Crumbling Infrastructure: Fixing our Nation's Failing Public Works

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

Thomas Blankinship
Fall, 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

Signature ____ Date __________
Thomas Blankinship

Approved ____ Date __________
Richard Jacques, Lecturer, Department of Engineering and Society

Introduction:

Since 1988, the American Society of Civil Engineers (ASCE) has periodically released an Infrastructure Report Card grading all aspects of American infrastructure including bridges, roads, drinking water, dams, energy production, and railways. The latest such report, released in 2017, gave American infrastructure an overall D+ grade (p. 5). They estimated that, in order to raise our infrastructure grade over the period between 2016 and 2025, it will cost roughly $4.6 trillion. This represents a funding gap of roughly $2 trillion (American Society of Civil Engineers, 2017, p. 8). This massive investment is both necessary to ensure a better quality of life in this country and well worth it economically. Our dilapidated infrastructure already causes trillions of dollars of damage to our economy per year (American Society of Civil Engineers, 2017, p. 7). Not only will this investment in our infrastructure mitigate that loss, it will provide jobs to an upwards of 11 million people through 2027 (Carnevale & Smith, 2017, p. 3).

In this paper, I will explain the benefits of addressing our infrastructure problems on our economy and the overall safety and quality of life of the American people. The time to address this problem is now: the longer we wait the more it will cost. Given limited human and capital resources, repair of certain infrastructure will have to be prioritized, or, perhaps more accurately, our infrastructure will have to be triaged. I will discuss ways to do this based on risk to the traveling public first and then damage to the economy. Further, I will propose a solution to mitigate these risks in the future. Finally, I will propose a way to view the cost of such infrastructure projects beyond the price paid by government entities. That is, I will propose a way to quantify societal costs of infrastructure projects in order to make better economic decisions regarding repair and replacement options.

America's Failing Infrastructure:

America's infrastructure is crumbling. Repairing it will be a herculean task requiring trillions of dollars in investment and extraordinary manpower. To elucidate the scope of this problem, it should be noted what areas the ASCE Infrastructure Report Card addresses: aviation, bridges, dams, drinking water, energy, hazardous waste, inland waterways, levees, parks and recreation, ports, railways, roads, schools, solid waste, public transit, and wastewater. Of these sixteen categories, twelve have a grade of D- to D+, three have a grade of C- to C+, and the remaining one has a grade of B (ASCE, 2017, p. 6). Overall, the ASCE assigned a grade of D+ for American infrastructure. Figure 1 below summarizes these gradings.

Figure 1: ASCE 2017 Infrastructure Report Card (ASCE, 2017, p. 6)

This report card presents a sobering view of infrastructure in the United States and makes clear the need to fully and unabashedly address the problem. The first and likely most major hurdle to solving this problem is a lack of political will. The massive amount of money required is contentious, but much of it is necessary. Infrastructure spending has garnered bipartisan support in recent years, but the devil, as they say, is in the details. An infrastructure bill lends itself to partisanship. Such a bill passed in the Democrat-controlled House of Representatives in July of 2020 but was quickly rejected by the Republican-controlled Senate due to a plethora of climate-friendly initiatives as well as spending for housing, schools, and internet access that Republicans felt were wasteful. Republicans in the Senate support a bill more narrowly focused on surface transportation such as roads and bridges (Politico, 2020). With Congress failing to come to any sort of meaningful compromise, the issue will not be addressed again until 2021.

Despite this lack of compromise, there is hope that something will be done. Both parties recognize the need to allocate money for so called surface transportation – primarily roads and bridges. This is the sector that needs the most investment, representing about $2 trillion of the needed $4.6 trillion (ASCE, 2017, p. 8). Further, supporting an infrastructure bill would be a good political move as well as an economic one. In this time of economic stagnation and job loss due to COVID-19, a massive influx of government money for needed projects is a commonsense way to stimulate the economy. Carnevale and Smith (2017, p. 3) state that a $1 trillion investment in infrastructure would lead to the creation of more than 11 million jobs over the next 10 years. It should be noted, however, that the vast majority, 92%, of these jobs would be filled by men and that it would likely be a short to medium term infrastructure boom rather than a long-term career for many (Carnevale & Smith, 2017, p. 9). With that said, infrastructure jobs pay better than other jobs for people with less than a Bachelor’s degree (Carnevale & Smith, 2017, p. 5). Given the outsourcing of American manufacturing in the past few decades, there is a great need for blue-collar job opportunities. An infrastructure boom would certainly help those that the economy has left behind and those whose jobs were lost due to COVID-19. Another reason to get an infrastructure bill done sooner rather than later is that traffic is at record lows due to COVID-19 (U.S. News and World Report, 2020). Government stay-at-home orders, canceling of vacations and holiday celebrations, and people working from home has all contributed to this decline. This would make the negative societal impact of potential infrastructure projects, due to traffic delays for example, much less disruptive than normal. An infrastructure bill at this point in time would therefore be excellent political and economic policy.

