hidden patterns and unique characteristics associated with these subgroups that might otherwise go unnoticed from a superficial examination of the data.

Balanced Group was the largest segment, consisting of nearly half of the total respondents. A unique characteristic of this traveler segment was the high level of consideration of all the cluster variables used for analysis. This can be seen by respondents assigning a 4-level of agreement to all cluster variables. It appeared that respondents in this segment preferred a comprehensive consideration of multiple factors and a balanced view when selecting HSR for domestic trips, especially in terms of speed and efficiency, cost and affordability, and safety and reliability of HSR. They tended to choose a transport mode that can provide a time-efficient journey compared to other mode options, and they were attracted by HSR's ability to offer quick and direct connections between major cities. The cost of HSR travel was another important factor. Respondents in the Balanced group tended to consider the affordability and value of money of HSR travel, likely considering ticket prices, potential discounts, and any additional fees or charges, especially compared to alternative transport modes. The Balanced Group segment assigned the highest value to the safety of HSR, indicating that safety was a crucial consideration for travelers to choose HSR. Clearly, travelers in this segment recognized the satisfactory safety record of HSR and were likely to prioritize HSR over other transport modes.

Overall, Balanced Group, as the name implies, is likely to represent travelers who have developed a balanced view of HSR, with a clear focus on the price, travel time, and safety factors in using HSR for domestic travel.

The comfort First group was the smallest segment in this analysis, exhibiting some unique characteristics. Respondents in this segment gave a low level of consideration of the cluster variables except for comfort. In other words, Comfort First travelers would not focus on some of the key factors often associated with HSR travel, such as price, speed, and safety, but instead only pay attention to the comfortability of travel when selecting HSR. Some characteristics of the respondents in this segment may explain the preference for the Comfort First group. This group was the least frequently traveled group of all the segments, and it was the only group that traveled more for business purposes than non-business purposes; both could make the respondents in this group put a higher requirement on comfort in travel than other groups. More importantly, in this segment respondents with mobility issues outnumbered respondents without mobility issues, making travel comfort a much more important factor compared to Balance and Comfort First groups.

The Price Sensitive group was composed of nearly a quarter of the total respondents, and it assigned the highest value to the price of HSR, hence the name Price Sensitive Travelers. It means that travelers in this segment would attach much greater importance to price than other factors. Noticeably, Price Sensitive travelers assigned the lowest value to transport culture considerations – much lower than the average value assigned to the price, travel time, safety, and comfort factors. This likely indicates a high level of disagreement with the transport culture impact when HSR starts operation in the US. The transport culture in this study referred to the unique air and car culture (Kamga & Yazici, 2014), which has been dominant in the US for decades and may present a barrier to public acceptance of passenger rail transport. The low value assigned to the culture factor in this segment may suggest that Price Sensitive travelers did not view the transport culture (air and car culture) as a strong influence on their use of HSR. In other words, they were open to the change that was brought by the introduction of HSR to the US market.

Lastly, the Traditional Travelers group assigned moderate values to the HSR-related attributes (price, travel time, safety, and comfort) and a high value to transport culture consideration. This means that respondents in this group, while giving a moderate consideration of the price, speed, safety, and comfort factors of HSR, focused substantially on the cultural impact on transportation in the US. They appeared to strongly believe that the use of HSR should be evaluated within the traditional transport system, which has been uniquely shaped by the air and car culture in the US. They believed that car and air travel will continue to play a dominant role in the transportation landscape, which must be considered first when adopting and utilizing HSR in the US.

