Public Transit Challenges in Sparsely Populated Countries: Case Study of the United States

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1. Introduction

Transportation has long been recognized both as a critical pillar of developed societies and a major contributor to pollution. Transportation is critical for access to food and other resources, employment, communication, and, thus, providing access to transportation is key to eliminating discrimination and socioeconomic barriers that limit several marginalized populations (Dostál and Adamec 2011). According to a 2020 report by the U.S. Environmental Protection Agency, transportation globally accounts for about 28% of CO_2 emissions (US EPA 2020). Thus, transportation today provides salient benefits to society, but also exacts a cost in terms of health and impact on the environment. With the global population continuing to grow and several large countries like Brazil, China, India, Indonesia, and most of Africa continuing to develop, the demand for transportation is only projected to increase.

To meet this growth in the most sustainable way possible, the answer must be clean transportation. The poster child is the electric vehicle (EV) powered by clean energy (e.g., solar, wind). An alternative is the hydrogen fuel cell vehicle powered by green hydrogen, which is hydrogen generated by electrolysis using clean electricity. These technologies also tend to be more efficient, from an energy standpoint, than conventional vehicles. For example, consider the 2020 versions of the Tesla Model 3 and the Toyota Camry, two passenger sedans of comparable size (~1550 kg). The fuel efficiency of the electric Tesla is about 5.7 km/kWh. For the Toyota, it is about 1.3 km/kWh, when the energy content of gasoline is factored in. Another way to consider efficiency is considering the efficiency of moving cargo or people. For example, the same Toyota can transport at most five passengers, but typically closer to 1–2. Thus, its efficiency would be about 0.4–0.8 kWh/km/passenger. For a typical mass transit bus that can transport 40 passengers, this efficiency is about 0.13 kWh/km/passenger, assuming the bus is full. Thus, the conclusion here is that mass transit is a critical piece in the transition towards a clean and sustainable future. Ideally, this mass transit would be fueled by clean energy sources, but even using conventional sources would result in a reduction in emissions (Yuan et al. 2019).

The focus in this chapter is on passengers, but a similar argument can be posited for goods or cargo. This chapter focuses on public transit challenges in sparsely populated countries. The case study of the United States is used to demonstrate how and why the historical factors that shape a country's policies are critical to planning any future improvements. Accordingly, some suggestions for the future of public transit policy are presented, together with a selection of recent projects and upcoming projects taking shape.

2. Sparsely Populated Countries

While mass transit may be an effective way to handle the increasing need for transportation in the most efficient manner, this would require a significant investment in infrastructure. Individual vehicles only require a road network. Transit buses also require bus stops, depots, drivers, transit schedules, coordinators, etc., not to mention the huge initial cost of the actual buses. Rail is more efficient, but even more capital intensive. Governments or private industry are willing to invest in these projects if there is an economic case. Additionally, this typically is a function of the population: the larger the target market, the larger the expected revenue. However, if the population density is too low, then there are additional challenges. Short, efficient trips become impossible and an expansive infrastructure leads to a prohibitive upfront investment. Compounding these factors are areas that house historically poor populations. While these populations have the greatest dependency on cheap transportation and would benefit the most, such areas are the least likely to see significant public investment as they are typically underrepresented in government and policymaking. On the other end of the spectrum are affluent areas. There is a strong correlation between vehicle ownership and per capita gross domestic product (GDP) (IRF 2013). Similarly, one would expect a strong correlation between per capita emissions and per capita GDP. However, other factors might be worth considering.

Figure 1 shows five indicators for 28 countries, which account for about two-thirds of the total global population as well as about two-thirds of the total global GDP (PPP or purchasing power parity). For each of these, the per capita emissions are plotted in relation to the population, population density (per square kilometer), GDP (PPP), GDP per capita, and percentage of urbanization. A trendline for the plot is also shown. Indeed, it can be concluded, based on the R^2-values obtained, that the GDP per capita has the strongest correlation to emissions. The next most important factor is urbanization, or the fraction of the population that lives in cities compared to rural areas. Another interesting trend is in the population density plot. It can be observed that countries with very low population densities

tend to produce far more emissions than those with high population densities. Taken together, the data point to the conclusion that the biggest polluters are countries with a high per capita GDP and urbanization, but low population density. Such countries also have high levels of vehicle ownership. All these factors contribute to high emissions per capita. In addition, it is argued here that such countries face significant challenges to adopting or expanding mass transit. To demonstrate this, the case of North America is examined, particularly focusing on the United States. The countries are highly developed and very rich in natural resources. They have a lot in common, including being sparsely populated and relatively isolated, both internally and externally.

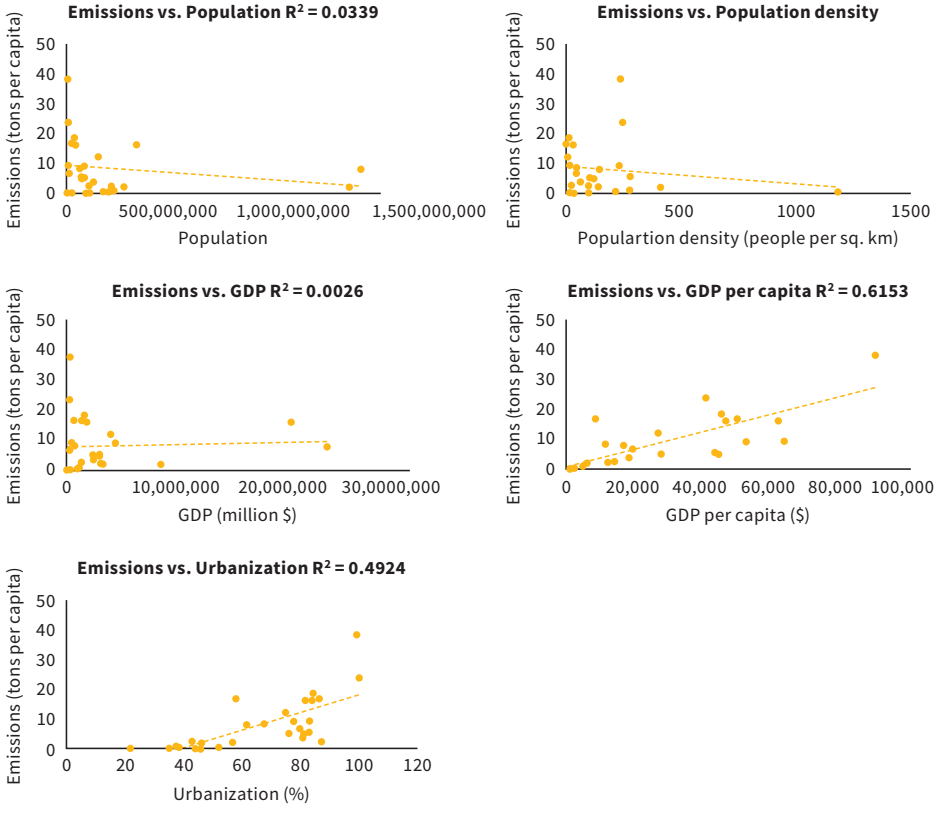


Figure 1. Influence of population, population density, GDP (PPP), GDP per capita, and urbanization on per capita emissions. Source: Graphic by author, data from (WDI 2021; Ritchie 2019; IMF 2020; UN 2019).

