

OUT OF SIGHT, OUT OF BUDGET: THE INVISIBILITY CRISIS IN U.S.
INFRASTRUCTURE MAINTENANCE

A Thesis

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Master of Regional Planning

by

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ABSTRACT

This thesis investigates why infrastructure maintenance in the United States remains chronically underfunded despite its economic and safety benefits. Focusing on roadway systems, it argues that the root cause lies in the low political and public visibility of maintenance activities. Through a literature review and in-depth interviews with transportation officials across state and local agencies, the study finds that maintenance is often deprioritized in budgets because it lacks the immediate, visible benefits politicians can leverage for credit-claiming. Case studies from six jurisdictions reveal how maintenance officials navigate funding constraints, visibility challenges, and intergovernmental dynamics. The research also explores the different strategies that can help elevate the profile of maintenance, as well as the implications of elevating visibility. This thesis contributes to the broader understanding of infrastructure policy and calls for changes to enhance long-term infrastructure asset stewardship in the U.S.

BIOGRAPHICAL SKETCH

Yixiao Edward Guo was born in Beijing, China. He has a B.S. in Urban and Regional Studies from Cornell University before continuing on to pursue this Master of Regional Planning degree. He is broadly interested in transportation and infrastructure planning, as well as their practical impact on communities at different scales in different locations.

To those who take care of us even when we don't notice.

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LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
ASCE	American Society of Civil Engineers
CHIPS	Consolidated Local Street and Highway Improvement Program
FHWA	Federal Highway Administration
GASB	Governmental Accounting Standards Board
GDP	Gross Domestic Product
IRI	International Roughness Index
MDOT	Michigan Department of Transportation
NCDOT	North Carolina Department of Transportation
NTSB	National Transportation Safety Board
P3 (or PPP)	Public-Private Partnership
PASER	Pavement Surface Evaluation and Rating
RSL	Remaining Service Life
TRIP	The Road Information Program, a national transportation research nonprofit
VDOT	Virginia Department of Transportation

INTRODUCTION

Infrastructure represents the critical foundation on which modern economies and societies operate. From the highways and bridges that facilitate transportation to the water and sewer systems that sustain public health, infrastructure underpins virtually every aspect of contemporary life. Despite its critical importance, infrastructure often receives little public attention until significant problems or failures occur. While high-profile infrastructure investments – new highways, airports, and train lines – routinely attract political support and media coverage, the daily maintenance and upkeep of existing infrastructure rarely receive comparable visibility. Yet, inadequate infrastructure maintenance can have severe consequences, creating public safety risks and economic disruptions, and even causing tragic losses of life.

Over recent decades, reports of infrastructure deterioration have increased, prompting concerns that chronic underinvestment and deferred maintenance have left American infrastructure systems dangerously inadequate. High-profile maintenance failures and close calls, such as California’s devastating wildfires sparked by aging transmission lines and visible cracks on the I-40 bridge Mississippi River, serve as reminders of the human and economic costs associated with maintenance neglect. Despite such incidents, maintenance activities continue to struggle to receive adequate funding.

This thesis seeks to explore the reasons behind the lack of maintenance spending by examining the concept of “visibility”. Through a literature review and expert interviews with roadway maintenance professionals at state and local government agencies across the United States, the paper explores how visibility, or the lack thereof, shapes decisions surrounding infrastructure funding and maintenance practices. The paper also evaluates the strategies

used by maintenance practitioners to elevate the profile of maintenance activities, secure funding, and prevent infrastructure deterioration. The focus of the paper is on roadway infrastructure as it is the most researched infrastructure sector in the U.S. context given the critical role roads and highways played and continues to play in the nation's development.

By clarifying the relationship between roadway infrastructure maintenance's visibility in the political process and the associated funding considerations, this paper hopes to serve as a stepping stone for broader discussions on insufficient infrastructure maintenance in general and ways to address it. By raising awareness of these challenges and opportunities, this thesis hopes to make a small contribution to ultimately enhancing the reliability, safety, and resilience of infrastructure systems in an increasingly interconnected and changing world.

BACKGROUND AND LITERATURE REVIEW

Infrastructure maintenance is a complex and multifaceted issue that spans numerous types of systems beyond just roadways. While this thesis ultimately focuses on roadway maintenance, many of the challenges identified, such as invisibility, funding constraints, and political dynamics, are common across infrastructure types. Different types of infrastructure share similar economic, technical, and institutional characteristics, and the problem of insufficient maintenance is widespread. Therefore, this literature review section draws from general infrastructure scholarship to establish a conceptual foundation for understanding maintenance practices, challenges, and implications across the broader infrastructure landscape.

2.1 What is Infrastructure and What is Maintenance?

In order to discuss infrastructure maintenance, it is necessary to clarify what infrastructure and maintenance typically refer to, respectively.

There is no easy definition of infrastructure. One of the most widely cited, and also one of the broadest, definitions of infrastructure came from Reimut Jochimsen, in which infrastructure is defined as “the sum of all material, institutional and personal assets, facilities and conditions available to an economy based on the division of labour and its individual economic units that contribute to realising the assimilation of factor remuneration, given an expedient allocation of resources (Jochimsen 1966; Weber, Staub-Bisang, and Alfen 2016, 11).” In essence, Jochimsen argues that infrastructure’s role is to enable and ensure that economic actors, workers, and investors alike, can be compensated fairly for their contributions to the economy and that resources are used efficiently and

effectively. This definition is, however, overly broad as any factor that contributes to the development and growth of a market economy, Jochimsen's central concern at the time, would be counted as infrastructure.

It is more helpful, therefore, to view infrastructure in the context of this thesis instead as physical objects that show a set of economic, financial, and other characteristics. Weber et al. (2016, 11–13) introduced a number of such traits. First, infrastructure often supports or provides *key public services* that make them a prerequisite for economic growth as Jochimsen recognized. Water, sewer, roads, electricity, and many others are some of the common key public services (also see Torrisi 2009). Second, infrastructure tends to have a *low elasticity of demand*. As they provide key and vital services, the demand for infrastructure is often independent of industry cycles and economic performance – stable and predictable. Third, infrastructure often exhibits *network effects* and *creates positive externalities*: roads, for example, are only useful if they are connected to other roads, and the more roads they are connected to the more valuable existing roads become. Hurlin (2006) supports the network effect argument, finding that when the available stock of infrastructure is very low, investment in this sector has the same productivity as non-infrastructure investment; when a minimum infrastructure network is available, the marginal productivity of infrastructure investment is greater than the productivity of other investments; and when the network is complete, infrastructure investment's marginal productivity becomes similar to the productivity of other investment again. Fourth, infrastructure often operates in (*quasi*) *monopolistic* situations with high barriers to market entry. Infrastructure's network effect, combined with the already high price to construct standalone physical infrastructure and the fact that infrastructure is difficult to move once constructed, makes infrastructure assets

difficult to completely replicate as the upfront investment cost would be prohibitively expensive. At the same time, after an infrastructure network is established, the cost of providing additional service within the network is low. These conditions create high barriers to entry for infrastructure, and there is often little competition in their provision. These characteristics of infrastructure make many infrastructure systems function as *natural monopolies*. Infrastructure's quasi-monopolistic nature also means that, as a fifth characteristic, the sector is often *subjected to heavy regulation* by the government to prevent opportunistic behavior from providers and ensure social welfare (Gómez-Ibáñez 2006). Sixth, infrastructure tends to have a *long service life* and a long designed life.

Maintenance is a key part of ensuring infrastructure can continuously achieve its designed purpose and life, and it is the central inquiry for this thesis. Like with infrastructure itself, the definition of infrastructure maintenance is vague with maintenance and operations often lumped together as one activity. Fox and Murray (2014), for example, referred to operations and maintenance together as “[t]he non-capital inputs in the production of infrastructure services[, which includes] labor, replacement parts and materials (potentially including some replacement capital), electricity (which is itself an infrastructure service), and many other infrastructure-specific factors.” Sometimes, maintenance is treated as a subset of operation, with Sánchez-Silva et al. (2016) stating that “[o]ptimum operation of structures and infrastructure requires maximizing the availability (i.e., operation over a predefined serviceability threshold) and safety at minimum cost, [and to] achieve this objective, it is essential to define cost-efficient operation policies, among which maintenance plays a significant role.”

Attempts have been made to distinguish the two activities. Ochieng and Ominde (2020), for example, suggest that while operations and maintenance signify all of the activities required to run and sustain an infrastructure project, “operations refer to the daily tasks needed to provide service delivery to the citizens, businesses, schools and other users,” while maintenance “entails technical activities, planned or retrieved, which are required to sustain the working system.” They argue further that maintenance requires functional checks, monitoring, testing, measuring, servicing, repairing, or replacing of necessary tools and supporting utilities throughout the lifecycle of the infrastructure asset. However, this distinction may be too arbitrary as a daily task needed to provide service delivery may double as technical activities required to sustain the working system. The acts of a technician checking the pressure of pumps in a water system, or of a maintenance worker clearing debris from roadways, may be performed to ensure users have clean water or safe roadways to drive on daily, but they can also be scheduled activities that ensure broken pumps are noticed and replaced and roadways do not suffer damage from fallen debris.

