# The Impact of Car-Centric Infrastructure on Public Transit Systems in the United States

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**Reese Jandrey Hertel**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor

Rider W. Foley, Department of Engineering and Society

## Introduction

In *Where we want to live: Reclaiming infrastructure for a new generation of cities*, author Ryan Gravel remarks on how his time studying abroad in Paris made him appreciate how transportation infrastructure constructs our way of life (2016). This message resonated with me because I had a similar epiphany while studying abroad in Valencia, Spain. Using transportation methods other than cars allows for greater connections between people and their environments. Cars isolate individuals, whereas alternative forms of transportation like walking, biking, or using public transit foster connections and interactions among people.

During the 20th century, the United States experienced a rapid change in transportation modes. The automobile began to be manufactured in volume in 1910 when Ford started producing the Model T at their Highland Park factory (Flink, 1972). Manufacturing innovations such as the moving-belt assembly line, which was implemented in the factory in 1913, played an important role in allowing Ford to begin the first mass production of automobiles in the United States (ibid). American car ownership rates changed drastically throughout the 20th century, growing from 8% in 1920, to 91.7% in 2022 (Ostermeijer et al., 2022; U.S. Census Bureau, 2023). The rise of the automobile led to changes in transportation behaviors and government transportation spending, upending existing transportation systems across the country.

In 2019 just 5% of all U.S. workers traveled to their workplace via public transit, whereas 75.9% drove alone (Burrows et al., 2021). Figure 1 shows how this proportion varied greatly depending on the density of one's environment. U.S. cities focusing on public transit have seen notable success, such as New York City, where 55.6% of commuters opted for public transit (ibid). Nonetheless, the proportion of U.S. commuters who use public transit services remains extremely low compared to those that use cars.

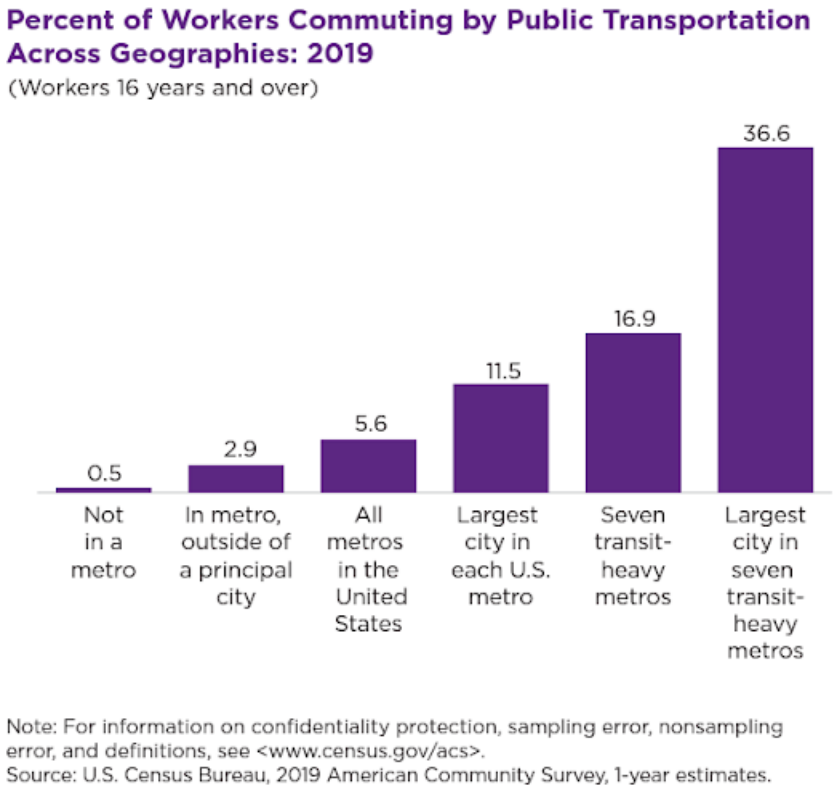


**Figure 1.** Percent of workers commuting by public transit: 2019 (U.S. Census Bureau, 2021)

Buehler (2009) found that neighborhoods and areas featuring mixed land uses and higher population densities experienced decreased car usage by their residents. This is because areas with mixed-uses allow residents to be less car dependent due to being denser and more walkable than single-use neighborhoods. Pedestrians should come first when planning for travel because pedestrian activity benefits physical health, mental health, and reduces environmental impacts (Barton et. al., 2021).