North America has three countries: Canada, Mexico, and the United States. These countries have a similar history and share many common characteristics. All three are relatively young, ranging from 1776 (United States) to 1867 (Canada). These countries were inhabited by various Native American civilizations, then settled by Europeans, who also brought several enslaved peoples to the continent. By the middle of the 19th century, slavery had been abolished in all three countries and each one experienced waves of immigration from various parts of the globe continuing to this day. This has only added to, and in many ways catalyzed, the natural population and industrial growth that is virtually unprecedented in history.

Table 1 shows statistics for various economic and transportation categories for Canada, the United States, and Mexico. There are some commonalities, like the degree of urbanization. However, Canada and the United States have more in common with each other than Mexico. Canada and the United States are considerably wealthier than Mexico. Part of the reason is because both countries are huge: second and fourth, by area. The United States is also third in the world by population, but its population density is still about half that of Mexico. Even if only the contiguous 48 states are considered, the population density only changes from 33.6 to 40 per sq. km. With wealth comes a higher standard of living and energy consumption, resulting in greater emissions. The United States and Canada emit about four times more than Mexico. The per capita vehicle ownership is similar. Even though the degree of urbanization is about the same, a closer look at the distribution is instructive. The top 100 combined statistical areas (CSA) account for 81% and 66% for Canada and the United States, respectively, compared to just 45% for Mexico. Summing the total for all cities above 100,000 residents, they account for 74% and 85%, respectively, compared to just 48% for Mexico. This leads to the conclusion that populations in Canada and the United States are much more concentrated than in Mexico. Part of this can be due to the presence of huge suburbs around a major city.

While Canada and the United States have a lot in common, this chapter will focus on the United States for several reasons. The United States has almost nine times the population, over 12 times the GDP, and is seen as a global leader and influencer in the world and has been that way since World War II. Furthermore, the United States has a history of invention and innovation in several critical sectors, including transportation: railways, automobiles, including mass production, road infrastructure, traffic laws, etc., aircraft, rockets, and more. Countries have looked to it for benchmarks and manufacturing standards and lessons learned and technologies discovered have often translated to international markets. Thus, if the United States were to, for example, stop manufacturing internal combustion vehicles and fully

switch to electric vehicles, that would put significant pressure on other countries to follow suit considering how huge a market space is controlled by the United States. Finally, the United States is also one of the largest consumer markets in the world in several sectors such as automobiles, electricity, petroleum, etc. Changes here would have a much greater impact than virtually any other country.

Table 1. Various economic and transportation statistics for North American countries.

Country	Canada	United States	Mexico
Area (million sq. km)	9.984	9.833	1.973
Population (millions)	38.01	328.24	126.01
Population density (per sq. km)	3.92	33.6	61.0
Population of top 100 CSAs (fraction of total)	0.81	0.66	0.45
Population of >100K cities (fraction of total)	0.74	0.85	0.48
GDP (nominal, trillion US dollars)	1.6	20.807	1.322
GDP (per capita, US dollars)	42,080	63,051	10,405
Emissions (per capita, metric tons of CO_2)	16.3	16.1	3.8
Urbanization (%)	81.6	82.7	80.7
Vehicle ownership (per 1000 people)	685	838	297

Source: Table by author, data from (IMF 2020; UN 2019; Statistics Canada 2016; US Census Bureau 2019; INEGI 2010; IOMVM 2013).

3. History of the United States: An Overview

The United States declared its independence from colonial rule in 1776. In its early years, it was not universally recognized as a nation for several years. Several established nations still viewed it as a potential colonial acquisition. Most importantly, the entire territory of the first 13 colonies was east of the Appalachian Mountains, north of Florida—about 11% of its extent today. Gradually, several territories were acquired, organized, and formalized as states. This included territories east of the Mississippi, then the entire Mississippi River basic (Louisiana Purchase), the Oregon Territory, Florida and the Republic of Texas, and Spanish

Territories all the way to the Pacific Ocean. Much later came the additions of Alaska and Hawaii. There were numerous smaller changes to the territory of the United States, but these were predominately outside the contiguous or lower 48 states—in the Caribbean and Pacific.

From the earliest colonial days, settlers engaged in importing slaves from Africa. From the 17th century up to the American Civil War that ended in 1865, millions of slaves worked predominantly in the Southern states on large cash crop plantations (cotton, tobacco, sugar, etc.). By contrast, the economy of the Northern states was predominantly predicated on agriculture and industry. Innovations in manufacturing and transportation technology—such as the steam engine—propelled the rise of factories and factory workers with several Northern states abolishing slavery in their territories. Southern fears over the abolishment of slavery in the Union led to the Civil War, which culminated in the permanent abolishment of slavery in the United States in 1863 and the defeat of the Confederacy of Southern States in 1865.

After the war, the conditions in the South degenerated for virtually the entire population. Black Americans were now free and full citizens of the Union. However, their White counterparts, some of whom were their former slaveowners, rejected all attempts of the federal government to integrate free slaves into society, even requiring military invention in certain cases. Simultaneously, unable to profit from free slave labor, several White landowners, including women, had to work the land themselves—a hardship not previously endured. Those in power engaged in various tactics to restrict the rights of Blacks, keep a stranglehold on political power, restrict their access to education, land ownership, etc. They set up various mechanisms that ensured a system very similar to the slave-owner system before the war, known as sharecropping. The Jim Crow Era in the South ensured segregation on the basis of race.

