Learning from Personal Rapid Transit Failures to Implement Safer and Healthier Transportation Infrastructure

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring 2020

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

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Introduction: ***A Briefing on the State of Transportation Infrastructure***

We rely on roadway transportation networks to go to work, to go home, and to go anywhere and everywhere in between. Unfortunately, we face an extreme and very real danger every time we use our roads. The World Health Organization (WHO) has identified roadway deaths as the leading cause of unnatural death and ninth overall, with 1.25 million fatalities per year globally (WHO, 2015 p. ix). Over a quarter of these fatalities come from pedestrians and bicyclists, and this percentage is only growing (WHO, 2015 p. 9). Addressing this issue on a global scale seems daunting, but the way to improve roadway safety is to construct infrastructure that accommodates more forms of travel.

The United States has been particularly behind in updating its infrastructure, with much of its infrastructure dating back to the middle of the 20th century when the automobile reigned supreme. Constraints have forced pedestrians and bicyclists to use roadways that were only designed to accommodate automobiles. Additionally, millions of Americans forgo mass transit use due to the convenience of automobiles. From 2014 to 2016 the Eno Center for Transportation reports a decline of 4.5% in public transit usage despite overall population and job growth (Eno, 2017 n.p.). Americans are now feeling the adverse effects of a nation built on cars, and they will continue to unless decision-makers enact change. These effects are not only displayed in the roadway fatalities statistic, but also in many of the other top ten causes of death. The overreliance on automobiles has contributed to the country's obesity issues. There are simply not enough safe or convenient ways for Americans to walk or bike. While many people are willing to walk up to a mile and bike up to two miles, "Americans use their cars for 66% of all trips up to a mile long and for 89% of all trips between 1 and 2 miles long" (Pucher and Dijkstra, 2003 n.p). This means Americans do not feel safe walking to public transit stations as well. The "last mile" problem is defined as a gap in available transit modes to provide for travel between residences and transit stations. Only if the U.S improves its infrastructure will it solve this "last mile" problem, and thus improve the safety and health of the nation.

This paper demonstrates that high costs are not the only hinderance to infrastructure improvement, as research illuminates that the actions of engineers, organizations, and politicians are also to blame. In particular, lessons from the failure of the French Personal Rapid Transit (PRT) system Aramis paint a very clear picture of the causes behind infrastructure implementation failures. The rest of this paper reviews the literature and previous case studies on transportation infrastructure implementation failures and identifies better methods for implementing transportation infrastructure, including ways for non-automobile-based transportation systems to flourish.

Part 1: *Scholars Offer Solutions for the Professional World*

Instead of beginning with scholarly sources, a simple example from *The Simpsons* provides an illustration of the issues brought up in this paper. In "Marge vs. the Monorail," the townspeople are considering two proposals for using windfall funds: they could implement modest repavement improvements to the pothole-ridden Main Street, but instead they go for an attractive yet expensive monorail project (O'Brien and Groening, 1993). The episode satirizes people's inclination towards exciting yet impractical solutions to transportation issues, even when a more effective approach is in front of them. Scholars back up this notion with empirical evidence on how professional decision-makers are coming up with faulty solutions to problems across all fields.

When there is a challenge as great as the one our country faces with transportation, the current system must be analyzed at every level to find solutions. This starts with taking outsider perspectives about the way problems are solved, and implementing these processes to address transportation problems. There is no better place to start, besides *The Simpsons* of course, than with the work of Gary Downey, who argues that, to understand how to properly implement safe and health-promoting transportation systems, one must first know what exactly the problem is. In other words, problem definition is a critical first step in this endeavor as in any. Downey writes in “Are Engineers Losing Control of Technology?” that engineering educators are not emphasizing problem definition. Instead engineers are plagued by the mindset that they are, “a provider of solutions, waiting for society to ask [them] for help or give [them] problems to solve” (Downey, 2005 p. 592). This suggests that engineers are able to give more to society when they are involved in deciding which problems to solve. It stands to reason that the better one knows a problem, the better one can work to solve it, but Downey goes on to say that “one also takes possession of it” (Downey, 2005 p. 590). Engineers who feel responsible for helping define a problem can begin to see how others define the problem and view potential solutions. The abilities to collaborate and to synthesize stakeholders’ interests are the skills an engineer practicing problem definition must acquire and use.