For the purpose of this thesis, the definition provided by the British Standards Institution, which states that maintenance “is the combination of the technical and associated administrative actions intended to retain an item or system in, or restore it to, the state in which it can perform its required function,” best fits with the scope (Sánchez-Silva et al. 2016). This definition would include both operation and maintenance activities as it is objectively difficult to separate which activities belong under which category.

Maintenance activities are typically divided into two categories: preventative and corrective. Preventative maintenance usually refers to scheduled and predetermined activities designed to keep the infrastructure operating above certain minimum performance

standards. Predictive maintenance, which utilizes monitoring to ensure minimum standards are met, is a type of preventative maintenance. Preventative maintenance may be proactive – occurring before problems develop, or reactive – after problems are identified. Maintenance activities that occur after the minimum performance standards are violated are defined as corrective maintenance. (Sánchez-Silva et al. 2016; Ochieng and Ominde 2020). In general, preventative maintenance is less costly than corrective maintenance – a report for the Indiana Department of Transportation found, for example, that “substantial reduction in corrective maintenance are achieved for unit increases in preventive maintenance levels (Labi and Sinha 2003, 356).”

While the focus of this paper is on public infrastructure, ownership may not be a meaningful factor that affects infrastructure maintenance. Both public and private entities have long lists of high-profile infrastructure maintenance failures. Bridge closures and failures are not uncommon, but equally common and destructive are utility failures and freight railroad derailments – ventures that are more often private rather than public (Kenny 2023).

2.2 The Importance and Benefits of Infrastructure Maintenance

Infrastructure maintenance is clearly important. In 2011, data from the Congressional Budget Office calculating capital and operation and maintenance spending on U.S. transportation and water infrastructure shows that maintenance accounts for 48.8% of total government spending on infrastructure, the latter which accounts for around 2.6% of total GDP in the U.S. (Vella and Kalyvitis 2011). In 2023, operations and maintenance spending

accounted for 56.7% of all public infrastructure spending (\$355 billion of \$625.8 billion total) (Kane, Tomer, and Swedberg 2025).

As infrastructure is the backbone to key public services, poor infrastructure creates significant economic costs. In a study conducted by TRIP, a national transportation research nonprofit, the average motorist in the U.S. loses \$599 per year, or a total of \$130 billion nationally, in additional vehicle operating costs as a result of poor roads – these costs include additional vehicle repair and maintenance costs, accelerated vehicle deterioration, and additional fuel consumption (TRIP 2018).

Poor infrastructure maintenance could also be a genuine threat to the life and safety of the average citizen. Severely worn hooks and hanger plates from 97-year-old transmission lines likely caused California's 2018 Camp Fire tragedy that killed 85 people and displaced tens of thousands (Rittiman 2021). Near misses are frequent. In 2017, the spillway of Oroville Dam suffered a partial collapse that was later determined to be the result of long-term systemic failure to recognize and properly address the deficiencies. While the incident did not result in casualties, over 188,000 people were evacuated as the likelihood of dam failure was high at one point (Alvi 2018). In 2022, hours before then-President Biden was scheduled to visit Pittsburgh to promote his infrastructure bill, the Fern Hollow Bridge in the city collapsed, sending cars and buses into the ravine. Luckily again, there were no casualties as the bridge collapsed in the early morning (Robertson and Kasakove 2022). Had the timing been different, a greater catastrophe may have occurred. The National Transportation Safety Board's later investigation concluded that the City of Pittsburgh's repeated failure to act on maintenance and repair recommendations from inspections resulted in the bridge's failure (NTSB 2024).

Thus, there are significant benefits to having a well-maintained infrastructure system, which at minimum can help avoid the above-mentioned economic and social costs. World Bank studies find that returns on maintenance on road projects were twice as much as those on projects that involved new construction, and the Congressional Budget Office calculates that highway maintenance in the U.S. generates an economic rate of return between 25 to 38 percent (Rioja 2013, 8). Gibson and Rioja (2017), modeling the Mexican economy, finds that given the current allocation of public expenditures in Mexico, spending more on maintenance rather than on investing in new infrastructure can increase aggregate GDP and improve the distribution of wealth. Kalyvitis and Vella (2015) examines the productivity effects of infrastructure operation and maintenance spending by state and local governments in the 48 contiguous states in the U.S. between 1978 and 2000 using the Congressional Budget Office's dataset on public spending on transportation and water infrastructure, accounting for transboundary spillover of capital and maintenance spending. They find that interstate spillover impacts are significantly positive and exceed direct impacts for both capital and maintenance spending, and that the cross-state spillover effect of maintenance outlays was considerably high, suggesting that maintenance investment in general contributes positively to the welfare of the nation. Vella and Kalyvitis (2011) also find that a rise in spending by states and localities on infrastructure maintenance would have a positive effect on future productivity growth of the U.S., although the study also finds that additional federal spending on maintenance would reduce growth.

The latter finding of Vella and Kalyvitis (2011) shows the fact that while maintenance spending in general is good for the economy, it is only good up until a certain point as the government has to balance investing in new infrastructure against maintaining

existing infrastructure. Too much spending on maintenance could result in the lack of new infrastructure to meet new demands, thereby hurting the economy, as shown in *Figure 1* (Rioja 2013). Since Vella and Kalyvitis (2011) found that U.S. allocation between new infrastructure and maintenance was close to optimal at the national level, its conclusion that additional federal-level spending on maintenance would be harmful is reasonable. At the local level, though, additional maintenance spending would continue to have positive economic effect as federal government’s matching grants to states and localities to construct new infrastructure may have lowered states’ spending on maintenance, and local governments do not account for the large positive interstate spillover effect of their infrastructure spending and thereby are likely to underspend on maintenance (Rioja 2013; Vella and Kalyvitis 2011; Kalyvitis and Vella 2015; Glaeser and Poterba 2021, 25).

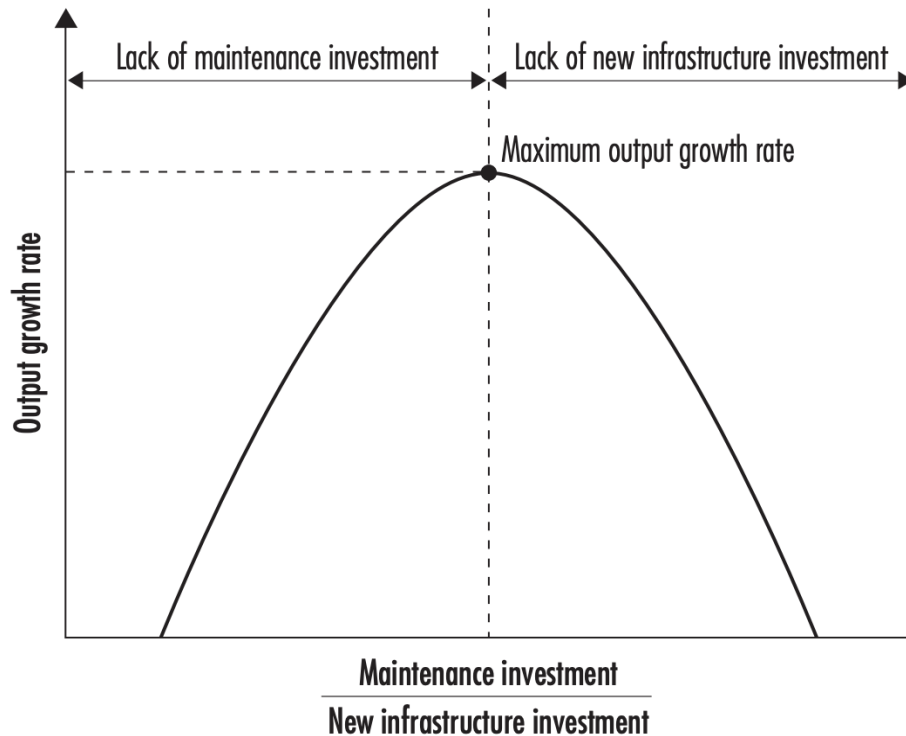


Figure 1. Relationship between growth and the ratio of maintenance to new investment (Rioja 2013, 353)

2.3 State of Infrastructure in the U.S.

The U.S. is a large nation supported by extensive systems of infrastructure funded and managed by entities at all levels of government and by various private companies. It is therefore difficult to holistically assess the current state and quality of all infrastructure in the U.S. with nuance as it is difficult to obtain comprehensive and comparable data.

However, a number of sources do provide a rough picture.

Before discussing the actual state of infrastructure, it is important to provide an overview of infrastructure spending and ownership. In recent years, the U.S. public sector has spent close to \$400 billion on basic infrastructure, although the number reflects the recent boost due to the 2021 Infrastructure and Jobs Act (USA Facts 2024; McBride, Berman, and Siripurapu 2023). State and local governments are the biggest public spenders on infrastructure, paying \$218.5 billion on infrastructure in 2021. The federal government, in comparison, spent \$76.7 billion directly and transferred \$98.2 billion to states for a total of \$174.9 billion in 2021 – although historical federal direct spending has been around \$40 billion (USA Facts 2024). Transportation spending is the largest category of U.S. infrastructure spending, with highways frequently receiving the most money in any given year (Bennett et al. 2020, 59–65). Approximately 34% of basic infrastructure is privately owned, with 4% being owned by the federal government and 62% by state and local governments. Over 90% of water and sewer systems are public and locally owned. Over 90% of transportation infrastructure is owned by state and local governments, which include the majority of highways, airports, transit systems, and water transportation. Rail

transportation is 100% private, and the power and utilities sector is heavily private (Bennett et al. 2020, 66).