The design of the built environment has a profound impact on people's daily lives, particularly in how they move about. Transportation infrastructure plays a crucial role in enabling this movement. This thesis will examine how elements of infrastructure have led to car dependence within the U.S. and two case studies will be used to examine public transportation systems of varying success levels.

**Shifting Gears: Transitioning Towards Human-Oriented Designs**

U.S. cities contain diverse transportation infrastructure, which is essential for fostering economic growth, enhancing mobility, and elevating quality of life (Cervero, 2009). The streetscapes of many U.S. cities are composed of infrastructure designed for cars, rather than people. Nonetheless, new types of street designs that are not car-centric have gained popularity in recent years. These streets are characterized as being multimodal, meaning that they comfortably accommodate multiple modes of transportation and consider all types equally (Gupta & Terzano, 2008). This doesn't necessarily imply the exclusion of cars, but rather emphasizes the preference for transit and support for pedestrians through wide sidewalks, medians, and crosswalks. These new street design styles are changing the way that humans interact with their built environments and are challenging transportation norms.

One approach to understanding the connections between humans and technology employs Star's (1999) theory of infrastructure. This theory relates infrastructure to a variety of dimensions that can be used to understand a technology's role in society. One assertion of this framework is that infrastructure ties into existing systems, also known as the "installed base" (Star, 1999). As new pieces of infrastructure are added to the built environment they interact with existing infrastructure. One way that this applies to development relates to how new infrastructure connects to existing transportation systems. When considering adding a bike lane to an area, it must be evaluated with respect to how it will fit into the existing biking infrastructure. Adding one bike lane will not increase bikeability unless it is part of a broader network of biking infrastructure (Codina et al., 2022). This principle applies to all forms of transportation systems and shows how existing transportation infrastructure impacts how users interact with new transportation systems.

Another facet of Star's framework is infrastructure's relation to existing customs or "conventions of practice." This includes the customs and practices that play an important role in shaping infrastructure, while simultaneously being shaped by it. One of the biggest challenges in creating public transit systems in new markets is generating ridership (Dunphy, 2007). Most people in the United States are accustomed to using automobiles as their form of transportation, and just 5% of workers commute using public transportation (Burrows, 2021). The United States' reliance on cars is greater than that of other developed nations as less than 5% of all trips in the United States are taken using bus or train. One reason for this trend is that most U.S. cities have been designed for cars, rather than pedestrians or public transportation networks. Greater car ownership rates create higher demand for parking, which creates a positive feedback loop further entrenching cars into infrastructure systems.

Communities become familiar with new infrastructure through exposure, which can lead to changes in behavioral patterns. For example, an individual is more likely to use the bus if they live in a neighborhood with signage that the bus passes directly through, compared to an identical individual who is not exposed to signage and lives farther away from the bus stop. Behavioral patterns are also influenced by those around you. Foreign-born urban residents are more than twice as likely to regularly use public transportation compared to their American-born counterparts (Anderson, 2016). These foreign-born residents were likely members of societies that utilized public transportation at higher rates, so they were more familiar with these types of infrastructure systems and were surrounded by others who used them.

According to Jacobsen (2017), both presences and absences should be considered when examining social and political dimensions of infrastructures. During the first half of the 20th century, a group led by car manufacturer General Motors purchased and destroyed electric

streetcar systems across the U.S. (Purcell, 2000). This dismantling of public transportation systems has led to transportation infrastructure that is absent of transportation options other than cars (ibid). By removing access to these transportation alternatives, automobile companies increased reliance on cars, which helped form conventions of practice favoring car use, further ingraining automobile reliance into American culture.

**Historical Background of U.S. Public Transit Systems**

In some parts of the United States the low rates of public transit usage are the direct result of a lack of supply. The American Public Transportation Association (APTA) estimates that as of 2019, 45% of Americans did not have access to public transportation (APTA, 2024). Despite this, nearly all Americans live in areas that have access to public roads or highways. One reason for this difference in accessibility can be attributed to disparities in government spending. Most government spending on transportation in the United States is made by state and local governments, making up roughly 90% of all transportation expenditures (U.S. Department of Transportation, 2024).