A focus on problem definition also helps to prioritize which problems to solve. Unfortunately, in large infrastructure projects with a countless number of stakeholders, the original problem often gets lost, and all that is left is a commitment to a solution. It is inherent of large organizations to suffer from this pitfall due to the social downsides of bureaucracy. One cannot simply blame bureaucracy for problems, because bureaucracy is here to stay. In fact, a strong organal structure is necessary to carry out the massive billion-dollar projects government agencies and contractors routinely undertake. The world of government contracting is filled with problems that have clear solutions and it is just a matter of logistics and funding to complete them. Examples of this include the many roadway projects which this paper is addressing.

However, sometimes the rigid nature of organizations restrict innovation, or at least direct it in the wrong manner, argues Arnold Pacey in “Innovative Dialogue.” Bureaucracies are excellent at “linear innovation” according to Pacey, enabling them to follow established methods and materialize products. Often the innovation within these organizations produce technology that is much like the PRTs of old, a type of high technology that ends up having little to no useful purpose to everyday people. While large government organizations can construct massive pieces of infrastructure, they can fall short of solving the transportation needs of people. Once an innovation is found, it can be milked to the greatest extent by the labs of these massive companies or agencies. Most novel ideas, however, are produced outside of bureaucracies and rely on “the imagination of the creative individual, on interaction among enthusiastic scientists or technicians, and often on interaction between experts and users, designers and potential clients.” (Pacey, 1983 p.142). This is referred to as “interactive innovation.” Pacey offers an optimistic viewpoint to preface his critique of modern institutions by reminding the reader that, while bureaucracy has risen, innovation certainly has not slowed down.

To further find the route of deficient transportation systems, one must assess how decision-makers are working on infrastructure, which has been wrong according to a recent study by Dowd, Franz, and Wasek. “A Decision-Making Framework for Maintenance and Modernization of Transportation Infrastructure” explains how the lack of maintenance and modernization in infrastructure monitoring has created economic consequences in the United States. The article further assesses the problem as the lack of “a holistic approach, objectivity, and topological aspect(s).” (Dowd, Franz, and Wasek, 2020 p.1). Dowd, Franz, and Wasek’s research describes solutions from an engineering perspective. The study recommends a systems engineering approach to prioritizing infrastructure improvements, enabling the decision-makers to leave personal biases out of the equation.

A synthesis of the perspectives of Downey, Pacey, and the team of Dowd, Franz, and Wasek creates a body of research dedicated to changing the problem-solving methods of today’s professional world. These scholars together present a body of work that shows decision-makers do not solve problems in the best manner. All too often professionals fail to properly define problems, fall prey to linear innovation, or follow their instinct instead of data science. Instead, the scholars offer a better way. These principles, when applied to transportation infrastructure institutions, can bring about solutions to the problems of today, namely the high roadway injury statistics and indirect adverse health effects.

Part 2: ***A Case Study of PRT Failures Highlights the Consequences of Poor Decision-Making***

The inspiration for this research paper came from the *Aramis: or the Love of Technology*, an innovative work by Bruno Latour. The French sociologist pioneered the concept of Actor-Network Theory (ANT) within the field of Science and Technology Studies (STS). The titular subject of his novel is a Parisienne PRT system that was suddenly shut down in the Fall of 1987. Involved parties disagreed on the exact cause of the stoppage, but Latour argued that it was the false belief in an inevitability of technological progress that killed Aramis. PRT was popularized in the late 1960’s at various World’s Fairs, advertised as the transportation of tomorrow. The logic was that “people were beginning to recognize the potential of computers,” and “it seemed logical to control vehicles from a central computer” (Latour, 1996 p. 15). The believers in PRT imagined a system where individuals could ride point-to-point, express style, in a small train car with great time accuracy and speed. They would simply punch in a destination, and a train would come pick them up and bring them there. PRT can be compared to an autonomous UberPool on rails, but users do not have to wait in traffic or stop at unnecessary stops. If there are multiple people in one car, it is because they are going to the same destination station. Figure 1 is a rough sketch of how the system would have worked fundamentally, with the single cars meeting up without mechanically coupling as they head towards the urban center.