The media consensus is that infrastructure in the U.S. is falling apart and in need of dire upgrades and repairs (Duranton, Nagpal, and Turner 2020, 1). The Council of Foreign Relations cites experts saying American infrastructure is “both dangerously overstretched and lagging behind that of its economic competitors (McBride, Berman, and Siripurapu 2023).” *WIRED* says that American infrastructure is “broken” and ill-prepared for climate change (Simon 2024). A *Time* writer states that “[the U.S. has] simply failed to live up to the task” of repairing its roads and bridges, upgrading its power and communications grids, and preparing for a changing future (J. Anderson 2024).

The American Society of Civil Engineers (ASCE), which has published a report card on American infrastructure every 4 years since 1998, agrees: the grade point average of American infrastructure was solidly in the D-range since 1998, and the C– it received in 2021 as well as the C it received in 2025 were the highest grade ever, reflecting of the increased infrastructure investment under former President Biden’s multiple infrastructure laws (ASCE 2021; 2025). The ASCE assigns a grade to each of the 18 infrastructure sectors it tracks based on the infrastructure’s capacity, condition, funding, operation and maintenance, effect on public safety, and resilience to future hazards, among other criteria. It found that while the U.S. has made incremental gains in some of the infrastructure categories, the long-term investment gap, which is the difference between current funding levels and the level of investment required for every category to reach a state of good repair, continues to grow – \$2.1 trillion over 10 years in 2017, nearly \$2.6 trillion over 10 years in 2021, and almost \$3.7 billion over 10 years in 2025 (ASCE 2021; 2025). Should investment

drop to pre-pandemic levels, ASCE (2025) estimates that \$5 trillion in gross economic output would be lost over the next 20 years, and \$244 billion in U.S. exports would be lost over the same period. While this cost is the result of both neglecting maintenance and not building enough new capacity, the maintenance piece remains significant as anywhere between 16% to 49% of total expenditure on transportation infrastructure goes toward maintenance (Rioja 2013, 11; Bennett et al. 2020, 91).¹ In drinking water systems, sources estimate that there are between 10 to 37 leaks and breaks per 100 miles of pipes with one report finding a 27% increase in water main break rates between 2012 and 2018 which reached an estimated 250,000 to 300,000 breaks per year (ASCE 2021). A survey cited by the ASCE (2021) claims that 47% of maintenance work undertaken by utilities is reactive and done as water systems fail. Of the 4 million miles of public roadways in the U.S., 43% remain in poor or mediocre condition, a number that has stagnated in recent years according to ASCE (2021). Of the over 617,000 bridges across the U.S., 42% are at least 50 years old and 7.5% of all bridges are considered structurally deficient. While the number of structurally deficient bridges has continued to decline, the rate of improvement has slowed and there is an estimated \$125 billion backlog of bridge repair remaining (ASCE 2021).

Not everyone agrees that American infrastructure is deteriorating. (Duranton, Nagpal, and Turner 2020, 116–17), for example, concludes that “most U.S. transportation infrastructure is not crumbling” and that “the conditions of the Interstate Highway network improved consistently, its extent increased modestly, and traffic about doubled.” They also

¹ Estimates from Rioja (2013) suggest that between 1956 and 2004, 48.8% of total capital and operations and maintenance expenditures on public transportation infrastructure went towards operations and maintenance. Bennett et al. (2020) created experimental estimates of maintenance and repair expenditures to total gross fixed investment for state and local highways and streets, and showed that between 14-18% of all investment went to maintenance of repairs between 1997 and 2017.

find that maintenance of bridges has been able to keep up with their deterioration, and that the number of dangerous bridges has decreased over time (Duranton, Nagpal, and Turner 2020, 175–79).

This finding, however, is incomplete. While it remains true that the Interstate system is the most intensely used – it accounts for 1% of road mileage and 2% of lane miles in rural areas but for 24% of all rural vehicle miles traveled, and accounts for 1% of road mileage and 4% of lane miles in urban areas but 24% of all urban vehicle miles traveled – it can by no means represent all roads or all infrastructure in the U.S. (Duranton, Nagpal, and Turner 2020) Data collected by the U.S. Department of Transportation on all roads suggest that, contrary to findings from Duranton et al (2020), the percentage of all roads that have acceptable International Roughness Index ($IRI < 170$)² has shown a declining trend since 1994, when the earliest data is available (see *Figure 2*).

Several recent publicized infrastructure maintenance failures, such as the sudden closure and subsequent demolition of the westbound Washington Bridge on I-195 in Rhode Island due to undetected “critical failure of some original bridge components from the 1960s,” or the multiple days of train delays on Amtrak’s Northeast Corridor and New Jersey Transit due to extreme summer heat sagging catenary wires that Amtrak’s inspection stated are not in a state of good repair, continue to leave the public wanting of better, well-functioning infrastructure and serve as indication that even if America’s infrastructure is not falling apart, it requires better maintenance (Leslie 2024; Hicks 2024; Heyward 2024).

² International Roughness Index (IRI) is a reference statistic of pavement surface roughness that simulates a typical vehicle body’s vertical response to moving over the road at 50 mph. The more any given vehicle moves up and down as it travels along a certain roadway, the higher the IRI of that roadway (MDOT 2022b, 17).

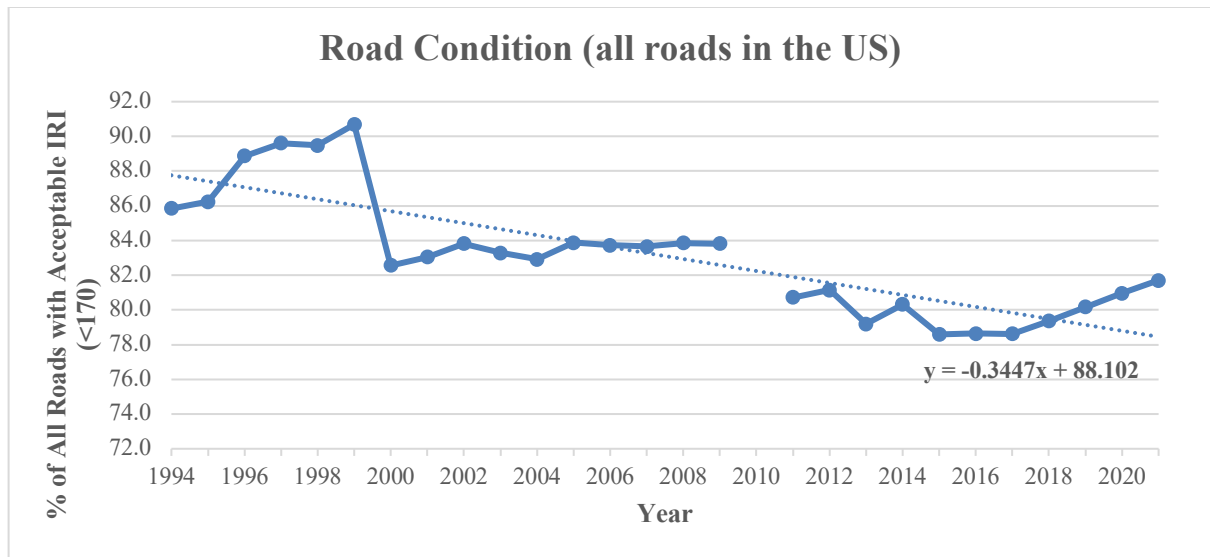


Figure 2. Road condition of all roads in the US (USDOT 2022, author’s graph)

2.4 Visibility and Maintenance

Visibility is argued to have a significant impact on infrastructure maintenance. The relationship between infrastructure and visibility has been pondered upon for at least a hundred years. In German Continental philosopher Martin Heidegger’s 1927 magnum opus *Being and Time*, he proposes the concept of *Zuhandenheit* and *Vorhandenheit*. He argues that the “things” that we deal with most directly in our daily lives – chairs, tables, pens – are tools that are taken for granted and we do not notice them as we utilize them. It is only when these objects break or become missing that we notice them and bring them to the center of our attention. In these instances, the objects’ mode of being transforms from *Zuhandenheit* to *Vorhandenheit*, from being “ready-to-hand” to being “present-at-hand (Vogel 2024, 40).” Well-functioning infrastructure are like the tools described by Heidegger: they disappear into view. The great Lewis Mumford once argued that the modern electricity and communication network helped create the “invisible city” (Mumford 1961, 563–67). More

recent theorization of infrastructure also emphasizes its invisibility. Star (1999) argues that invisibility should be incorporated as part of the meaning of the term “infrastructure” and that for something to be considered an infrastructure, it must withdraw from public attention. She suggests that infrastructure has properties such as embeddedness (sinking into and inside of other structures, social arrangements, and technologies) and transparency (invisibly supporting other productive tasks), and becomes visible only upon breakdown.