From 1982 to 2019, the federal government approached transportation spending with the "80-20 approach", allocating about 80% of transportation funds to highways and 20% to public transit (Duncan, 2021). A dramatic shift occurred in 2021 with the passing of the Bipartisan Infrastructure Law, which allocated $89.9 billion for public transit, the largest investment in public transit in U.S. history (The White House, 2021). Despite the increase in federal public transportation spending that occurred following the Covid-19 pandemic, state and local spending remained heavily concentrated towards highways, making up over 68% of transit spending in 2021 as seen in Figure 2. While some highway spending is necessary to maintain existing

infrastructure, there is greater flexibility in new infrastructure projects. Elected officials face pressure from their constituents, making it difficult for them to make radical changes in government spending. By continuing to heavily invest in infrastructure that encourages car use, local and state governments are further embedding car-dependency into the United States' infrastructure and culture.

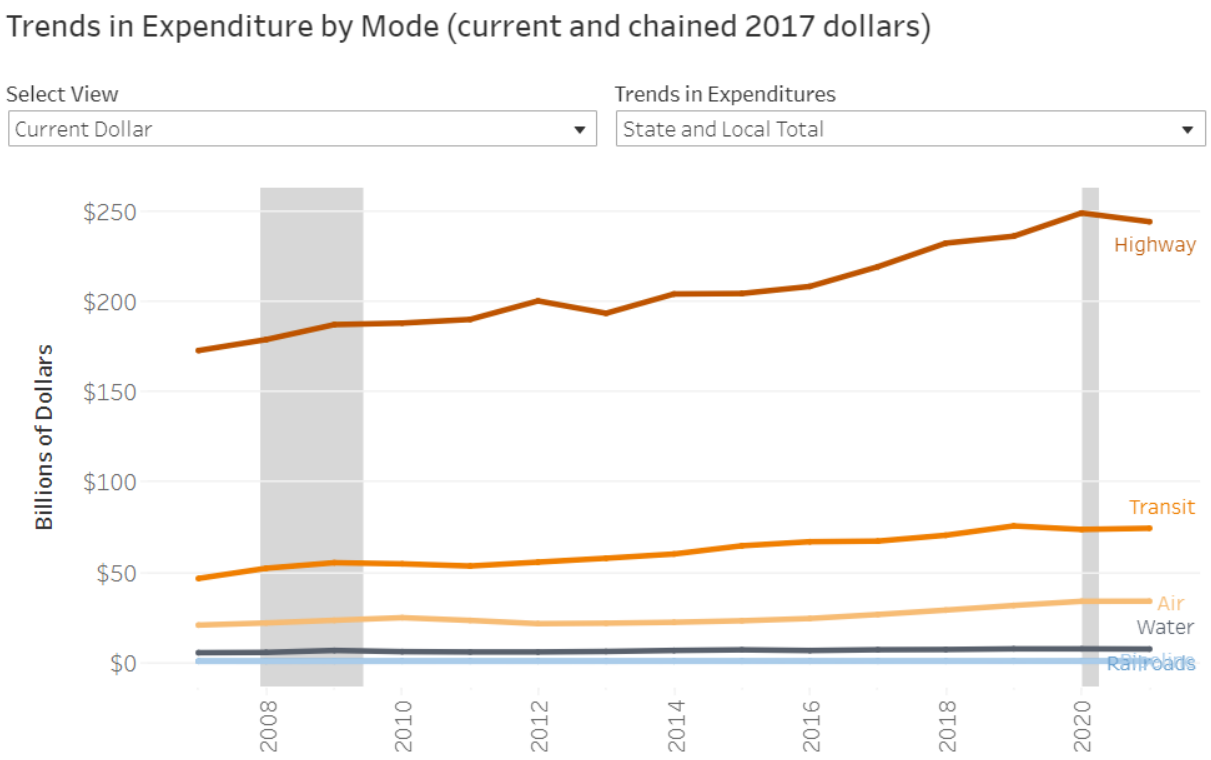


**Figure 2:** State and local transportation spending (U.S. Department of Transportation, 2024)

Urban sprawl is characterized by low population density suburbs, typically consisting of single-family homes. This phenomenon often occurs in areas surrounding cities and has its origins in the suburban flight of the 1950's, which was the emigration of populations from city centers to the suburbs (Resnik, 2010). Legislation, and zoning ordinances in particular, have been a key driver of urban sprawl, which has played an important role in shaping transit systems