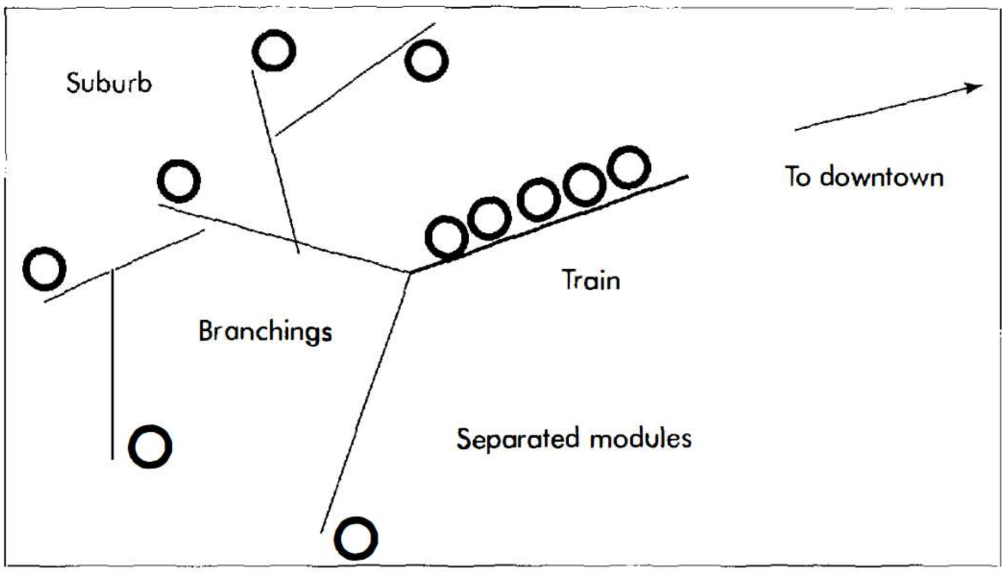

Figure 1: PRT Network This is a crude detail of how a PRT system functions, with the circles representing individual cars on rails that bring people to a central track. They then non-mechanically connect and travel together to the city, and unload at a station. The system was designed with sparse suburbs in mind and to offer better service with less empty train time (Latour, 1996 p. 20).

Unfortunately, the exact way to create such a system was always murky at best. There was not one engineering team who developed the idea, but a collective agreement among all engineers that PRT was the technology to invest in. As government support continued, the blindness to design flaws only grew, and stubbornness permeated each nation's research teams.

Latour uses the eventual failure of Aramis to explain ANT. Ultimately, there was a disconnect where the engineers, institutions, and politicians believed Aramis was an object existing by itself instead of merely the representation of the network of relationships bringing it all together. In other words, they "believed in the autonomy of technology." (Latour, 1996 p. 292). In the epilogue of the novel, Latour freely uses the device of personification, giving the failed transportation a monologue to finish the book. This brings attention to the ridiculousness of considering a technology as more than a sum of the people who bring it to be. It was in fact the failure of the professionals involved to see this point that led to the "murdering" of Aramis. Aramis itself states: "The finest project in the world can't give more than it has, and what it has is what you give it." (Latour, 1996 p. 294). Latour further exposes the relationship between humans and technology in defining ANT. He describes ANT as maintaining that pieces of man-made technology, i.e. transportation infrastructure, possess a presence on the world since they can have a profound impact on the lives of people; however, since Aramis was still a concept and not a working technology it was only existing in the network of relationships between engineers, organizations, and policy makers.

In addition to the free use of personification, the book as a whole has some unique features. Latour writes in a style he came up with called Scientifiction, which he describes as a "hybrid genre" for the purpose of "bring[ing] about this fusion of two so clearly separated universes, that of culture and that of technology, as well as the fusion of three entirely distinct literary genres – the novel, the bureaucratic dossier, and sociological commentary" (Latour, 1996 p. viii). As a sociologist, his purpose in writing such a book was to explain how technology interacts with people through the concept of ANT. Other genres would further false perceptions about technology's social setting, so he chose a writing method that combined fact and narrative in a new way. By creating this new genre, Latour found a way to explore the range of factors that contributed to the failure of Aramis, a project that seemed poised to succeed because it had political backing and a more than capable engineering team. The mystery of its downfall is what provided Latour the opportunity to uncover an important but typically overlooked feature of the relationship between humans and technology.