6. Conclusions

With the renewed discussion, HSR has been given new opportunities in the US. This study investigated HSR from the traveler’s perspective, mainly focusing on travelers’ choice among air transport, HSR, and cars in the highly competitive LA-SF corridor. The impact of COVID-19 on travel and HSR characteristics was explored, especially regarding the travelers’ geographic locations. Potential HSR travelers were further examined by creating segments based on attributes associated with the use of HSR. There were three major findings from the analyses of logistic regression, two-way MANOVA, and cluster analysis, including 1) convenience in transport, travel frequency, income, gender, mobility issues, and total travel time were key determinants of the choice between air, HSR, and cars in the LA-SF market, though they affected choice in different ways due to the specific mode characteristics. Convenience in transport and travel frequency were major factors in the decision between air and HSR, while the choice between cars and HSR was mostly influenced by travel frequency and total travel time; 2) Most travelers have changed their view about which transport mode to use for domestic travel as a result of COVID-19, and they were more likely to travel by train and had a greater intention to use HSR in the post-pandemic era. In addition, travelers from the northeast region had significantly less intention to use either train or HSR compared to travelers from the southern or western US. Finally, neither change in view nor geographic location could individually affect the travelers' knowledge level of HSR; rather, the knowledge level is determined by both factors. Travelers from the southern US reported the highest level of HSR knowledge, while travelers from the Northeast and Midwest were least knowledgeable of HSR; 3) With the collective use of five HSR and transport attributes, including considerations of transport culture and prices, travel time, safety, and comfort of HSR, four segments were created using the survey data, namely Balanced, Comfort First, Price Sensitive, and Traditional Traveler segments. The Balanced group tended to provide a comprehensive evaluation of all the five transport and HSR attributes and to strike a balanced view toward introducing HSR as a new transport mode to the US. The Comfort First group focused almost exclusively on comfort in travel, likely due to mobility issues reported by members of this segment, among other reasons. Price Sensitive group attached the greatest importance to HSR prices, and they were open to accepting HSR as a new addition to the transport system in the US. Lastly, the Traditional Traveler group was most focused on the predominant air and car culture in the US, and this group is likely to have some doubt of the public acceptance of HSR due to the unique cultural impact in the US.

This study contributes to the HSR literature in two important ways. While the choice between HSR and other transport modes has been frequently studied in other countries, little research has been conducted on mode choice involving HSR in the US. Most of the literature on HSR in the US is exclusively focused on policy and economic aspects, and travelers' perspective is rarely considered. Thus, the findings in this study on the key determinants of choice between air, HSR, and car, as well as the segmentation of potential HSR users, can fill this research gap. The findings also reveal significant associations between COVID-19, HSR use, and geographic patterns in the US. To the best of our knowledge, this is the first study to examine HSR use in the broad context of COVID-19 in the US. The finding of the impact of COVID-19 on the potential mode shift, together with the geographic patterns of HSR intentions, significantly enhanced the understanding of the interest and intention toward HSR, especially given the long-time debate of whether HSR is a suitable transport mode in the US.

At a practical level, the findings of this study provide useful implications for HSR providers and government agencies to ensure the success of HSR in the US, which is particularly valuable given the long-time controversy over HSR development in the country. First, the survey revealed a preference for HSR over air and cars in the LA-SF corridor, where HSR operations may begin in the near future. This suggests a positive attitude and possible public acceptance toward HSR, which is essential for the success of HSR in the US. Specifically, the respondents cited convenience and total travel time as significant factors for their mode choice, which can inform strategy formation in the competitive transport market. An important implication is that HSR should be promoted primarily based on user convenience (e.g., quick access, simplified station procedure) and shortened total travel time (as a result of convenience locations and speed acceleration) to increase public acceptance of HSR. Second, understanding which demographic segments are more likely to choose HSR is critically important for HSR's success in the US. The findings on the gender and mobility factors imply that efforts should be made to promote HSR to female travelers and travelers with mobility issues to broaden the customer base. Third, the findings reveal that COVID-19 has changed the view of many travelers in the US regarding their transport mode for domestic travel, and travelers now have a greater intention to use HSR. The post-pandemic views offer a potential opportunity for successful market entry and a greater public acceptance of HSR in the US. From these findings, the government and HSR providers should promote HSR as a safe, hassle-free, and less crowded travel option to accommodate travelers' mode preference in the post-pandemic era. Fourthly, the geographic patterns identified in this study indicate an uneven interest and intention to use HSR across the US. Therefore, efforts should be made to promote HSR, especially in the northeast region where interest and intention to use HSR are low. Reliable information, especially from government sources, is essential for increasing the interest in HSR. This is particularly relevant given the limited information on HSR available to the US general public. Lastly, understanding potential HSR user segmentation in the US can assist in marketing and customer service efforts targeting different HSR traveler segments. For example, knowing that travel comfort is a significant consideration for travelers in the Comfort First segment, likely due to reasons such as mobility issues, HSR operators can develop strategies to improve traveler comfort and relaxation, which can directly impact user satisfaction, loyalty, and the overall appealing of HSR in the US.