and societal transportation customs (Lewyn, 2000). One primary cause of sprawl is the Standard State Zoning Enabling Act of 1922 (SZEA), which was a model law adopted by at least 19 states that created standard zoning codes limiting building sizes, neighborhood densities, and land uses (ibid). The legislation led to a rise in single-use developments that caused sprawl. Highways were originally built to provide access from suburban areas to central business districts. Despite this initial goal, highway construction has exacerbated sprawl in places such as Washington D.C. where the Capital Beltway has led to office and retail centers being built near beltway exits (ibid). These spaces are only accessible by cars, which limits the freedom of movement of individuals. Zoning regulations and highway construction are two initiatives led by the federal government that have contributed to the dominance of car-centric infrastructure in the United States.

The physical and mental health of individuals is impacted by transportation modes that they use. A study of Queens College commuters found that traveling by public transportation increased daily energy expenditure (Morabia et al., 2010). Similarly, a study on a large population sample from New South Wales, Australia found that longer driving times were associated with a variety of negative health impacts including higher odds for smoking, insufficient physical activity, obesity, and worse mental health (Ding et al., 2014). Additionally, a report by the APTA found that taking public transit instead of driving in the United States decreases one's chances of being in an accident by 90% (APTA, 2016). These studies suggest that the use of public transportation instead of cars results in improved physical and mental health.

## Research Question & Methods

My research into the history of transportation systems and infrastructure in the United States leads me to ask: When considering Star's theory of infrastructure, how have the installed bases of infrastructure, conventions of practice, and absences shaped the development of transportation systems in the United States? How has infrastructure led to successful, and unsuccessful, public transportation systems at different scales?

As a part of this research, I will use Yin's (2009) procedure to conduct case studies on transportation systems in Madison, WI and New York City, NY. Madison's public transportation system exclusively uses buses. Conversely, New York City's transportation system is more complex, as it transported over 1.7 billion riders on buses and subways in 2019 (New York City Transit, 2020). These cities are of interest because they represent the implementation of public transit systems at different scales. Additionally, their car ownership rates differ drastically, and I am curious to understand what has influenced these conditions.

I will investigate each of these systems, with a particular focus on infrastructure-related factors that have influenced their success. I will research their histories, which will provide background leading to a better understanding of how local conventions of practice around public transit have evolved. Additionally, I will investigate usage rates of each system by analyzing ridership data as a function of metro populations.

## Results

New York City's public transit system has been evolving for over 200 years with modernizations building upon previous infrastructure. The Metropolitan Transportation Authority (MTA) has united the region, improving connectivity and making transit across the

metropolitan area accessible. New York City has prioritized public transportation infrastructure, discouraging car ownership and encouraging public transportation use as a local custom. Madison, a smaller and less dense city with a vehicle ownership rate nearly double that of New York City, see Table 1, had similar transit system development from the early 19th century until the Great Depression. The two cities' transit paths diverged in 1935, and since then Madison's transit infrastructure has prioritized cars. Madison's bus system has much lower ridership as a function of its metro population compared to New York City, and local customs favor car use as the preferred means of transit. These cases can be used to better understand how societies' relationships with streetscapes and cars impact the success of their public transit systems.

**Table 1.** 2019 Transportation system statistics. Note: Data gathered from U.S. Census Bureau (2022)[a], MTA (2022)[b], Metro Transit (2020)[c], National Equity Atlas (2024)[d], and rides per person per year were calculated using columns two and four.

| | Metropolitan population | Population Density | Total public transit ridership | Rides per person per year | Rate of car ownership |
|---|---|---|---|---|---|
| New York City, NY | 19,617,000[a] | 2,935 people per square mile[a] | 2,375,375,086[b] | 121.1 | 44.56%[d] |
| Madison, WI | 687,000[a] | 208 people per square mile[a] | 12,856,541[c] | 18.7 | 87.35%[d] |