Many other PRT systems met the same fate of Aramis, and most of them actually died earlier. These projects were merely the dreams of engineers, and Latour reminds us that, “a technological project is a fiction, since at the outset it does not exist, and there is no way it can exist yet because it is in the project phase” (Latour, 1996 p. 23). Still, one PRT system did in fact become a reality in Morgantown, West Virginian, serving the University of West Virginia’s three campuses. The project finished three year behind schedule with a budget over triple of what was originally estimated, leading to a worker proposing “that students be given golf carts so that at least they could ride them on the P.R.T. guide way” (Hamill, 2007 n.p). Despite its beginnings as a wasteful project, financed by the Nixon administration for political gain, the Morgantown PRT has become a useful way for students to get around town.

One of the stations, all of which have bypass tracks, can be seen on the next page in Figure 2. The eventual $138 million dollar price tag still has to be questioned, and the costs of further necessary updates seem daunting to the city and university. Despite being “culturally significant” and working most of the time, as Michael Levy pointed out in a 2010 article, the unreliability of the system creates a poor image for the university. In a personal conversation with an alumnus ,this sentiment was echoed, and it is apparent that constant breakdowns have resulted in the PRT being a common excuse for class tardiness (Levy, 2010 n.p). Even though the Morgantown PRT is functional in a physical sense, its financial failures demonstrate that PRT technology was a less than ideal solution.

Figure 2: PRT Station Here is the PRT Engineering NB station at WVU. Cars can stop at the station or continue around the station if the destination is a different station. This station was recently closed indefinitely due to a rock fall (Rail System, 2015).

Aramis and the overall history of PRTs demonstrate the enormous power transportation infrastructure builders have, and how critical it is for everyone involved to be working in the present instead of being overly enamored by an expected future. While able to create a working PRT system, the people behind the Morgantown PRT still face scrutiny over the extreme costs associated with the system. The lessons from PRT apply directly to transportation engineers of today as they face the challenge of incorporating different ways to travel in an automobile-centered environment. The issue is not simply a lack of funds, but also a resistance against changing the methods of design that lead to these unsafe and unhealthy transportation systems in the first place.

Part 3: ***Solutions Emerge from Key Players***

The reasons why the PRTs discussed in this paper failed are the same reasons that doom many large transportation projects of today. It is fortunate to have such a clear case study for improving the manner in which transportation infrastructure is designed; however, it takes more than learning from history to change the future. Through the analysis of PRT failures and using Actor-Network Theory it is apparent that incorrect assumptions by engineers, organizations, and politicians prompted the long and expensive downfall of PRTs, a fate that will fall upon other systems unless there are fundamental changes in the design and decision-making process. In the words of Latour: "The finest project in the world can't give more than it has, and what it has is what you give it." (Latour, 1996 p. 294). Transportation systems are not inevitable or existent until they are actually working both from a physical and financial standpoint. Prior to this, they are merely the visions of the people behind them, meaning great power is bestowed upon the infrastructure creators of today. Utilizing the research of Downey, Pacey, and Dowd, Wasek, Franz, a few specific solutions emerge that, if implemented, have the potential to significantly improve transportation systems. These solutions pertain to the engineers, organizations, and policy makers who design and spawn into reality the transportation infrastructure our nation depends on.

First, engineers need to take more of a leadership role in the design process. Engineering education prioritizes problem-solving to prepare students to face the challenges of tomorrow, but while this provides bright, critically-thinking and hard-working minds to throw at society's problems, it does not go far enough. The same skills that apply to solving math problems apply to solving management problems. Instead of burying their heads in work, engineers should spend time considering every stakeholder of the new project in order to arrive at a more appropriate solution. In order to accomplish this, companies should be wary of extreme hierarchies and instead give more autonomy to engineers right beside the decision-making politicians.