Meanwhile, the new territories in the West continued to grow and develop at the expense of the native population, who were continually pushed further west. Initially, the Indian Territory was west of the 13 colonies, then moved to the Missouri Territory, and finally reduced to the area of the modern State of Oklahoma. On the back of the railroad and steam locomotive, American industry grew prodigiously. Total track length progressed from about 60,000 miles (96,000 km) to about 160,000 miles (100,000 km) in the 1890s with the completion of the Transcontinental Railroad. This figure peaked during World War 1 (254,000 miles) and is about 140,000 miles today (Stover 1999). Some of the most iconic and enduring American companies were founded during the latter half of the 19th century and the early 20th century: Standard Oil (later Marathon, ExxonMobil, BP, and Chevron), General Electric, AT&T, Emerson

Electric, Carnegie Steel (later U.S. Steel), Ford, General Motors, etc. The vast majority of these were headquartered and had most of their operations in Northern States.

After World War I, there was a period of booming economic growth in the country. The transportation section grew with major innovations in aviation, automobile technology, rail (e.g., diesel locomotive), and shipping. Then, came the Great Depression followed by the New Deal, a series of major economic and infrastructure reforms aimed to lift the country out of the Depression. World War II continued to drive the growth of the massive American industrial complex accompanied by a surge in population, the "baby boom". The Interstate System that was signed into law during the war made road travel easier than ever. Simultaneously, little progress towards equity was happening in the American South. Multiple incidents of racial violence, voter suppression, the rise of the Ku Klux Klan, lynching, segregation, etc. made it virtually impossible for Blacks to gain political power or good jobs or education or even improve their lives in any tangible way. This prompted a mass exodus of millions of Black families from the South to the North and West. Coupled with continued immigration, several cities like Philadelphia, Detroit, Chicago, Cleveland, Baltimore, and New York City saw a huge increase in their population and a change in their demographics. This lasted roughly from 1916 to 1970. On the other hand, after World War II, thousands of veterans left the cold harsh winters of the North and migrated to the Sun Belt states. Cities like Los Angeles, San Diego, Las Vegas, Dallas, Houston, and Phoenix grew significantly.

3.1. Urban Sprawl

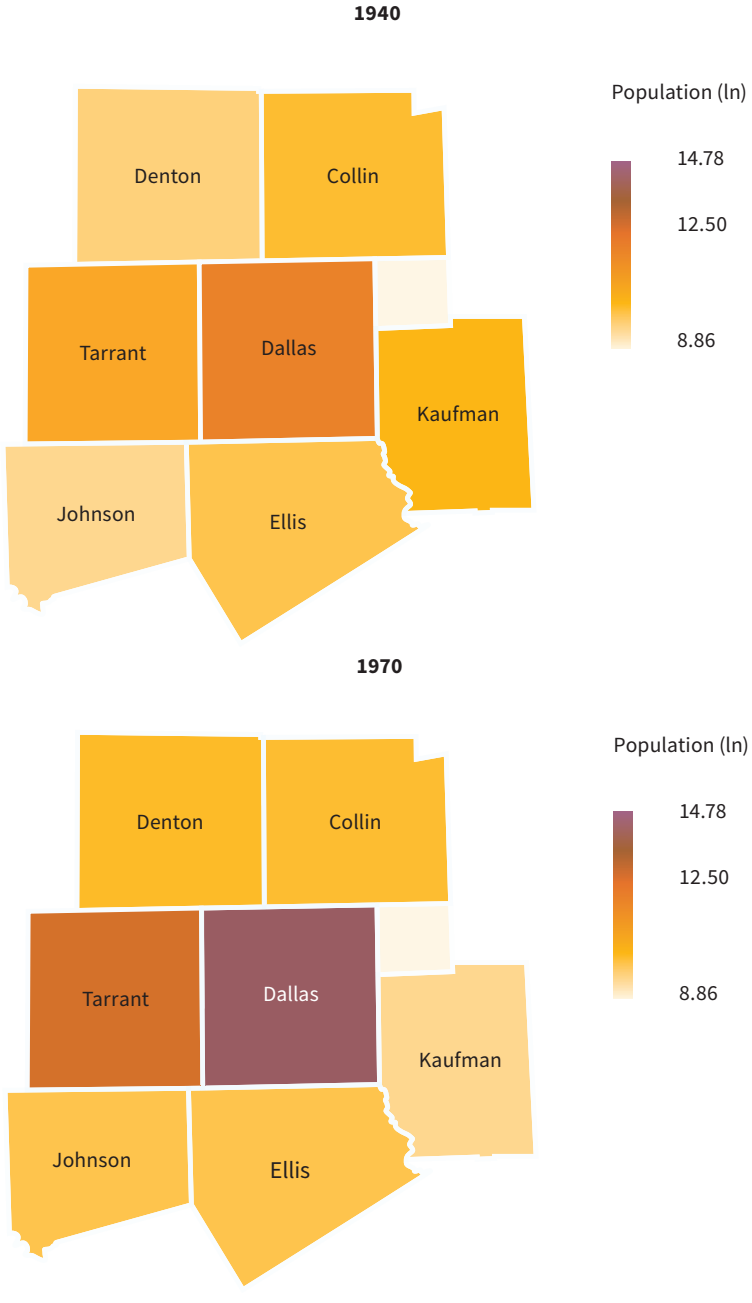
During this period of urbanization, a pattern began to emerge: the gradual move of large populations from city centers to small satellite towns and communities within close proximity, commonly called the suburban development or suburbs. Spurred by legislation like the Federal Home Loan Bank Act of 1932 and the National Housing Act of 1934 along with contributions from the Veterans Administration, families were able to buy homes in newly developed areas outside cities. No longer did they need to live in cramped, densely packed apartments in crowded, polluted, and noisy city centers. The United States transitioned from a primary economy (natural resources) to a secondary one (manufacturing). To travel to these well-paying jobs in the cities, workers bought increasingly affordable cars, one of the most important products of this new economy. The total number of miles of paved road continued to increase, especially between cities.

Thus, what happed was that the traditional city centers absorbed the majority of the Black and immigrant population, while most of the middle-class White residents

flocked to the suburbs. Under the National Housing Act, the Federal Housing Authority (FHA) created several guidelines and minimum standards for new housing developments. Unfortunately, it also strongly promoted racial segregation in its guidelines. The design of suburbs focused on car-friendly, wide streets and left out pedestrians. Instead of grid plans, curved and dead-end or cul-de-sac designs were adopted. These were designed to slow cars down, limit traffic through streets, but also ensure that cars were necessary to get around. The FHA rated any designs submitted within these guidelines as "good plans" and the rest as "bad plans", making it riskier for developers to pursue. Suburbs grew, their design made walking and public transit inefficient, and existing public transit systems in the city centers fell out of favor and became neglected. Their use was associated with being of the poor class. The people who depended on these systems the most had little power to influence their improvement.