**New York City, NY**

Mass transit in urban centers was a concept that was first developed in Europe but quickly made its way to the United States. In 1827, New York City became the first American city to have mass transit when an omnibus service was launched (Roess & Sansone, 2013). Omnibuses were adapted stagecoaches pulled by horses that followed fixed routes. They quickly gained popularity and by 1835 various companies operated over 100 omnibuses (ibid). The New York and Harlem Rail Company began operating the first horse drawn street railway in 1833, see Figure 3. (ibid). Street cars were preferable compared to omnibuses because they had greater capacities, required less horsepower, and moved at higher speeds. More street rail lines were built, and by 1860 the system consisted of 14 lines, which combined to move over 38 million passengers per year (ibid). These transit lines made transportation more accessible and led to an accelerated northern expansion of the city. Street cars underwent various changes in power sources, and by the early 20th century electric powered cars dominated.


**Figure 3.** Horse-drawn streetcar in 1917 New York City. (New York Transit Museum, 2019)

The first elements of an underground subway system began operation in 1904 (New York Transit Museum, 2019). These underground systems were run by two private corporations that both went bankrupt in 1940 due to fare ceilings (ibid). The government-controlled New York City transit authority assumed control of the systems. Organizational changes were made in 1968 when the New York State legislature formed the Metropolitan Transportation Authority (MTA) to oversee transportation systems in the twelve counties in and around New York City (ibid). The MTA now serves over 5,000 square miles, making it the largest regional transit system in the United States (MTA, 2024). This social organization seeks to dissolve local boundaries, creating a transportation network with a large spatial reach that connects people in New York City, Long Island, and Connecticut. Populations within this area share a transit system along with conventions of practice around transportation.

The modern MTA subway system is composed of more than 6,455 subway cars which run on 665 miles of track and are connected to 472 subway stations, while the bus system has 5,780 vehicles that service 234 routes (MTA, 2022). In 2019 the subway system had a total annual ridership of about 1.7 billion, while total bus ridership was about 680 million (ibid). The population of the New York City Metropolitan area was 19.6 million, with the average resident taking 121.1 public transit rides per year (U.S. Census, 2022).

The high rates of public transit use in New York City can be attributed to transit infrastructure, local customs, and barriers to access car infrastructure. Transportation routes have served as the installed base, and as new technologies have emerged, they have been quickly adopted and integrated into existing infrastructure. In addition to physical elements that have led to New York City's public transit success, social elements have also played a role. About two thirds of New York City commuters travel to work via public transit or by walking, a rate higher

than that of any other major city in the United States (New York City Department of Transportation, 2010). The custom of commuting to work via public transit is a convention of practice ingrained in New York City's society. The city has a vehicle ownership rate of less than 45%, far below the national average (National Equity Atlas, 2024). One reason for this can be attributed to a lack of accessible automobile infrastructure, especially when it comes to parking. Parking supply around one's home plays a significant role in determining car ownership decisions, so the absence of these parking spaces is a deterrent for buying new cars (Guo, 2013). If the car ownership rate in New York City was the same as the national average, a parking lot the size of the island of Manhattan would need to be added to accommodate the additional vehicles (New York City Department of Transportation, 2010).

**Madison, Wisconsin**

Madison, Wisconsin is the capital city of Wisconsin and is home to the University of Wisconsin-Madison. The university and state government offices have been influential in the city's development. Madison's first public transit vehicles were omnibuses, which were replaced by horse-drawn street railcars run by the Madison Street Railroad Company in 1884 (Fadelli, et al., 2016). The animal-powered rail system did not last long, and electric streetcars were implemented by the newly reorganized Madison City Railway Company in 1892 (ibid). Automobiles gained popularity in the early 1900's which hurt streetcar companies across the country, including Madison's system.

The final nail in the coffin for streetcars came in 1935, when an ice storm downed power lines leading to the complete decommissioning of Madison's street cars (ibid). This marked a pivotal point in Madison's history, as infrastructure planning shifted to meet the growing

demands of car owners. The Madison Bus Company was established in 1910 and expanded service to areas previously served by streetcars following their disservice. The bus system was purchased by the City of Madison in 1970 and renamed “Metro Transit” (Foley, 1970). The system’s current infrastructure includes 201 fixed-route buses, 221 shelters, and 1,724 bus stops (ibid).