Invisibility relates to infrastructure and its maintenance in several ways (Young 2021, 105–8). Young argues that, first, invisibility sometimes denotes the way different forms of infrastructural systems are often deliberately removed from view. Electricity wires inside houses, water and sewer pipes under city streets, and cell towers that are shaped like trees are all examples of intentional concealment of infrastructure (Miller 2021). Young summarizes that a second sense of invisibility pertains to knowledge surrounding infrastructures: “Knowledge concerning the specific forms of social organization that emerge around infrastructural technologies and the particular configurations of activity that are permissible in relation to them, can only be acquired via participation in a community.” Once these knowledge are attained, these forms of understanding of infrastructure develop into a naturalized familiarity which lends specific organizational arrangements a “taken for granted” character. The best example of this type of knowledge may be a New Yorker’s familiarity with the quirks of the city’s subway system. Third, as illustrated earlier, infrastructure is often argued to be invisible because it functions as mere tools enabling activities we truly want to accomplish. When we are cooking dinner at night, hardly are we thinking about the network of copper wire and generators that is keeping the lights on, or the pipes supplying natural gas to the stoves. The visibility of infrastructure only emerges when

the lights are out or when the fire will not start – the tasks we aim to accomplish are thus interrupted and we direct our attention to diagnosing and fixing what is wrong with the infrastructure.

The lack of visibility on infrastructure and its maintenance is a reflection of societies typically viewing infrastructure as a form – we consider “the efficiency of technological artefacts to stem exclusively from the way they are produced[: from] the quality of their design, materials, and construction (Young 2021, 108).” When viewed as a form, according to Young (2021), we then tend to believe that technological devices, or in this case infrastructure, require minimal human intervention and overlook the various kinds of activities users and other people contribute to the function of these forms of technology. Graham and Thrift (2007, 10) argue that “[c]ultures of normalized and taken-for-granted infrastructure use sustain widespread assumptions that urban ‘infrastructure’ is somehow a material and utterly fixed assemblage of hard technologies embedded stably in place, which is characterized by perfect order, completeness, immanence and internal homogeneity rather than leaky, partial and heterogeneous entities.”

The reasons behind this monolithic view of infrastructure are many. Kaika and Swyngedouw (2000), following a Marxist inquiry, argue that perceptions of infrastructure as an unbreakable object are the result of fetishization, in which the form of infrastructure systems as commodities are “severed from (their) historical and geographical (hence social) process of production” as maintenance practices and the people that contribute to the building and maintenance process are hidden from view. This analysis may well be accurate, and the (intended or unintended) concealment of maintenance activities – scheduling

subway maintenance and road sweeping occurs at night to reduce disruption, and hiding maintenance access points, for example – contribute to the low visibility of maintenance.

But other more practical reasons exist that explain the low visibility of maintenance. Infrastructure systems are complex, and it is difficult to examine the state of the system and the state of individual assets as they are often large and complicated structures. In the case of highway bridges, the most common routine inspection is a purely visual check which relies heavily on subjective assessments made by bridge inspectors, resulting in “significant variability” with regard to their reported structural condition (Phares et al. 2004, 403). These visual inspections can only detect surface defects or subsurface deterioration that have reached a significant level; the visual detection rate of fatigue cracks was only 65% (Abdallah, Atadero, and Ozbek 2022). The aforementioned Washington Bridge in Rhode Island suffered from such structural invisibility – its July 2023 inspection showed it was in “good condition” with no significant issues, but it was closed in December 2023 after workers found “alarming structural problems” with the bridge that led to its ultimate demolition (Nesi and Bawden 2023). Additionally, maintenance work on infrastructure tends to be performed by people with less social status and wealth, leading to greater invisibility (Young 2021).

There are plenty of criticisms of viewing infrastructure and its maintenance as invisible, particularly in the academic world. Edwards (2003) argues that this idea is biased in the experience of the global North, stating that residents in Southern nations routinely experience failures of their infrastructure network and have to cope with such failures on a daily basis. Young (2021), Vogel (2024) and many scholars therefore advocate for abandoning the view of infrastructure as a stationary, perfect and invisible physical asset and

instead view it as processes of daily and difficult labor by construction crews and maintenance workers. The former is a valid criticism, but given the scope of this paper focuses on global North nations and the U.S. in particular, this point is withheld from further consideration. With regards to the second, it is the opinion of the author that infrastructure and its maintenance should be viewed as a continuous process, but this view is clearly not mainstream. A simple Internet search of the terms “infrastructure failure” and “infrastructure maintenance” illustrates this point clearly: the first term yields major national and international media headlines reporting on various infrastructure failures, whereas the second yields industry journals and location-specific mentions of maintenance plans or results.

While the data on the impact of visibility on infrastructure maintenance is little, the ones available do suggest that greater visibility increases maintenance. McDonough and Yan (2024) examine the effects of changing accounting standards on state maintenance spending for roads and bridges. Prior to Governmental Accounting Standards Board (GASB) 34, an accounting standard for government entities that was issued in June 1999, state and local governments did not prepare government-wide, accrual-basis financial information. GASB 34 introduced government-wide, accrual-basis financial statements to the governmental financial reporting model, and required governments to report infrastructure assets. State and local governments could use one of two methods to report infrastructure assets under GASB 34: the depreciation approach, or the modified approach. Under the depreciation approach, which is the accounting system for other capital assets, governments expense the cost of “using up” infrastructure assets over their estimated useful lives using straight-line depreciation. Under the modified approach, a government entity does not need to report

depreciation to infrastructure assets if certain conditions are met but instead records expenditures made on infrastructure assets that are not for additions or improvements as expenses. The modified approach requires governments to have an asset management system that has an inventory of all eligible infrastructure assets and is capable of providing the following information as required supplementary information: (1) the condition of those eligible infrastructure assets, (2) evidence that those infrastructure assets are being preserved approximately at or above the government's predetermined and disclosed condition level, and (3) an estimate of the cost needed to maintain and preserve the infrastructure assets at or above the established condition level, as well as the actual amount spent in each year. If the government entity cannot maintain its modified-approach infrastructure assets at or above the predetermined condition level, it must revert to the depreciation approach. Out of the 50 states, 23 use the modified approach and 27 the depreciation approach. Using a difference-in-difference analysis, the authors found that relative to depreciation-approach states, modified-approach states had an incremental increase in annual infrastructure maintenance of more than 20%, or about \$0.20 per square meter of infrastructure or about \$40 million, following the adoption of GASB 34. The quality of bridges in modified-approach states post-GASB 34 also improved relative to depreciation-approach states. The authors suggest that the additional reporting requirement associated with the modified-approach accounting standard improved both external monitoring and internal government decision-making capacity as more information is available – states using the modified approach are also less likely to enact a midyear budget cut to their general fund transportation spending, and less likely to divert fuel tax revenue to non-road related projects compared to depreciation-approach states.

2.5 Consequence of Low Visibility: No Political Support, and No Funding

Infrastructure maintenance's lack of visibility reduces its political importance, and therefore contributes to the insufficient allocation and misallocation of funding for maintenance-related tasks.

A major way politicians retain power and win reelection is through the mechanism of “credit claiming” as explained by David Mayhew (2004, 52–61). Credit claiming is defined as politicians acting in ways to generate belief in the electorate that he or she is personally responsible for causing the government, or some unit thereof, to do something that the electorate considers desirable. Those in the electorate who believe that the politician can make pleasing things happen will, in turn, want to continue to keep him or her in action.

Infrastructure maintenance's invisibility does not aid credit claiming. Infrastructure assets are typically geographically dispersed and long-lasting. This means that any voter regularly uses only a small portion of the total infrastructure, and maintenance deferral only infrequently causes infrastructure failures in the near term. Thus, the benefits of maintenance are not immediately apparent to the vote, and therefore maintenance is often sacrificed in a fiscal slowdown to preserve more visible government functions such as public safety that enable easier credit claiming for politicians (Pagano 2011, 5; McDonough and Yan 2024). Additionally, as argued in *section 2.4*, the maintenance activities are often conducted out of view of infrastructure's users, and the real conditions of infrastructure assets may remain unknown as they are difficult to observe, the consequences and costs of maintenance deferral often remain unknown (Pagano 2011, 5). This characteristic of infrastructure maintenance lowers the political cost of ignoring maintenance, allowing

politicians to shift political and actual capital to activities that can generate more visibility and enable greater credit-claiming activities.

Infrastructure maintenance's political invisibility, and the resulting lack of funding for maintenance, are reflected through theoretical modeling and in practice. In a political agent modeling by Gailmard and Patty (2019), politicians can spend money on two types of projects with regard to natural disasters: a prevention project that reduces the harm when natural disasters hit, and a relief policy that takes place only after the disaster has occurred. The key assumptions in the model are that all prevention policies entail up-front public costs, prevention policies vary in their streams of future benefits to voters, incumbent politicians observe more information than voters about the expected benefit of a given prevention policy, and that incumbents vary in the degree to which they themselves benefit from spending on prevention through granting of favors, and while this last assumption is clear to the politicians it cannot be easily observed by voters. Under these assumptions, even when prevention policies can be more beneficial to the public as they reduce long-term costs, rational voters cannot compel politicians to undertake prevention if and only if it is beneficial because voters cannot observe the government's investment opportunities, the effectiveness of such projects undertaken, or whether the elected officials making the decisions are corrupt. Rational voters would know that if they simply trust the incumbent to enact only socially beneficial prevention policies, corrupt politicians will pretend that all prevention projects are beneficial and effective and enact all of them. The only possible equilibria under this model is allowing politicians to pursue all prevention projects or no prevention projects. And, if the voter expects neither honest nor corrupt politicians to pursue any prevention projects, those attempting to push through prevention projects would be

viewed as corrupt. In summary, voters punish prevention spending but reward relief activities as the latter is much more visible. Infrastructure maintenance is similar to the prevention policies modeled.