Even if Black families wanted to move out of the city centers, 'redlining' made it impossible for them to secure affordable housing. This was the practice by government agencies of systematically denying goods or services to particular groups by a number of tactics ranging from selectively raising interest rates or prices to placing strict criteria on specific goods and services. The Fair Housing Act of 1968 put a gradual end to this practice, but the intervening decades had done their damage. Whole generations of minority populations, such as Blacks, were unable to afford homes or had to buy homes in less desirable or segregated neighborhoods. For most middle- and low-income families, home ownership is the surest way to build wealth. For those unable to do so, renting is the only option and does not result in any increase in equity. Similarly, minorities were also denied access to education and political power with suppression of voting. It was only after the Civil Rights Acts of the 1960s that some of these practices slowly began to decrease. Still, the country is recovering from these effects to this day. Some studies show that segregation in some cases, such as the workplace, is worsening (Hall et al. 2019).

Figure 2 shows the urban sprawl for two major cities: Dallas, Texas located in the southern United States and Detroit, Michigan located in the northern United States. The figures show not only growth of population within the city center itself (Dallas County for Dallas and Wayne County for Detroit), but the surrounding counties as well. Some of these experienced triple-digit growth rates. The average home in the United States grew in size from 1500 sq. ft. in the 1970s to over 2,000 sq. ft. nowadays (Friedman and Krawitz 2001). Interestingly, the average lot size has continued to decrease as pressure for suburban housing continues to increase.



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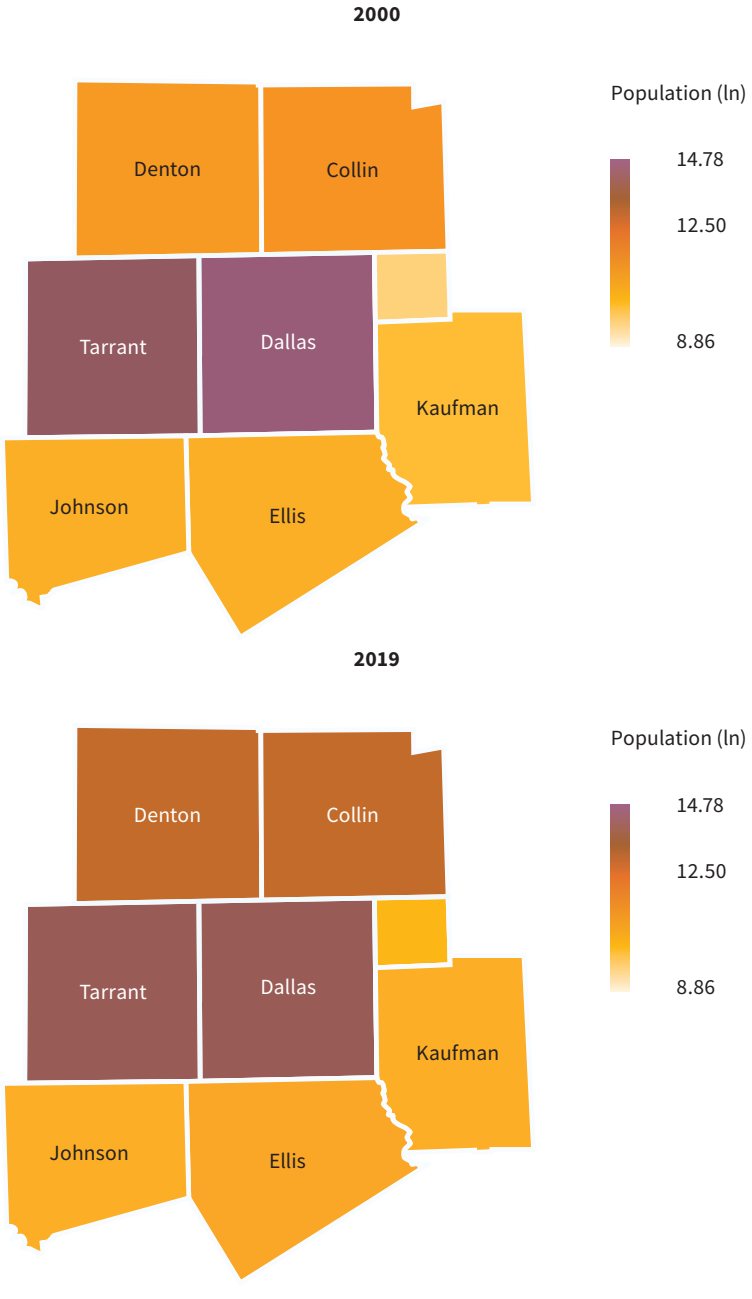

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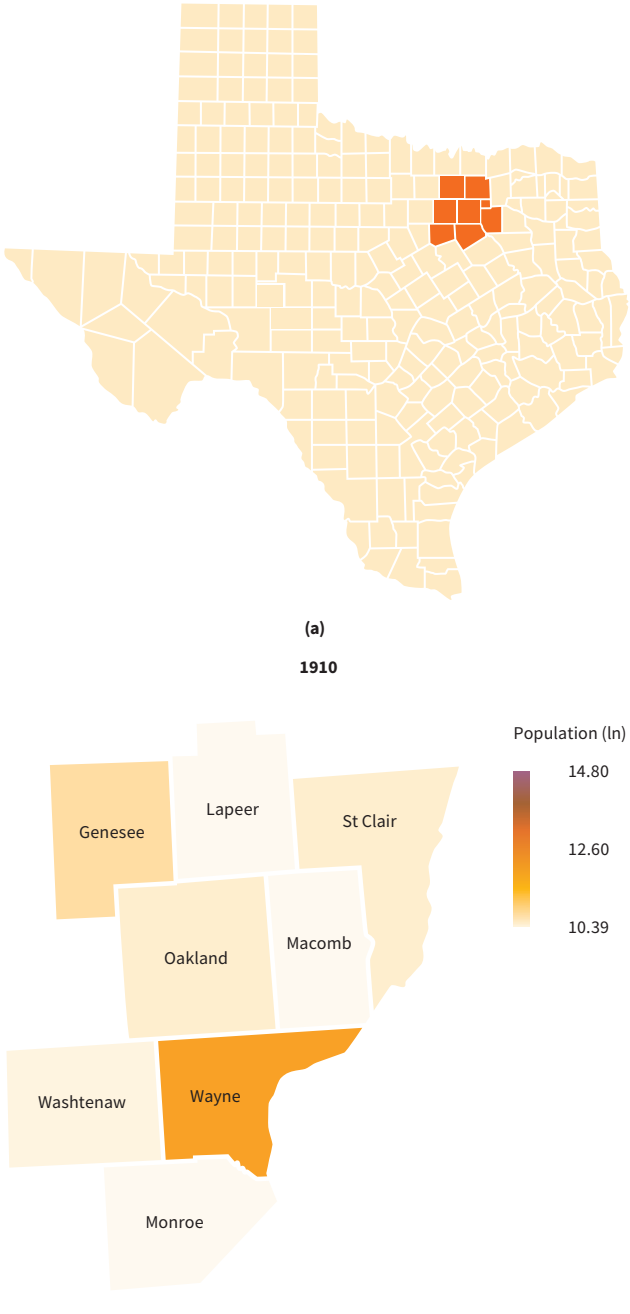