In 2019, Madison’s buses carried the city’s metro population on 18.7 rides per person per year, far less than New York City’s rate of 121.1 rides per person per year, see Table 1. The dominating transit method in Madison is the automobile, and the city has a car ownership rate of 87%, almost double that of New York City. The practice of automobile ownership is embedded into the social culture in Madison. Local populations have built conventions of practice around car use that make travel by car more popular and more socially acceptable. As members of the car-owning community, individuals are highly reliant on automobile infrastructure. As a result of this, Madison’s current streets have been designed with the interests of car owners in mind and are largely absent of transit-oriented infrastructure.

Madison’s metro area covers 3,308.8 square miles, about half the size of New York City’s metro area (U.S. Census, 2022). Despite having a larger footprint, New York City’s metro area is 10 times denser, see Table 1. Madison’s layout is more sprawling, making it challenging for public transit lines to reach all parts of the city. The construction of transit infrastructure is expensive, and Madison’s metro population is less than 4% that of New York City. This smaller population means that the area receives less tax revenue and has a smaller potential customer base to collect fares from. This lack of resources in conjunction with conventions of practice that favor car use pose significant barriers to the success of Madison’s public transit system.

Madison is working to redesign its roadways in tandem with its public transit network by implementing a Bus Rapid Transit system (BRT). BRT systems run high-capacity buses on dedicated bus lanes built along covered boarding stations, see Figure 4 (City of Madison, 2024). As Madison transforms its streetscapes along the BRT route, it is creating spaces designed to be used exclusively by buses and bus riders. These infrastructure pieces, which include bus lanes, boarding stations, and enhanced pedestrian crossings, will tie into existing roadways that were previously designed for cars. These new designs will alter the sense of place by being more inviting towards bus riders and pedestrians. Updating roadways to embed bus infrastructure permanently into streetscapes will change the way that society views street spaces and the bus system. Planners hope that these infrastructure improvements will increase bus ridership, changing local conventions of practice surrounding transportation.

**Figure 4.** Partially completed BRT system in Madison, WI. (City of Madison, 2024).

## Discussion

The transit systems of New York City and Madison were on similar trajectories until the mid-1930's when a divergence occurred. New York City diversified its spending to support the various needs of pedestrians, cyclists, subways riders, buses riders, and drivers. Madison went on to design its roadways highly prioritizing cars, which was part of a positive feedback loop that led to urban sprawl. As these cities grew, their populations developed transportation habits that were influenced by local infrastructure systems. Much of the MTA's success in gaining high ridership can be attributed to New York's investment in diverse, multi-modal transportation infrastructure. Madison's failure to build a widely used, successful public transit network can be attributed to the evolution of local customs that favor travel via automobiles, a trend influenced by the lack of multi-modal transit infrastructure. To best understand the role of transit systems within their respective societies, the specific context of a region's infrastructural development and transit history must be considered.

One element of my research that was limiting was the investigation of social perceptions of transportation systems. Generalizations were made about the impacts that streetscape infrastructure had on pedestrians. Assumptions were also made regarding conventions of practice based on online resources.

In the future I would perform a wider analysis researching a greater variety of cities. Additional analysis would allow me to investigate cities with different transit histories at different scales. Exploring newer systems, such as the Washington DC metro, which opened in 1976, would provide insights into the outcomes of more modern transit planning (WMATA, 2022).

Although I will not be working in transportation engineering, there are lessons from this research that can be applied to various areas within civil engineering. When considering changes to the built environment, existing infrastructure systems and local customs are two social factors of particular importance. It is important to view infrastructure systems as complex, sociotechnical systems that are the outcomes of historical and social factors.

## Conclusion

Future research should investigate how the changes implemented in Madison's RTN corridor impact the city's bus system. If successful, this type of transit system overhaul could be used to improve bus systems across the country. Additionally, further case studies should investigate other cities with successful transportation systems to identify factors that have led to their success. Finding similarities in successful public transit networks can provide insights into how infrastructure shapes social factors that influence transportation decision making.

City planners, developers, and engineers should understand local histories of transportation systems in communities in which they work in. These local histories provide context that helps explain how infrastructure and social customs have been developed. As these professionals work to improve transportation systems, they continue to shape the physical and social structures of our cities. By considering existing infrastructure, social customs, and absences, engineers can better understand the relationships between a society and its transit system. This improved understanding will lead to the design of systems that better meet the specific needs of a region and its society.

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