In practice, as shown by Kim (2022), election cycles and partisanship at the state level negatively affect highway maintenance spending. In previous research, the author and collaborators already found through other data and interviews that “[g]iven limited budgets, maintenance spending generally was not attractive to political decision makers because it was not as urgent as other needs, and citizens prefer funding of more visible services” – in one case, local officials decided to give millions to a local zoo rather than address maintenance issues as the zoo was more politically popular (Kim and Ebdon 2021, 273).” In Kim (2022), the author finds that “political incentive and conflict are key factors delaying state highway routine maintenance spending” with re-election-minded governors and legislatures tending to allocate less funding to maintenance to satisfy the current taxpayers using panel data from 47 states between 1995 and 2009. Specifically, states where the governor is not term-limited and remain eligible for the next election spend 3.49% less than states where the governor is term-limited, and states facing legislative elections spend 4.67% less on maintenance than states that are not in a legislative election year – a clear indication that the need for political visibility compromises maintenance spending. The study also finds that politically divided states spend 3.57% less on highway maintenance than a unified government, with the author conjecturing that this is due to higher transaction costs in a highly contested and thereby highly visible policy-making process.

Infrastructure maintenance’s political invisibility also means that it often does not have a dedicated funding source, and is squeezed by more politically visible projects, further

reducing funding levels. Out of 50 U.S. states, Kim (2025) finds that only 14 have dedicated funding mechanisms for maintenance as of January 2020: California's Road Repair & Accountability Act of 2017 created a Road Maintenance and Rehabilitation Account to address deferred maintenance by increasing transportation-related taxes and fees, and Colorado has a new motor vehicle fees, fines, and surcharges dedicated to improving roadway safety and repairing deteriorating bridges. A few other states, according to Kim (2025), collect taxes that generate revenue for the stated purpose of enhancing maintenance, but the revenue goes to the states' general highway trust funds and it is unclear whether all of the money is spent on maintenance. Further, 30 states have highway trust funds that dedicate fuel taxes and motor vehicle-related taxes and fees to highway-related expenses, while the other 20 allow the money to be spent on other transportation modes. There is also a history of the state diverting money from transportation funds to general funds for other purposes (Kim 2025). The lack of dedicated funding sources for maintenance, and the ease with which any dedicated money can be used for other purposes, contributes to the maintenance funding crisis.

Beyond creating insufficient funding for maintenance, politicians' preference for greater visibility to facilitate credit claiming creates a misallocation of funding. Opening new infrastructure is always more visible compared to existing ones, and there is an ever-increasing demand for capital expenditures, which further stretches maintenance budgets. As observed by Pagano (2011), federal policies in the U.S. have been stimulating spending on new and expanded infrastructure via grants to state and local governments as federal highway funding has a preference for capital projects over maintenance – In 2017, \$44

billion (or 96 percent) of federal spending for highways went to capital investment³ (Campbell and Bhandarkar 2020). The federal government's emphasis on capital investment is the result of a long-standing tradition in infrastructure funding. Since the Federal-aid highway program began in 1916 under President Woodrow Wilson, states have been responsible for maintenance based on the concept that the states own and operate the roads. The Federal-Aid Highway Act of 1956, which launched the modern Interstate system, retained the premise that the states would maintain the new highways, and no federal money was provided for maintenance at the time (Weingroff 2023). Federal maintenance programs were introduced over the years, but the majority of these programs focus on funding repaving and reconstruction, which is corrective maintenance, as opposed to preventative maintenance (Weingroff 2023). This capital-heavy federal funding structure, executed by grants, often makes local governments feel as if they are getting free money, thereby encouraging the construction of new or the expansion of existing fixed assets. This results in local governments taking on increasing responsibilities to fund infrastructure maintenance. The federal government spent 63.6% of their total infrastructure spending in 2023 on capital investments (\$83.8 billion of \$131.6 billion), whereas state and local governments spent 62.1% of its infrastructure spending on maintenance (\$307.1 billion of \$494.2 billion), signaling the maintenance pressure of new and existing infrastructure that weighs on state and local governments that own the actual assets (Kane, Tomer, and Swedberg 2025). New

³ Capital outlay is defined generally as funds used to purchase a fixed highway asset or to extend its useful life; these highway improvements can include new construction, reconstruction, resurfacing, rehabilitation, and restoration; and installation of guardrails, fencing, signs, and signals. It also includes the cost of land acquisition and other right-of-way costs and preliminary and construction engineering, in addition to construction costs. Maintenance outlay are routine and regular expenditures required to keep the highway surface, shoulders, roadsides, structures, and traffic control devices in usable condition. These efforts include spot patching and crack sealing of roadways and bridge decks, and maintaining and repairing highway utilities and safety devices, such as route markers, pavement markings, signs, guardrails, fences, signals, and highway lighting (U.S. Department of Transportation. Federal Highway Administration. 2021, 2–6).

York State, for example, warned that its local governments are increasingly unable to meet their infrastructure upkeep needs due to persistent underfunding of maintenance and the rising costs over a decade ago (Office of The New York State Comptroller 2012). With 22 states funding infrastructure using a pay-as-you-go model, under which capital projects are paid with cash on hand only, more visible capital spending may crowd out less visible maintenance spending (Blair 2017).

Politicians' search for political visibility and credits is often executed through earmarks, which are legislature-mandated spending for specific projects. Earmarking distorts funding for maintenance and reduces road quality. Earmarks have long been shown to decrease the likelihood of electoral challenges and increase campaign contributions (McLaughlin 2023). To curb the influence of earmarks, the U.S. Congress passed a moratorium on inserting earmarks into legislation in 2011. However, research finds that the moratorium did not eliminate the influence of earmarks transportation funding (McLaughlin 2023). Earmarks in the 2005 surface transportation law (SAFETEA-LU) continued to benefit certain states in 2020 as newer transportation spending reauthorization used funding formulas based on FY2009 allocations, effectively locking in the 2005 earmark advantages for states that received them and the 2005 level was not adjusted to reflect transportation needs since (McLaughlin 2023). Additionally, the moratorium on earmarks did not stop representatives from seeking funding for projects that impact them: they simply opted for more opaque methods such as letter-marking – explicitly asking in writing the head of administrative agencies to retain or allocate distributive benefits to their districts (Mills and Kalaf-Hughes 2016). Congress ended the moratorium and brought back earmarking in 2021, designing new rules with the hopes of introducing greater transparency in legislators'

funding advocacy efforts (Courser, Thorning, and Wuerfmannsdobler 2023). Research does not exist in the U.S. to show how earmarking impacts maintenance, but data from Switzerland shows that earmarks negatively impact the efficiency of road construction and maintenance. On average, Christen and Soguel (2021) found that additional expenditures by earmarked funds of 1,000 Swiss francs lead to an increase of input requirements by 5.4 percent.

This conclusion of this section is that maintenance funding is negatively influenced by maintenance's invisibility, which allows politicians to benefit from reducing funding allocation to maintenance. This is opposite the conclusion reasoned by Bel, Fageda, and Warner (2010), which argued that as bureaucrats and politicians have control rights under public ownership but do not enjoy property rights, they cannot, unlike private owners of infrastructure assets, directly benefit from the profits generated by cost reduction. As the review of existing literature shows, politicians and their administration can benefit from cost reduction on maintenance as the saved money can be used on other more visible projects, thereby aiding their credit-claiming efforts. This conclusion also provides a different perspective to compare and contrast with Finkelstein (2007), which found through examining Electronic Toll Collection systems that people are likely to pay more taxes if taxes have low salience – a proxy for visibility to an extent – as the removal of the act of physically stopping and taking out cash made payment more effortless and thereby less memorable and objectionable. Maintenance costs are less salient to politicians as maintenance activities are invisible, and politicians actually choose to spend less rather than more.

2.6 Regarding Principal-Agent Problem

The literature reviewed earlier suggests that infrastructure maintenance suffers from principal-agent problems. In essence, the principal-agent problem describes a central paradox that arises in relationships between principals and agents in contractual or other third-party arrangements. Nominally, the principal retains ultimate control of the entity in question through some form of ownership or capital provision. However, agents appointed by and made to represent the principal often gain the upper hand as agents in such relationships typically have more information than their principals about what they are doing with the discretion that is inevitably left in their hands by the principals. Agents, therefore, have significant opportunities to “shirk” their duties and subject the principals to the “moral hazard” of having to rely on agents whose competence and diligence the principal cannot fully know (Salamon 2011, 1630–31).