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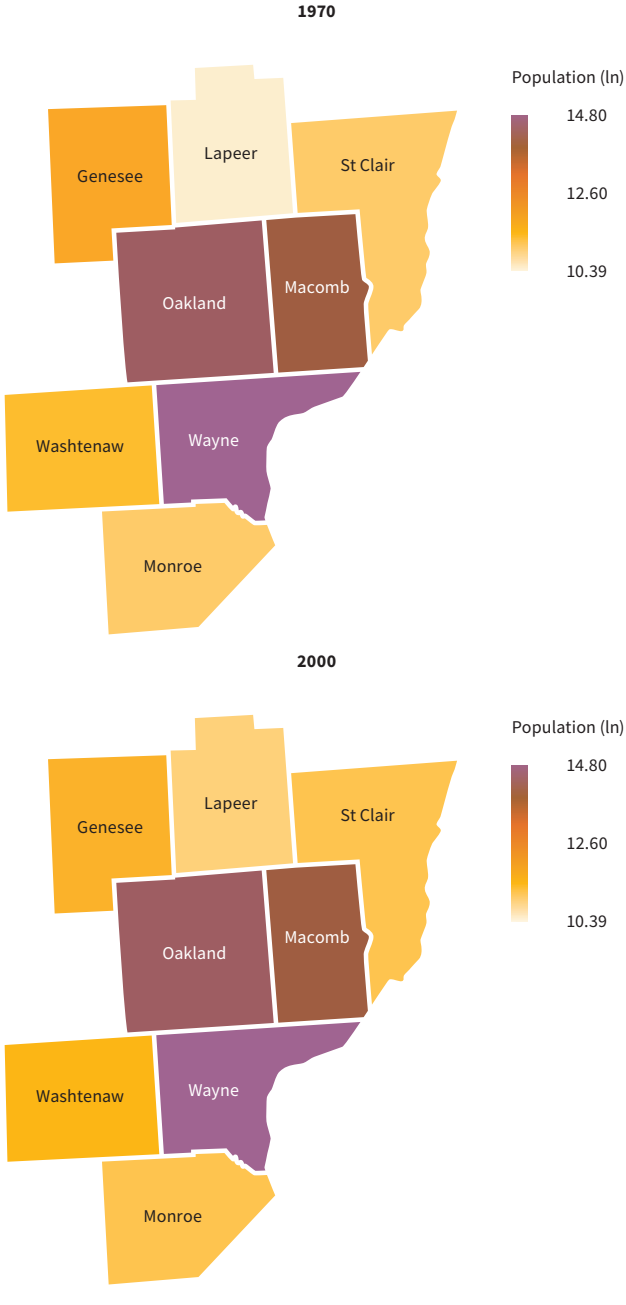

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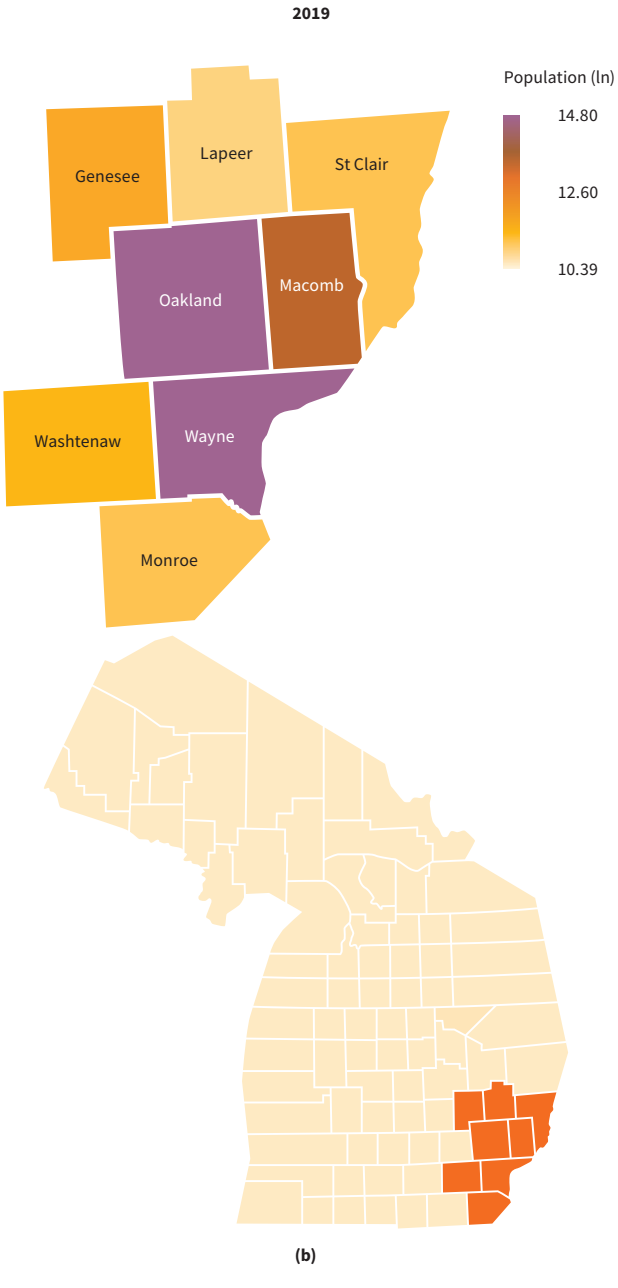

Figure 2. Growth of suburbs in the 20th century in (**a**) Dallas, Texas and (**b**) Detroit, Michigan. Source: Graphic by author, data from (US Census Bureau 2020).