This study has some limitations. The convenience sampling method and the cross-sectional nature of the survey design may limit the generalizability of the findings, especially to HSR users outside the US. Also, survey data collected from MTurk is typically skewed toward younger, more educated, and lower-income participants. In addition, to estimate a comprehensive model predicting intermodal choice, the researcher selected factors from multiple categories for greater coverage while keeping the number of predictors manageable. Consequently, some factors that might influence the mode choice may not have been included in the model. Future research can build and expand on the findings of this study, and more factors, especially comfort and price of HSR, can be added to the model to enhance the overall findings. Researchers should also continue exploring the direct impact of the pandemic on the intention to use HSR. As HSR is a new phenomenon in the US, and the literature, especially from the travelers' perspective, is limited, the findings of this study can provide a meaningful starting point for researchers and travelers to re-think the preferred modes of domestic travel in the post-pandemic era.

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Appendix A

Data Collection Device

Here is a brief introduction of HSR in the US:
Currently, the Northeast Corridor (Boston - New York - Washington DC, 457 miles) is the only route that provides high-speed rail service. However, only on some part of this route can the maximum speed reach 150 miles/hour. Dining and WiFi are available onboard the train.
The much-anticipated high-speed rail line - San Francisco-Los Angeles, 350 miles - is currently under construction. With a much higher maximum speed of 217 miles/hour, it will run from San Francisco to the Los Angeles basin in **under 3 hours** (station to station time). By comparison, flight time on this route is about 1**.5 hours** (airport to airport time). More high-speed rail lines with maximum speeds over 200 miles are under planning throughout the US.
Now think about this new transport mode – do you intend to use high-speed rail for travel within the US if it become available to you? We are particularly interested in the factors that would affect your decision to use high-speed rail. Please evaluate the following statements using a five-point Likert scale, from strongly disagree to strongly agree.

Construct	Scale Item	
Total Travel Time	TT1	Total travel time consists of access time, pre-boarding time, onboard time, and egress time, and therefore it's a better way to estimate travel time for a trip
	TT2	When choosing a transport mode, I consider the time spent on the entire trip rather than only onboard the vehicle
	TT3	When total travel time is considered HSR is an attractive way to travel
	TT4	When total travel time is considered, HSR can compete with air travel on short- and medium- distance routes
	TT5	I value the time-saving benefit of HSR when total travel time is considered
Convenience	CN1	Train station is easy to access
	CN2	Train station is quick to access
	CN3	Train station is well-connected with public transport
	CN4	Train station is often conveniently located in/near the city center
Habit	HA1	I frequently use the same transport mode
	HA2	When making travel decision, I quite happily work within my comfort zone rather than challenging myself
	HA3	I tend to stick with the transport mode that I am familiar with
	HA4	My past travel experience has a large influence on my new trip decisions
Behavioral Intention	BI1	I intend to travel by HSR
	BI2	My intention to use HSR is hight
	BI3	I intend to use HSR whenever it's available
	BI4	I intend to use HSR frequently
	BI5	I intend to recommend HSR to others

Appendix B

Dendrogram Illustration.