By now, it should be clear that our infrastructure needs an overhaul and that the perfect opportunity to do so has presented itself, but let's take a step back and consider what happens if we do nothing. A topic of particular interest to me, as an aspiring structural engineer, is bridge diagnosis, repair, rehabilitation, and replacement. According to the ASCE (2017, p. 28), roughly four out of ten bridges in the United States are 50 years or older. An additional 15% of bridges are between 40 and 49 years old. With a typical design life of 50 years, over half of bridges are past or quickly approaching the end of their design life. Further, one in eleven bridges in the US was designated structurally deficient in 2016 (American Society of Civil Engineers, 2017, p. 27). These bridges have degraded due to corrosion of steel reinforcement, concrete degradation, lack of maintenance, and generally a history of neglect (Rehman, 2016, p. 59). Given these dire assessments, it is almost a miracle that bridge collapses are rare occurrences. And because, on average, roughly 188 million trips are taken across structurally deficient bridges every single day, it is a fact that bridge collapses have the capacity to be devastating (American Society of Civil Engineers, 2017, p. 27). While bridge collapses offer a visceral example of what can happen when our infrastructure fails, they are not the only threat. For example, after years of neglected roadways, traffic fatalities increased by 7% between 2014 and 2015 (American Society of Civil Engineers, 2017, p. 76). Further, the poor state of our infrastructure causes significant damage to our economy. The ASCE (2017, p. 7) estimates that by 2025 failure to close the infrastructure investment gap will cause $3.9 trillion in losses to the GDP, $7 trillion in lost business sales, 2.5 million lost jobs, and result in American families losing upwards of $3,400 in disposable income each year. When comparing the costs of doing nothing with the costs and benefits of fixing our infrastructure, the need for action is crystal clear.

Risk Assessment and Mitigation:

If and when infrastructure funding becomes available, the work has only just begun. While the capital problem will be solved, there still will be a lack of manpower and equipment to do everything at once. Because of this, we will have to determine which sections of our infrastructure require the most immediate attention. Due to my interest in bridges, I will focus my attention on bridge assessment, repair, rehabilitation, and replacement. As it stands, damage to bridges is often hard to detect and superficial surface inspections only take place about once every two years (Chang, 2003, p. 257). These inspections are also relatively subjective and rely on visual inspection of concrete conditions, for example. The problem with this is that oftentimes bridges start to degrade beneath the surface of the concrete first: the reinforcing steel rusts and then expands and contracts with temperature changes causing cracks in the concrete from the inside out. Oftentimes, once surface damage is visible, a lot more damage has happened under the surface. To address these concerns, a field known as Nondestructive Testing (NDT) has emerged. This practice allows workers to go into the field and better determine the structural integrity of existing structures. These techniques should be utilized as soon as possible to create an accurate list of those bridges at most risk of failure. The riskiest bridges should then be taken care of as quickly as possible.

After the bridges at risk of imminent failure are taken care of, the next thing to consider is economic impact. For example, if there is a major road or bridge that is relatively safe, but constantly congested, resources should be spent widening the road or otherwise relieving that congestion. The impact of relieving this traffic will be great: ASCE estimates that $160 billion was wasted in time and fuel in 2014 due to traffic delays (2017, p. 76). At the same time, we will need to be smart about how we go about fixing infrastructure so as to spread out construction-related traffic delays. This way we can, hopefully, minimize the impact on individuals. We should also “overbuild” our infrastructure so that we are building something that we can use long into the future. If the state of our current infrastructure is any indication, we will probably need it.