3.2. Public Transit Challenges

Therefore, the United States arrived at the situation in which it is today: declining urban centers surrounded by sprawling suburban development. The coronavirus pandemic of 2020 has only continued to accelerate a general move out of major cities as companies allow employees to work from home. This has shaped transportation policy and consumer trends. According to the Bureau of Transportation Statistics, 76% of employees who commute to work do so in a passenger vehicle alone, whereas only 5% use public transit (US DOT 2020). Similarly, total public transit ridership has continued to trend down in recent years, reaching a peak in 2014. Part of this has been attributed to the rise in ride-hailing and vehicle-sharing apps. Average commute time has gone from under 22 minutes in 1980 to a peak of 27 minutes in 2018. Passenger vehicles continue to become bigger and more expensive. For example, the number of midsize sedans sold in 2020 was about 50% of what it was in 2012. Sport utility vehicles (SUV) made up 47.4% of all sales in 2019 and that is expected to rise to 78%. Expectedly, the average transaction price of a new vehicle continues to trend upwards, reaching about USD 39 thousand in 2020, up from USD 35.5 thousand in 2016. In 1960, about 80% of households had one car or less. In 2019, it was only about 40%. As for local travel, defined as trips of 50 miles or less, there were 3140 average person-trips per household in 2017. Of those, 329 were walking, 2592 were by passenger vehicle, and only 80 by public transit. As for the totality of domestic travel, between 2010 and 2018, air travel, passenger vehicle travel, and public transit increased—though the increase in public transit was only about 2%. Inter-city rail saw a slight decrease. When looking at passenger-miles traveled in 2018, inter-city rail and public transit combined were 62 times lower than passenger vehicles.

The above statistics provide sufficient evidence on the preference of personal passenger vehicles over more efficient public transport. Personal vehicles are less environmentally friendly and more expensive than using public transit. However, they offer more convenience and flexibility. Given the lack of demand, there is a very weak economic incentive to improve existing public transit infrastructure. The people who rely on it the most typically have the least political power or financial capital to do so. This leads to a vicious cycle of further neglect and depredation. Transportation has been identified as one of the critical factors in helping people to escape poverty (Department for Transport 1997). The transformative Interstate System was a huge boom to the country's economy. However, in several cases, poor communities were displaced and bypassed by the new highways. Transportation is also the second biggest expense for the average family. Thus, minorities and

immigrants continue to have reduced access to transportation options. This only worsens the inequity within society.

The United States has led the world in innovation in several key transportation-related technologies. However, implementation of the next generation of clean mass transit projects is severely lacking. There are plenty of demonstrations and projects to prove the efficacy of technologies that are viewed skeptically by the public in this country (Bamwesigye and Hlavackova 2019; Behrendt 2019; Fialová et al. 2021; Freudendal-Pedersen et al. 2019; Łukaszkiewicz et al. 2021). Of course, with transportation, proper land use is another critical issue in United States. There are several recent studies and analyses on smart and sustainable land use (Al-Thani et al. 2018; Hammad et al. 2019; Tobey et al. 2019) that can inspire policymakers in the United States as well.

Another important thing to keep in mind is that, like Canada and Mexico, the United States has a federal government with strong state governments. Critical sectors like education and transportation are funded and regulated by all levels of government. Most importantly, there is no federal transit authority that operates one bus or rail network for the entire country. This includes Amtrak, which provides inter-city rail service in the United States. It receives funding through a combination of state and federal subsidies, but is a for-profit organization. This makes it very difficult to improve existing transit services or invest in the development of new projects, whether by government or private industry. Approvals, cooperation, and shared resources need to come from multiple agencies and governing bodies, and this often becomes the prohibiting factor. For example, any bus service across multiple states would have to abide by emissions regulations, safety regulations, disability services, etc. in each state. Further, minimum pay, employee benefits, levels of funding from each state authority involved, etc. would all serve to complicate the project.

Arguably the biggest challenge to implementing widescale public transit in the United States is geography or population distribution across its geography, which can be understood with Figure 3. It shows the locations of all the CSAs with a population greater than 200,000 in both Canada and the United States. The marker size is scaled, the smallest being about 200,000 and the largest being about 8.4 million. Almost the entire population of Canada lives within 100 miles of the Canada–United States border. For this reason, a lot of companies and services operate across the border. Examples are sports leagues, companies, particularly in the Seattle–Vancouver, Detroit–Windsor, and Toronto–Buffalo areas, and service by Amtrak railway. The Quebec City–Windsor corridor, which includes Ottawa, Montreal, and Toronto, has a

population of about 18 million, nearly half of Canada. The Great Lakes region has about 55.5 million people and the Northeast corridor (Boston to Richmond, Virginia) has about 52 million people. Other notable megalopolises include the California (north and south) region (38 million) and the Texas Triangle–Gulf Coast region (33 million). All these regions are clearly visible in Figure 3. Given this distribution and considering that these megalopolises are hundreds and thousands of miles apart, it is not easy to create a nationwide public transit system like the Eurozone. Americans prefer the flexibility of air travel and road trips to travel between major cities and everywhere in between. Unfortunately, both these forms are the worst emitters of greenhouse gases.