Furthermore, looking at organizational arrangements, a second solution presents itself: institutions must work to enable interactive innovation while still maintaining a bureaucratic network. There are benefits to the freedom a start-up type company allows as well as benefits from large logistical bureaucracies. Usually the parties that work on a transportation infrastructure project are government policy-makers, a government transportation office, and large contractors and design firms. While smaller design consultants with a greater ability to innovate can be a part of a bid team, they are rarely the entity making decisions. Instead of a top-down approach, teams should create an environment for interactive innovation to prosper by gathering together to think of ideas, allowing each individual to learn from the different experiences of others. Contractors should understand what the designers are trying to accomplish and may come up with a more efficient process. Engineers can learn from construction workers on the constructability of certain aspects of the structure. And all professionals should know what stakeholders' needs are being addressed by the project and if it is an ethical use of taxpayer money. One bid method that currently promotes these activities is the Design-Build (DB) method for bidding (as described in Figure 3 below). The strict timelines associated with DB can lead to rushed work from the professionals involved, but with the right management DB can allow for innovations that save large sums of money. It is possible for bureaucracy and interactive innovation to coexist and thrive, and utilizing DB or other cooperative bid methods can promote such a coexistence.

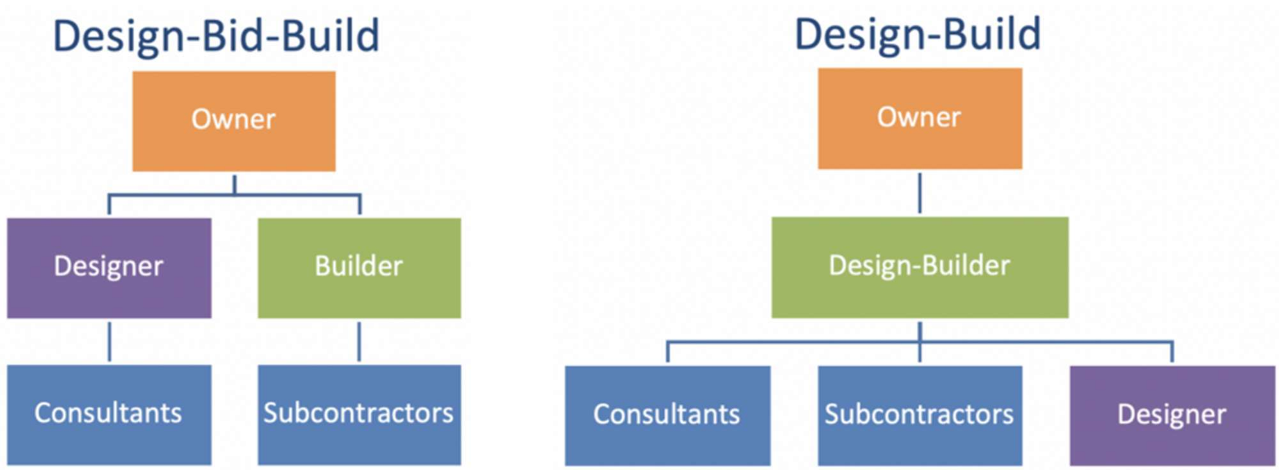

Figure 3: Bid Methods A comparison of Design-Bid-Build (DBB) and Design-Build (DB) methods of contracting is shown. Historically DBB has been used, but in recent years the DB method has become more popular because it allows the design and the build teams to work concurrently (Harwood, 2019).

Even with engineers engaging more in leadership roles and a balance of power between companies in a bid team, at the end of the day, there will always be politicians who have the final say on the large taxpayer-funded projects our nation relies on for transportation. That means these politicians need to be informed as much as possible on both the needs of their electorate and the technical solutions to these needs. Engineering leaders can advise our political leaders on the technical aspects, but they need to be careful about the biases that shape their judgement. Systems engineering pillars of objectivity, proper data collection, and calculated results should be implemented into the decision-making process instead of gut feelings and emotions. As this paper has demonstrated, PRTs have failed in part because decision-makers followed their dreams and visions and ignored hard facts. The West Virginia system was funded partly because the Nixon administration wanted good press prior to re-election. Aramis had similar issues yet still had political backing. A comparison of the two systems and how all these problems applied to them is shown below in Figure 4.