Moving forward, we will also need to determine a sustainable way to ensure that we have adequate funding for infrastructure maintenance and repair. Many of the problems we face wouldn’t be as dire as they are if adequate funding for maintenance was provided. One way to provide this funding is to raise taxes on gasoline and keep these taxes tied to inflation. This may not prove a good long-term solution, however, as cars are increasingly more fuel efficient and electric vehicles are more common. Another way is instituting tolls on roads that are repaired. These options have the benefit of charging fees based on use of the roadways. The state and federal governments should also allocate some amount of money towards basic infrastructure maintenance in perpetuity to ensure that these needs are met. Most importantly, these funds allocated for infrastructure projects and fees collected from toll roads and gasoline taxes should be untouchable by other areas of government. This money should be guaranteed to be used for infrastructure only so that we will have it when we need it.

Quantifying Societal Costs:

The cost to fix the infrastructure of the United States is massive. As with anything, the contracts will likely go to the lowest bidder. Unfortunately, the price of construction is only a part of the equation. Bridge and road repair are particularly disruptive to traffic resulting in countless manhours of wasted time and innumerable gallons of wasted gasoline. These costs may be less tangible, but they are every bit as real as the winning bid on an infrastructure project. These costs are spread out among every driver and passenger similarly to how taxes are spread out among every taxpayer: they are paid by society as a whole. In order to truly determine the most economical solution to a particular infrastructure problem, then, we must develop a framework that fairly accounts for both hard to come by tax dollars and external societal costs and benefits.

In order to develop this accounting framework, it makes sense to determine which external societal costs will be accounted for and determine a fair estimated value for these costs. As mentioned above, wasted time in construction delays is a major cost. The median personal income in 2019 was $34,248 (Social Security Administration, 2020). Assuming a 52-week year with 40-hour work weeks, this calculates to $16.47 per hour or $0.27 per minute. Therefore, we could argue that a delay of one minute costs society $0.27 per person delayed on average. Wasted gasoline and the extra pollution that it creates is another external societal cost. Cars can burn up to a half of a gallon of gasoline per hour while idling (South Carolina Department of Health and Environmental Control, 2015). The national average price for gasoline was $2.60 per gallon in 2019 (U.S. Energy Information Administration, 2020). This means that a minute delay spent idling costs about $0.02 per car delayed in wasted gasoline alone. Burning extra gasoline also causes extra pollution and pollution can cause illness or death. Estimates of the cost of vehicular pollution ranges from $0.003 per vehicle mile to $0.417 per vehicle mile (Victoria Transport Policy Institute, 2020, p. 5.10-10). The average car in the United States in 2016 got 24.20 miles per gallon (U.S. Department of Energy, 2020). Assuming again that an hour of idling would burn half of a gallon of gasoline, idling for an hour is equivalent to driving 12.10 miles and idling for a minute would be equivalent to driving 0.20 miles. If we assume a relatively conservative estimate for the cost of pollution at $0.05 per vehicle mile, the price due to pollution while idling is about $0.01 per minute. This time spent idling also adds wear and tear to vehicles, but decent estimates for these costs proved hard to find. While there are undoubtedly other costs associated with traffic delays to the traveling public, wasted time is likely the largest factor. Adding these external societal costs associated with wasted time, wasted gasoline, and added pollution we end up with a low-end estimate of $0.30 per minute of delay per car. Extrapolating this cost out to the tens or even hundreds of thousands of cars a roadway may see per day, it is obvious that these “invisible costs” that every driver pays are massive.

Now that we have established a rough estimate of the societal cost of traffic delays, it is obvious that they are significant. For example, for my capstone project we were tasked with replacing a section of Route 250 in Albemarle County. This section of road had an Average Daily Traffic (ADT) of 11,500 vehicles. If we assume a five-minute delay for every driver due to construction, this amounts to at least $17,250 wasted every day. As such, traffic delays should be reduced as much as possible throughout the process of fixing our infrastructure. This means using techniques and strategies that reduce the impact of roadwork to the traveling public. One such technique is known as Accelerated Bridge Construction (ABC). It uses prefabricated concrete pieces that are shipped on site and put in place. ABC is more expensive than conventional bridge construction methods, but it is significantly faster. ABC techniques have been used to replace bridges and major bridge sections in as little as 48 to 72 hours (Federal Highway Administration, 2012, p. 1). I believe that moving forward, given the amount of work that needs to be done to fix the infrastructure problem, time should be the priority on all but the least travelled roads. The significant societal costs of delayed construction, especially on such a massive scale, far outweigh the extra costs of Accelerated Bridge Construction.