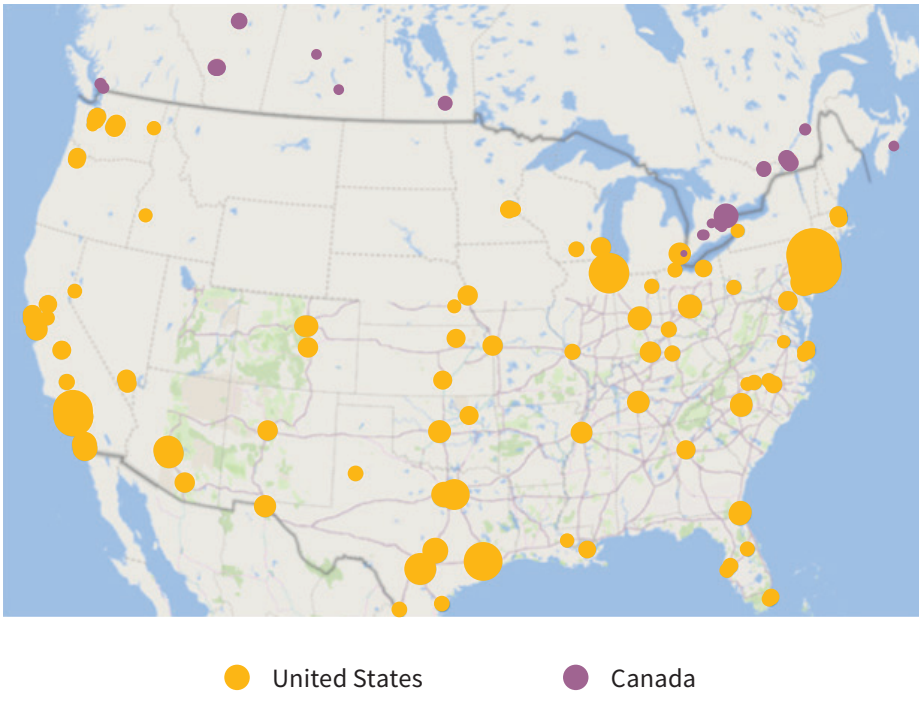

Figure 3. CSAs with population over 200,000 in Canada and the United States—marker size scaled from 200,000 to 8,400,000. Source: Graphic by author, data from (Statistics Canada 2016; US Census Bureau 2019).

4. Potential Solutions

4.1. Sustainable Transportation: A Multiobjective Approach

Despite the challenges described, climate change appears to be the extreme coercion driving promising new projects. This section briefly introduces a multi-objective approach to selecting sustainable transportation options. The ideal public transit system would satisfy multiple objectives:

- Accommodate multiple passengers;
- Efficient, use the least amount of fuel to cover the most distance;
- Safe;
- Affordable;
- Level of service;
- Low maintenance and operating costs;
- Low initial capital requirement;
- Technologically feasible;
- Sustainable, environmentally friendly.

Of course, there are other considerations; these are just examples. Note that some of these are 'cooperating', meaning improving one also improves another. Using a more efficient powertrain contributes to being sustainable. Other objectives are 'conflicting', meaning improving one worsens another. Having a high level of service typically means a more expensive system due to having a larger fleet or perhaps longer travel times due to frequent stops. In classical multi-objective optimization, it is desirable to optimize conflicting objectives to produce a series of optimal solutions. This technique can be extended to the choice of public transit type in order to demonstrate how such a technique might be adopted in such cases.

Table 2 shows some key transit metrics for the most common types: buses and trains. Electric buses are also shown along with conventional diesel buses. As for trains, the two most widely used categories are shown: rapid transit rail and commuter or inter-city rail. The operating cost refers to how expensive it is to operate the vehicle. The capital refers to the upfront cost to purchase one additional vehicle for an existing transit system. Speed and trip time are average or typical values. The efficiency is the amount of energy consumed per passenger-mile. The cost refers to the price the customer pays per passenger-mile. Note that, given the complexity in determining the values in Table 1, a lot of assumptions are made by the reporting agency. Ranges are provided wherever appropriate. Thus, these should be taken as representative values only for comparison. However, by comparing the numbers directly, an informed decision can be made.

Table 2. Various economic and transportation statistics for North American countries.

Mode Objective	Bus	Electric Bus	Rapid Transit Rail	Commuter/ Inter-City Rail
Operating cost (USD/vehicle revenue hour)	166.51	41	312.09	562.96
Capital (million USD)	1.1	1.7	30.4	30.4
Speed (mph)	9	9	16	40
Trip time (min)	22–45	22–45	47	47–120
Efficiency (kWh/passenger-mile)	3319	1107	3228	1688
Cost (USD/unlinked passenger-mile)	1.31	1.31	0.92	0.51

Source: Table by author, data from (US DOT 2010, 2018, 2020).

When multiple conflicting objectives are in play, improving one often worsens another. Thus, it may be difficult for a customer or a transit authority to choose one mode over another. A graphical representation of the decision-making criteria is shown in Figure 4. Only three modes of transportation are shown. More can be added as needed. Only two objectives are plotted: average trip cost to the passenger and the average emissions per passenger-mile. It is desirable to minimize both these objectives, so values of zero and zero would be ideal. However, this is not practical. However, whichever mode can approach this point would be the closest to ideal. Accordingly, it is clear that trains are the best mode, having the lowest cost and emissions. Personal passenger cars are the worst. Note that electric buses could prove to be the best if powered by clean, renewable energy. For Figure 4, it was assumed that the electricity was the average grid mix for the United States. Even so, the choice between electric buses and conventional buses is clear: the former have lower emissions and lower average trip costs. This methodology can be extended to an arbitrary number of objectives and "solutions" (modes of transportation).

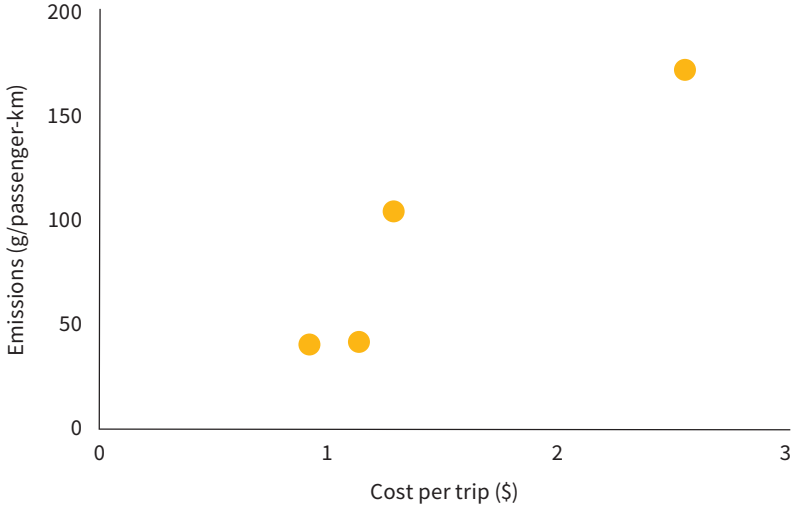

Figure 4. Emissions versus trip costs for common modes of transportation. Source: Graphic by author, data from Table 2.

4.2. Transportation Policy

In the United States, only about 17% of the total cost of public transit projects (capital only) are funded by the Federal government (Mallett 2021). The rest comes from state and local governments and, in some cases, private investors. The Federal Public Transportation Program has gradually increased its funding from 2011 ($10 billion) to 2018 ($13 billion). For 2020 and 2021, the COVID-19 relief package provided an additional $39 billion in total. As climate change and its effects, both immediate and long term, come into sharper focus, federal and state governments are increasing funds allocated to public transit projects. These are geared to reduce carbon emissions. They also increase access to transportation across the different segments of population, increasing equity. This, too, has moved into the spotlight during the social unrest in the United States during the COVID-19 pandemic.