In economics and business, shareholders of a corporation are often conceived as principals and managers as agents. While managers are monitored via the short-term results they generate, long-term plans allow for moral hazard due to information asymmetries and divergent risk preferences. Over time, agents begin to shape market norms and values through their constant presence, leading markets to reward agent-centric behavior such as flashy plans rather than principal-centric goals of sustainable returns (Kaskarelis 2010). Taking this model into the political science and infrastructure maintenance context, citizens would be the principals and government officials would be their agents. However, compared to the corporate world where the goal for agents – profit generation – is at least clear, the goal for government is multifaceted and cannot be easily defined, and the results cannot be easily measured. If Tiebout (1956) and his sorting concept are to be believed, every citizen

or principal has his own set of preferences for any given government's goals and results. The invisibility of infrastructure maintenance compounds the measurement problem. As citizens cannot directly measure the result of their agents in terms of maintenance, they turn to (or are convinced by the agents to do so) evaluating agents by the latter's vision or things citizens can observe (social services, welfare, or visible new capital investments), as illustrated in the previous two sections. Politicians then act against the principals' interest of maintaining stable infrastructure in pursuit of their own interests, which is to seek reelection, by investing in more visible projects.

In political science and government, however, the principal-agent problem extends beyond this simple relationship of citizens and politicians. As Bel and Warner (2015) illustrate, there can be multiple layers of principals and agents embedded in society and governance structures, and the same entity can simultaneously be an agent and a principal: municipal government, nominally the agent of citizens' will, can become a principal of inter-municipal cooperation agreements and the associated agencies tasked to execute such an agreement. In the case of infrastructure maintenance, for example, the governor of a state, an agent of the people's will, is a principal who manages and delegates to various government department heads overseeing different functions of the government. The state Department of Transportation chief, an agent of the governor, is in turn a principal who manages and delegates deputies that oversee the different functions of the department – from advancing new roadway projects to maintaining existing highways to promoting transit, perhaps. Each agent involved in this chain has its own set of motivations that may become a moral hazard for the principal. Maintenance engineers and maintenance department

supervisors may feel as if they can only keep their job if there are potholes to fill, and may be incentivized to keep things as is.

Overall, infrastructure maintenance suffers from significant principal-agent problems at many different levels. Salamon (2001, 1630–31) argues that the only way for principals to avoid principal-agent problems is to secure better information about how the agents are performing, but this involves costs. Every principal, therefore, has to find an equilibrium between the level of control it would like and the level it can afford. The informational cost between the multiple levels of principal-agent relationships involved in infrastructure maintenance is presumably high given the complexity of the relationships. Even if equilibrium is found at each individual level, the equilibrium may not be the most ideal at the fundamental citizen-politician level. Herein lies the difficulty of improving infrastructure maintenance, as earlier sections show well.

METHODOLOGY

This thesis takes an interview approach and is researched in three steps. First, relevant literature regarding infrastructure maintenance is reviewed to examine the possible reasons behind the lack of maintenance. Second, several semi-structured interviews were conducted with state-level and local-level roadway maintenance officials to learn from their experience of overseeing and conducting roadway maintenance. Interviews were also conducted with scholars focusing on infrastructure-related research to provide additional background context. Third, the interviews are transcribed and analyzed for main findings.

The following maintenance officials were interviewed for this thesis:

Name	Title	Interview Date
Joe Wisinski	Superintendent of Highways, Madison County, New York	February 4th, 2025
Charles Vezzetti	Superintendent of Highways, Rockland County, New York	February 6th, 2025
Timothy Card	Director of Public Facilities, Chautauqua County, New York	March 14th, 2025
Emily McGraw Cheryl Barbour	Director of Highway Operations, North Carolina DOT Business Manager II, North Carolina DOT	March 13th, 2025
Robert Crandol Robert Prezioso	Assistant State Maintenance Engineer, Virginia DOT State Maintenance Engineer, Virginia DOT	March 27th, 2025
Lina Chapman Elizabeth Wilson	Transportation Planning Supervisor 14, Systems Evaluation and Program Development Unit, Michigan DOT State Administrative Manager of Financial Operations Support, Michigan DOT	April 17th, 2025

Table 1. List of all individuals interviewed

The research interviewed both local and state-level officials in order to gain a fuller picture of the road maintenance landscape as officials with different levels of responsibilities

and facing various financial circumstances may perceive the maintenance question differently. Local officials interviewed here were recommended through Cornell University's Local Roads Program, according to which these local officials in New York state demonstrated innovation in maintenance and good stewardship of local roads. Interviewed state officials were initially identified using the Reason Foundation's *Annual Highway Report*, which ranks states by the overall performance of their highway systems (Feigenbaum et al. 2025). Maintenance officials in higher-ranking states' departments of transportations were contacted. Significant communication difficulties were encountered in this process as many state officials did not respond to interview requests. However, officials in North Carolina and Virginia, which ranked first and fourth in the 2025 *Annual Highway Report*, did agree to be interviewed (Feigenbaum et al. 2025). Coincidentally, the two states are among the few states in which the state department of transportations are responsible for all roads in unincorporated areas as the counties in both states do not maintain their roads. As both North Carolina and Virginia are of fairer weather, Michigan officials were interviewed to explore the potentially different set of challenges associated with winter maintenance despite the state ranking only 23rd on the list. Interviews were not done with officials in states or localities that have difficulty maintaining their roadway systems: the interview probed the role of visibility in infrastructure maintenance, which is tied deeply with local politics – locations that are underperforming may not be willing to speak candidly about their issues as this may garner further negative attitude.

The interviews were semi-structured. 6 core questions were asked in all interviews, and some additional questions followed the interviewees' answers for clarification purposes or for further exploration. The core questions asked include:

- How would you evaluate the quality and roads in [location], and what are the recent trends with regards to their quality?
- How does your agency approach and execute roadway maintenance?
- What are some challenges your agency has experienced when it comes to roadway maintenance, and how did your agency overcome those challenges?
- How does public or private ownership and operation make a difference in terms of how the infrastructure is maintained [in your location]?
- What maintenance services does your agency keep in-house, and what does your agency contract out? Why?
- In your opinion, how can governments at different levels address the roadway infrastructure maintenance backlog, especially if funding is limited?

CASE STUDIES

To better understand how infrastructure maintenance is managed in reality, this section presents case studies of six state and county transportation agencies, examining how visibility, or the lack thereof, affects maintenance practices, funding decisions, and long-term asset stewardship. Drawing from interviews with public officials in Madison County, Rockland County, and Chautauqua County in New York State, and the state transportation departments of North Carolina, Virginia, and Michigan, these case studies offer insight into the political, financial, and operational dynamics that shape maintenance outcomes.

4.1 Madison County, NY

Madison County's highway department manages 435 centerline miles of roadways, 123 bridges, along with thousands of culverts, signs, and other roadway infrastructure in the Central New York region. The County has two maintenance facilities, and employs over 80 people.

The maintenance philosophy is "to keep that minimal." This does not mean doing no maintenance, however, but instead means the County would "rather invest a little more money in...capital funds to keep the roads in good condition than let them deteriorate to a worsening condition and then have to do more maintenance." The County is also committed to doing preventative maintenance to reduce the need for more significant maintenance or reconstruction later. The County employs a work order system that every maintenance crew has access to, and the system is used to track maintenance activities as well as potential maintenance needs, which are reported through the system by maintenance workers and investigated. All roads are surveyed annually through visual inspections as the roads are in

generally good condition so visual inspection would suffice. A ride quality tracking mobile phone application mounted to maintenance vehicles also assists with road quality data collection. The County performs scheduled rehabilitation of around 20 miles of roadway annually, and the rehabilitation is coordinated with drainage, guide rail, road sign, and other improvements in the same section.

The County's Superintendent of Highways was open about the influence of politics in maintenance decisions, stating that "politics is a factor almost at every level." Madison County functions with a board of supervisors system as each member on the county board also serves as the supervisor of their respective towns. The Superintendent says that over his 20-year career with the County, there have been cases where a particular supervisor has more interest in their town getting something than the county getting something. According to the Superintendent, in the early years of his career, there were supervisors who asked him to do road projects in their towns as it helps them "look good to [their] constituents." The Superintendent rejected this, considering such requests to be unsound asset management strategies as "[one doesn't] just pick roads because it helps [local supervisors] win elections."

As large parts of the County highway budget, both for capital projects and maintenance, are raised by the County property tax, the Superintendent says that "[it is] good for [the board of supervisors] politically" if the board can keep property taxes at the same level. However, when the economy experiences widespread inflation as was the case in the pandemic years, maintenance work with the same budget becomes more difficult as materials, contracts, equipment, and labor all cost more than before.

The Superintendent argues that “[Madison County’s] roads are in the good condition that they are in...because [the County’s] board has, for whatever reasons, trusted [his] judgment.” When the Superintendent puts together a plan for the budget for the highway department now, he is able to tell the board the reasoning behind each decision, the goals that the department is trying to accomplish, and the cost of each project. However, this was not always the case. When the Superintendent first took over the position, he recalls that the board “did not have as much trust in what [he] would do or not do,” and that the board tended to want to cut the highway budget, resulting in “a few years where [he] struggled” as the board removed positions and made it difficult for the Superintendent to complete certain work. The Superintendent states that he had to work over the years to earn the trust of the board of supervisors and get the funding back.