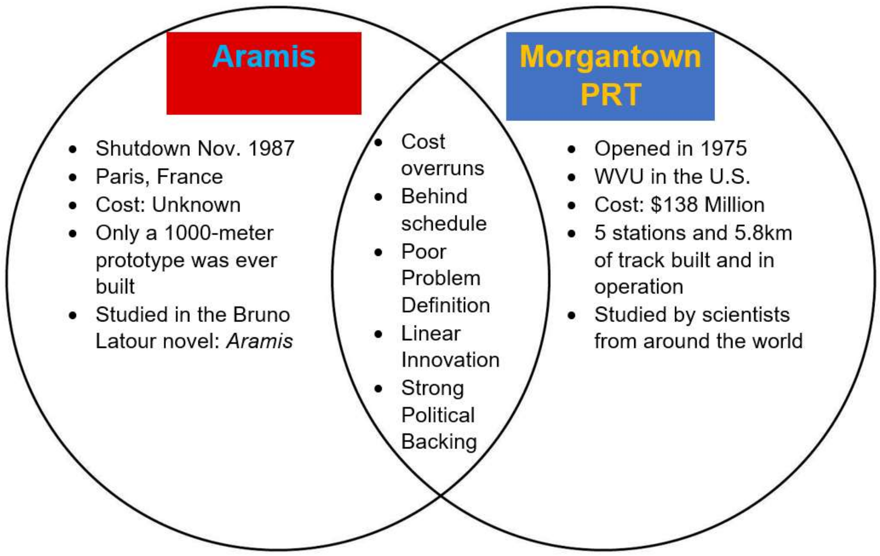

Figure 4: Venn Diagram of PRT's A Venn Diagram of the two PRT's studied in this paper shows some major differences between the two, but also demonstrates that their shortcomings can be attributed in part due to the same reasons (Created by Author).

In the future, the nation and world will be faced with new technological prospects such as automated vehicles, yet all still face many obvious technological barriers. Decision-makers must be cognizant of the implications of their chosen projects and be motivated by sound engineering judgment instead of short-term political advancement. This leads to a final warning that emerges from the in-depth research on PRTs: caution must be exercised when considering large and exciting new-technology based infrastructure improvement projects. While they may seem highly innovative, they are often in fact a product of linear innovation. It is natural for people to become charmed by a new technology, and as Pacey puts it, "high technology is concerned with high performance and complexity for its own sake" (Pacey, 1983 p.137). When people become overly attached to their pet projects that are aimed at achieving performance goals instead of actually solving real world problems, then resources are often spent unwisely. The amount of money funneling into PRT research is astounding, especially when considering what could have been if that money was spent towards actual solutions to traffic problems. Many smaller improvements can go further than the biggest projects can. For example, instead of inventing systems to replace automobile infrastructure, professionals could work towards implementing smaller systems to work alongside cars. It is far less costly to provide maintenance to an existing public transit system, or to improve the bicycle and pedestrian aspects of our roads, than it is to install a completely new transit system. These small and cost-efficient solutions can little by little make safer roads that promote a healthier lifestyle.

Conclusion: ***Moving Forward to a Better Future***

The case studies and research analyzed in this paper demonstrate, the people who make decisions about transportation projects often practice problem definition poorly and fund pet projects that continue a linear innovation path and do not make sense economically. Politicians make decisions about which projects to fund based on emotion and elections instead of applying system analysis and objectivity to the situation. People fail to learn from other cultures and organizations and instead follow along with the hierarchy of their own organization. These failings have produced transportation institutions that attempt to solve problems they do not have while ignoring the ones that they do. In effect, roadway deaths are a major problem for the world, and the indirect health consequences of automobile culture are profound.

By examining the case study of PRT from Aramis and the Morgantown PRT, and specifically the STS discoveries of Latour, in conjunction with the findings from the works of Downey, Pacey, and the group of Dowd, Franz, and Wasek, professionals can be given solutions to the safety and health problems in transportation. Government agencies must heed the warning against large and costly projects, like the monorail from *The Simpsons*, since they often go against this framework for problem-solving. Engineers should be given greater leadership positions, and the bidding process for large projects needs to be similar to the Design-Build method. Through problem definition, interactive innovation, and a systems engineering mindset, these transportation professionals could design infrastructure that promotes small-scale improvements to biking, walking, and existing public transit options in order to better both the health and safety of our nation's citizens.

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