The next section presents some of the largest upcoming public projects in the United States. However, none of these are interstate projects and there are few inter-city projects in the works. Consider that, between 2010 and 2019, the United States added 1203 miles (1936 km) of transit compared to 21,950 miles (35,318 km) of new highway and arterial roadway (US DOT 2019). This is emblematic of transportation trends in the United States. Given the trends in oil prices, consumer vehicle purchases, and the complicated nature of funding and politics in the country,

passenger vehicles and planes will continue to dominate long-distance and even local travel.

For cross-country or even interstate transit, the country's geography and population distribution will continue to pose a significant challenge. This is also true for Canada. In the short term, the best bet would be for the United States to improve domestic transit infrastructure and electrify its fleet. The reason China has about 99% of the world's electric buses and over 500,000 charging stations is because electric vehicles are part of the transportation policy at a national level. The United States has not prioritized electrification in the same way. The current administration has emphasized electrification of the federal fleet, a good way to lead by example. This means conversion or replacement of some 645,000 vehicles, comparable to the annual emissions of countries like Haiti or DR Congo. Once the federal government takes the lead, state and local governments would follow. Consumers are already adopting electric vehicles, with several automakers planning for all-electric fleets as early as 2035.

However, this is only one piece of the puzzle. The other piece is public transit. Cities and suburbs in the United States are not pedestrian-friendly. Transit maps are oriented to facilitate travel from the suburbs to the city centers. There is little interconnectedness between suburbs and neighborhoods. This makes it very difficult for people to use the transit system outside of work or trips to the city. This means that owning at least one personal vehicle is virtually a requirement for living in and around major cities. In rural communities, the vast majority of the land area of the United States, personal vehicles are the only way to travel. Future transit projects need to address this disparity or shortcoming to reduce the dependence on personal vehicles. This is reflected in places like New York City. In the borough of Manhattan, 22% of households have at least one vehicle compared to the nationwide rate of 838 per 1000 residents.

The final facet of sustainable transportation for sparse countries is land use. Infill development is the rededication of vacant parcels or plots of land within large urban spaces. City planners need to focus on transit-oriented development. City blocks and spaces need to be designed around the concept of the "15-minute-city". This is the idea where the majority of daily needs are located within a 15-minute walk. This includes mass transit. Rather than removing housing from work, new developments should integrate housing with businesses and office spaces. Furthermore, developers need to ensure that new development has sufficient variety to serve the needs of young, single professionals, small families, and also the retired community.

4.3. Current and Future Projects

The following are some of the largest public transit projects that are being undertaken or are soon to be undertaken.

1. Heavy rail and subway—this project was completed in the San Francisco Bay area in 2020, the largest public infrastructure project undertaken in Santa Clara County. Its project cost was USD 2.4 billion and added 10 miles to the existing coverage. It is set to link San Jose and Santa Clara, two neighboring cities. This project required the cooperation of multiple transit authorities, such as the Bay Area Rapid Transit and the Santa Clara Valley Transit Authority. Issues pertaining to platform configuration and additional training for operators using ramped tunnels had to be overcome during the project.
2. Light rail—the cities of Boston, Los Angeles, San Diego, and Seattle have light rail projects totaling USD 8.5 billion opening in 2021. These projects account for over 28 miles of light rail. COVID has impacted all these projects, as can be expected. Even outside the pandemic, some of these projects faced technical challenges, cost overruns, issues with contractors and unions, etc. All of these have been delayed in coming online. This is the nature of such mass transit multi-billion-dollar projects.
3. Electric bus—Indianapolis' Bus Rapid Transit system has a planned extension, the Purple Line, under construction and slated to open in 2022 or 2023. This would double the existing capacity of the Red Line. The 15-mile extension is expected to cost USD 155 million. The entire transit system is electric, specifically using the BYD K11 electric bus. The fate of the project is a bit uncertain—including future extensions. This is because of legislation introduced that challenges the financial obligations of the county and the operator, IndyGo (Indianapolis Public Transportation Corporation).
4. Hyperloop—this refers to the proposed mode of passenger transportation where a high-speed train travels in a sealed tube at vacuum or very low pressure. This low air resistance allows the train to travel at very high speeds very efficiently, making it competitive with air travel over distances under 1,500 km in terms of travel time. White papers have proposed a project along the Los Angeles–San Francisco corridor with an estimated cost of USD 6 billion. Virgin Hyperloop conducted its first human passenger trial at a speed of 172 km/h at its test site in Las Vegas. SpaceX built a one-km track in Hawthorne, California. This technology has the potential to be a true interstate transit system. Various countries are also investigating this new transportation technology. In the United States, significant political and economic challenges would need to be

overcome to make this idea a reality. In California, for instance, the California High-Speed Rail Authority is already working on its first project, slated to open in 2029, costing upwards of USD 64 billion for Phase I. It would be very difficult to justify a second similar project. It must be noted that in the United States, while there is technically high-speed rail, only about 34 miles of track actually allow trains to reach up to 150 mph (241 km/h) for only 34 mi (55 km) of the 457 mi (735 km) track.

5. Closing Remarks

The future of clean transportation and public transit in the United States is far from decided. While the United States has been a leader and innovator in several areas, it severely lags in this one. It need not be stated that this is because of its unique history and particular circumstances. This chapter examines the complex history and multitude of factors quite briefly and with a focus on trying to understand the state of affairs from an engineering and technological standpoint. Public transit and urban sprawl are far from the only public interest items shaped by the country's history. Additionally, it would be overly simplistic to assert that what was presented herein were the only factors. Indeed, the influence of geopolitics, the progress of technology, political and economic cycles, public opinion, etc. all have left their mark on the United States.

Thus, it is not prudent to generalize the lessons learned here to other regions with similar characteristics. It is not sufficient to just consider the statistics, but also the history and societal factors. Consider neighboring Canada: despite the vast similarities, it has a considerably different climate. Its history was also shaped differently, having been largely influenced by its relationship with the United Kingdom. Recent developments, such as the effect of heat waves and wildfires and the discovery of thousands of Indigenous children buried in unmarked graves, will, no doubt, have an effect going forward. Perhaps this is the key takeaway from the foregoing chapter: when applying policy to populations, one must do so in consultation with the population while being respectful of their history and culture.

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