When asked about why the highway budget was lowered in his earlier years, the Superintendent spoke directly about visibility issues of highway maintenance. He says that the County highway budget is less supplemented through federal and state funding compared to public health or social services, and that a position eliminated in those departments would generate only 30% to 40% of budget savings compared to highway position, for which the budget saving is 100% of salary. He mentions that only cuts in the highway department or the sheriff’s department are “dollar-for-dollar” cuts, and “if it is a choice between highway and sheriff, typically politically, the highway is a safer political move because what they cut from [the highway] department is not immediately noticeable by the general public.” During the years when the highway budget did not increase or was lowered, the Superintendent says that most of the public did not notice that there were fewer people working in the highway department as workers are “not typically seen a lot.”

However, when bridges started to get into poor shape due to lack of maintenance and had to be closed off – forcing people to take detours, the general public started to take note and the board would inquire why closures were occurring. Maintenance is “not a politically shiny object...[that] people notice the effects right away,” the Superintendent says, instead comparing maintenance to a “slow-moving ship.”

While the County certainly does not have any PPP projects, it does have a collaborative relationship with private contractors that play major roles in infrastructure maintenance. In general for the County, work that requires more specialized and expensive equipment that is outside the County’s budget would be contracted out, as would work that can be scheduled in advance to fit in contractors’ timelines. The Superintendent says that, for example, a cold in-place recycling train, which is a series of equipment used to reclaim and reuse existing pavement material without the application of heat, would not make sense to have in-house and such work is contracted out (Aschenbrener 2022). Culvert replacement and tree work, which are smaller in scope and the latter may be more unpredictable, for example, remain in-house to allow for scheduling flexibility according to the Superintendent.

Overall, the Superintendent wishes highway officials, especially at the town and city level, could have better training and more stringent experience requirements. He says that some local highway officials are “elected based on...popularity context,” and that it is possible for people with little or no experience in highway maintenance to be elected. More training and expertise, and less politically-driven decisions, in the opinion of the Superintendent, would improve the maintenance quality of roads and highways in the County.

4.1.1 Analysis

The influence of visibility on maintenance is clear in the case of Madison County. Local politicians asking for road work in their district is a classic example of politicians attempting to increase their political visibility in elections, which has the potential to drive resources away from rationally-planned maintenance. When facing the trade-off of visibly increasing taxes or invisibly delaying infrastructure maintenance, the County's case shows that politicians value the former over the latter. When facing fiscal constraints, the highway department budget was deemed easier to reduce than the police department budget as the latter is perceived to have a greater impact on everyday life by politicians and the general public. Maintenance does not receive due attention until more dire emergencies with infrastructure assets – such as bridge closure due to structural issues – occur.

At the same time, however, experience in the County also shows that visibility can be used as a tool to advocate for better maintenance. When there is a good database that allows the Superintendent to monitor the conditions of the County's infrastructure and plan maintenance accordingly, and when the Superintendent is able to use such data to present logical, comprehensive maintenance plans, the visibility of maintenance increases, which led to, in this case, increased trust from the legislature in the maintenance official and less interference with maintenance funding.

4.2 Rockland County, NY

Bordering the New York City metroplex, Rockland County and its highway department have responsibilities over approximately 340 lane miles of roadways from 167

centerline miles, 83 bridges, 115 culverts, and 78 miles of waterways through 14 streams within the county's jurisdiction. The department employs over 80 people, and has recently opened a \$40.5 million maintenance facility that was awarded Public Works Project of the Year by The New York Metropolitan Chapter of the American Public Works Association in 2024 ("Award-Winning Rockland County Highway Facility Complex Project" 2024).

Rockland County's maintenance approach prioritizes proactively identifying and addressing potential road problems before they escalate. When the Superintendent first took over in the early 2000s, the County did not have pavement preservation programs in place and simply conducted repaving when the roads fell apart. The Superintendent instituted various pavement preservation practices. All roads within the County are now visually inspected twice a year by teams of engineers and technicians, and reactive preventative maintenance such as crack sealing, which is "the cheapest, biggest, best bang for your buck" technique to prevent potholes from forming according to the Superintendent, are performed when issues are identified. Additionally, the Superintendent examined the long-term cost and benefit of different capital construction standards, which led the County to laying thicker pavement. "For 25% more cost, [the county is] getting 50% more life," the Superintendent says when comparing the life-cycle costs of two-inch of asphalt overlays with one-and-a-half inch overlays. These proactive maintenance techniques allowed the County to increase the mileage of roads it is able to treat (up to 10% of the County's roads are resurfaced and treated annually), and led to a 50% reduction in maintenance costs per mile.

The County places significant emphasis on keeping up with technological innovation. The Superintendent introduced a systematic fleet replacement program, through

which the department regularly replaces vehicles and machinery to avoid breakdowns and costly repairs. The new maintenance facility further helps extend the lifespan of equipment, which can now be stored indoors. The County also developed customized salt-spreading equipment which reduces salt usage by up to 50% and can more effectively remove snow and ice during the winter.

The Superintendent stresses that staffing and personnel management is another crucial aspect of the county's maintenance strategy. The County values experienced, well-trained employees and tries to foster a culture of accountability and continuous improvement through regular performance evaluations. New or seasonal employees train with and are evaluated by multiple senior employees to ensure they are qualified. This practical human resources strategy eliminates nepotism.

When asked about challenges with regard to maintenance, the Superintendent was clear that the lack of visibility affects the funding availability for maintenance. He says that “[he has] had to deal with a lot of financial challenges,” and that sometimes “elected officials, the people who control the purse strings, do not see the value in what [the highway department is] doing and they don't understand.” Everybody uses the road, but “most people don't acknowledge it, [and] they take it for granted,” he follows.

The Superintendent constantly works to increase the visibility of maintenance work. He says that “[one has] to impress on [the decision makers] that [the highway department's] services are basic services, and that's the purpose of [the] government.” When discussing budgets, the Superintendent makes the argument that highways are a critical safety concern – children and first responders depend on well-maintained roads to ensure they can get to their destinations safely. “That is the only way [one] can argue with [the politicians, and]

most of the people understand that,” he says, “[the money people] never ran anything, they do not know anything...[they just want to make] sure that the number at the bottom of this line meets the bottom of that line.” Therefore, the Superintendent tries his best to be proactive, which means keeping local decision-makers informed about possible changes in road conditions, and having back-up equipment and personnel ready at all times.

Over the past couple of years, the Superintendent remarks that he thinks the country went through a period of social activism in which as long as people advocated for their social cause loud enough, the government funded those initiatives. He says that at the local level, “the parks budget was bigger than the highway budget,” which was not necessary.⁴ He later relates the situation to the post-9/11 days, when “all the money was sucked out...a lot of it was sucked out of public work” and went into police and fire as the country looked to address more pressing national security issues. But “most people do not realize that highway departments and public works are first responders too. Something happens out on the road. How are the police gonna get there? How is the fire department? How's the ambulance gonna get there? Unless we get that road open,” he says.

The one ability the Superintendent wishes to have is “the ability or reputation of not taking no for an answer.” “You have to fight for everything you get in public works,” he says, although acknowledging that it used to be a lot harder. Once the reputation is established, the job gets easier. “[If people] recognize that [you are] doing a good job, people are more likely to give you what you need. Not what you want, but what you need.”

⁴ It was unclear from the interview whether the Superintendent was speaking about Rockland County or elsewhere. Rockland County’s recent capital and operating budgets suggest that highway-related spending are higher than spending on environmental resources, which includes parks (“County Budget,” n.d.). However, parks and related spending may have been allocated via the general fund.

4.2.1 Analysis

The case in Rockland County shows the intimate interplay between the visibility of maintenance and its funding. The Superintendent describes that people do not tend to value or acknowledge the key role roadway infrastructure plays in our daily lives and in emergencies, which requires him to constantly increase highway work's visibility through reminding policymakers that a functioning highway ensures safety. Being proactive, being clear, and having a reputation for good work ensures that highway maintenance can continue to receive the funding it needs.

The County's effort to improve maintenance also shows that with innovative, long-term thinking, maintenance can be successfully done. From spending more upfront to lower the life cycle maintenance costs of roadways, to instituting new vehicle and employee training programs, to deploying innovative maintenance techniques based on careful observation of the job, Rockland County's story demonstrates that even with limited resources, the road quality does not have to suffer.

4.3 Chautauqua County, NY

Situated on the shores of Lake Erie, Chautauqua County is the western-most county in New York State, and the County's Department of Public Facilities is responsible for the safe and efficient operation of 552 center-line miles of roads, 308 bridges, and 258 major culverts that make up the county-owned highway system.

The County's approach to highway maintenance, according to its Director of Public Facilities, is to emphasize consistent, proactive upkeep through regular condition assessments conducted by the County's engineering department, aiming to "keep good roads

good," which is more cost-effective than reconstructing roads after they deteriorate. The engineering department tracks the history and surveys all county roads, and the County is able to administer surface treatment to around 100 miles of its roads annually. Roads in poor condition or requiring more complete resurfacing are rebuilt accordingly.