Conclusion:

The infrastructure problem in the United States is a big one. It will require the cooperation of many different sectors of our society and impact nearly everyone in one way or another. This impact can and hopefully will be a net positive, however. It will provide millions of jobs, boost our economy, increase our competitiveness on the world stage, and provide us with safer, more robust infrastructure systems for years to come. In order to reduce the negative impacts of its repair, we will need to prioritize fast build times over price because delayed traffic has an enormous hidden cost to society. In order to do this, we need an infrastructure bill that is large enough to allow us to because the savings for society will be worth the extra money from taxpayers. Further, we will need to use relatively new techniques such as Nondestructive Testing to determine which bridges are at the most risk and prioritize their repair, replacement, or rehabilitation. After those infrastructure projects that pose a risk of bodily harm to the public are addressed, the next priority should be eliminating traffic congestion. This will save countless hours of time currently wasted in traffic and innumerable gallons of gasoline. It will also reduce greenhouse gas emissions as well as smog and other pollution related problems. By prioritizing these needs, we can maximize the positive impact and minimize the negative impact of repairing our nation’s infrastructure.

References:

American Society of Civil Engineers (ASCE). (2017). 2017 Infrastructure report card: A comprehensive assessment of America's infrastructure [PDF file]. Retrieved from https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/2017-Infrastructure-Report-Card.pdf.

Carnevale, A.P., & Smith, N. (2017). Trillion dollar infrastructure proposals could create millions of jobs [PDF file]. Retrieved from https://cew.georgetown.edu/wp-content/uploads/trillion-dollar-infrastructure.pdf

Chang, P. C., Flatau, A., & Liu, S. C. (2003). Review paper: Health monitoring of civil infrastructure. *Structural Health Monitoring: An International Journal, 2*(3), 257-267. doi:10.1177/1475921703036169

Federal Highway Administration. (2012). Every day counts: Accelerated bridge construction [PDF file]. Retrieved from https://www.fhwa.dot.gov/innovation/everydaycounts/edc-2/pdfs/edc_abc.pdf

Politico. (2020). House sends massive infrastructure bill to the Senate, where it has no path forward. Retrieved from https://www.politico.com/news/2020/07/01/house-infrastructure-bill-347355

Rehman, S. K., Ibrahim, Z., Memon, S. A., & Jameel, M. (2016). Nondestructive test methods for concrete bridges: A review. *Construction and Building Materials, 107*, 58-86. doi:10.1016/j.conbuildmat.2015.12.011

Social Security Administration. (2020). Measures of central tendency for wage data. Retrieved from https://www.ssa.gov/oact/cola/central.html

South Carolina Department of Health and Environmental Control. (2015). Idling: Why it’s a problem and what you can do [PDF file]. Retrieved from https://scdhec.gov/sites/default/files/Library/CR-010109.pdf

U.S. Department of Energy. (2020). Average fuel economy by major vehicle category. Retrieved from https://afdc.energy.gov/data/10310

U.S. Energy Information Administration. (2020). U.S. average retail gasoline prices in 2019 were slightly lower than in 2018. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=42435#:~:text=U.S.%20regular%20retail%20gasoline%20prices,the%20rest%20of%20the%20year

U.S. News and World Report. (2020). Low U.S. traffic levels ‘Unprecedented’ amid coronavirus. Retrieved from https://www.usnews.com/news/best-states/articles/2020-04-15/low-us-traffic-levels-unprecedented-during-coronavirus-pandemic

Victoria Transport Policy Institute. (2020). Transportation cost and benefit analysis II – Air pollution costs [PDF file]. Retrieved from https://www.vtpi.org/tca/tca0510.pdf

Virginia Department of Transportation. (2017, January 6). VDOT: Proposed Route 250 Little Ivy Creek bridge replacement project, Albemarle County [Video]. YouTube. https://www.youtube.com/watch?v=Pg0qOX50nwI