However, the county faces ongoing challenges, particularly related to the lack of funding for maintenance work. The COVID-induced inflation and subsequent rises in construction costs have not helped. The Director says that he struggles sometimes with public officials with regard to maintenance funding as he wonders what could be more important than ensuring roads and bridges remain in good condition – if the infrastructure is not maintained and upgraded accordingly, emergency services cannot get to where they need to be. To ensure there is sufficient funding for roads, the Director works hard to speak with legislators to convince them that roads are important. He, along with 700 other New York's local transportation officials, attends events such as the annual Local Roads Are Essential Advocacy Day, which is organized by New York State's Association of Town Superintendents of Highways in Albany to better communicate local roadway concerns to state officials. The Director says that his work requires having good relationships with legislators at all levels – if the legislators understand his work, it becomes easier, and legislators appreciate having open and frank conversations. The County also faces manpower challenges as many may not be interested in the maintenance line of work. The County has developed programs that will hire and train people to obtain a commercial driver's license in exchange for 5 years of service.

Similar to Madison County, Chautauqua County does not participate in any PPP programs that cede roadway maintenance responsibilities to private parties. The County has

its own paving and bridge crew, and surface treatment is done in-house. The size of the job tends to be the determining factor on whether contractors are brought in – larger paving and bridge works are done outside of the department. Projects over \$350,000, if using Consolidated Local Street and Highway Improvement Program (CHIPS) funding, are required by law to undergo competitive bidding. According to the Director, the cost limit has not been raised in recent years as elected officials fear contractors may lose jobs otherwise.

4.3.1 Analysis

In Chautauqua County, funding and visibility are again closely linked. The Director acknowledges that funding for maintenance is a constant issue, and actively tries to increase the visibility of the maintenance work by building positive relationships with lawmakers and showcasing the importance of maintenance. The County also utilizes proactive asset monitoring and preventative maintenance to ensure the life-cycle cost of its roadways is lower.

4.4 State of North Carolina

North Carolina's highway system is one of the largest in the United States, and the North Carolina Department of Transportation (NCDOT) plays a unique role in managing it. The state is responsible not only for its primary roads but also its secondary road network, a practice that began in the 1930s as an effort to consolidate roadway management and reduce costs during the Great Depression. County-level governments do not maintain roads in North Carolina. As a result, NCDOT is now responsible for over 167,000 lane miles of

pavement over 81,000 centerline miles of roads, over 13,700 bridges, 900,000 road signs, and a host of other assets (Finger 2025). The state is growing and its road network is expected to handle increased demand – 130 billion vehicle miles were recorded on its roads in 2024, which is expected to rise to 150 billion by 2050 (McGraw 2025).

The condition of the State’s road network is generally good. 89% of Interstate pavements are in good condition, higher than the 85% target; secondary road condition has improved since 2017, and reached 70% good in 2023, level with the standards; however, primary road conditions have dropped since 2017 – 15% of primary roads are categorized as in poor condition, twice the target level and 10 percentage points higher than 2017. While conditions are generally acceptable, the State’s repaving cycle is 3 times longer than the recommended industry time, and the pavement preservation cycle is 6 times longer than industry recommendations – more work is certainly necessary especially to accommodate the state’s growing population (McGraw 2025).

North Carolina’s roadway maintenance approach is comprehensive and data-informed. The department conducts annual automated pavement condition surveys on primary roads and Interstate highways according to the requirement of the FHWA, and annual windshield surveys are conducted for its secondary roads. Bridges are inspected on a 2-year cycle while pipes and other functional assets are inspected on a 5-year cycle (Finger 2025). The State, according to the Director of Highway Operations, has had an integrated maintenance management system along with a financial management system for 22 years, and these systems allow for the planning, documenting and budgeting of capital and maintenance work. The State has also recently completed a full-scale assessment of its functional assets. NCDOT is constantly looking at bringing in new technology to aid its

maintenance program as well and has near-term plans to introduce LiDAR, high-resolution imagery, and machine learning to its analytical system.

Funding is naturally a challenge, and spikes up or down in funding are especially challenging according to the Director as they make planning for the future difficult. It is difficult to bring excitement to maintenance according to the Director, who compares the ribbon cutting of new projects to the excitement of buying a new car and the daily maintenance to the nuisance of changing the tire on the car. The Director recognizes that the legislature has the difficult task of balancing multiple priorities, and has always had fine reactions when speaking with the state legislature. However, she also says that explaining maintenance to legislators is challenging as they are not transportation practitioners, and they tend to focus more on acute pavement or traffic concerns over planned proactive maintenance. While specific projects or funding programs, such as repaving or bridge replacement, may receive special attention and funding, the general maintenance budget, which at 41% of NCDOT's \$2.2 billion budget is the largest funding bucket that takes care of everything beyond repaving and bridge work, is often the portion that gets cut when the legislature says "we need to tighten our belt" per the Director.

A surprising revelation from the interview surrounded lawn mowing and litter removal along roadways. NCDOT has a Citizen Action Request System which allows citizens to report roadway maintenance issues such as potholes or missing signs. The Director says that the department gets so many complaints "when our highways don't look good" or when the lawn next to the highway is not mowed – "People will call about that faster than anything." When asked about why that is the case, the Director says, "It's a pride thing." How things look makes an impression on drivers when they drive through the state,

the Director continues, and says that NCDOT as well as the public want things to look good. She compares these maintenance requests to the pot of flowers in front of the house – there is no need for them, but they are nice to have.

However, recent challenges facing the state may mean that functional asset maintenance gets cut back. Inflation has significantly increased the cost of construction, and Hurricane Helene in 2024 caused over \$6 billion in damages to public roads and bridges within the state – far higher than any previous weather event. It is still unclear how much money would be required to build back the infrastructure, but it is likely to make an already tight budget even tighter. NCDOT hopes to minimize the impact on structural assets, which are harder to bring back to a state of good repair if they are allowed to deteriorate, but this would mean reducing maintenance on functional assets. Ultimately, the Director says that it is the legislature and the broader public’s job to decide whether they wish to live with decreases in infrastructure conditions or reductions in particular services, but it is the agency’s role to supply information and data that can support decision making and communicate clearly to all stakeholders so there are no surprises.

Unlike smaller counties in New York State, North Carolina does have a P3 highway project. When asked about whether having a private entity involved with the management of the roadway makes a difference in maintenance, the Director says that she is not sure. She says that the nice thing about P3 projects is that they have a maintenance plan, but since the State is not maintaining those roads, she cannot speak to whether the private operator is following the plan. Over the years, NCDOT has reduced its size and turned increasingly to contracting out work as, per the Director, the state legislature prefers smaller government agencies. NCDOT employs around 9,000 people today compared to 15,000 in the early

2000s. The philosophy behind contracting work is “If you can plan it, you can contract it.” Emergency response work is kept in-house, although the Director says that NCDOT has figured out a way to contract out dead animal removal. She says that there is no inherent quality difference between public and private work, and there are processes in place to ensure the quality of work meets requirements, although contractors do need to make a profit whereas the agency itself does not. She is grateful to have industry support as highway maintenance work cannot be done alone.

The Director also speaks about the role of data in maintenance work. Having a full inventory of assets is great, but it is a massive undertaking according to the Director. “Data is good the day you [collect] it,” but that needs to be accompanied by a thorough process to update the inventory, which in and of itself is time and effort-consuming. The Director says that the whole world is moving into a data age, and a lot of information is needed to plan for a good maintenance program. She believes that civil engineers and transportation workers, while having valuable sets of skills, have historically not been trained in data analytics. She hopes in the future she can have more employees with those skills to really streamline incorporating data and forecasting into maintenance.

4.4.1 Analysis

North Carolina’s case shows the different ways visibility is at play in the infrastructure maintenance puzzle. First, the state’s extensive data on maintenance has helped NCDOT better track and maintain their roads; however, this internal visibility does not necessarily translate to external visibility – legislators continue to focus on more visible aspects of infrastructure breakdown of potholes or traffic congestion, and less visible

maintenance budgets remain vulnerable to elimination. Second, it is clear that the general public, at least in North Carolina, is concerned with the more visible aspects of maintenance. According to the Director, the general public monitors lawn mowing and garbage closely. This attention, however, does not appear to extend to less visible aspects of maintenance such as preventative maintenance or bridge condition evaluations. Third, it is interesting to note that with regard to contracting out work, NCDOT has found that if an activity can be scheduled it can be contracted. Scheduling may be considered a way to make particular maintenance tasks visible as the act of scheduling is a form of planning. Last but not least, NCDOT's increasing desire to incorporate more data into their asset management program speaks to a desire to understand more about the infrastructure they are responsible for and increase their visibility through advanced analytics. More data may help the agency communicate key trends and conditions better to the legislature and the general public, thereby increasing the importance of maintenance in funding considerations.

4.5 State of Virginia

The Virginia Department of Transportation (VDOT) manages an extensive and diverse roadway network that spans 60,000 centerline miles – the third largest state-managed system in the nation after North Carolina and Texas (“Highways” 2024). The 60,000 centerline miles translate to over 128,000 lane miles across the state's Interstate, primary, and secondary systems, and VDOT is also responsible for over 20,000 bridges and large culverts, 6 tunnels, and various other traffic assets (Virginia DOT 2019). Similar to North Carolina, Virginia's DOT is responsible for local roads as well as a result of a Great

Depression-era decision – county-level governments do not maintain roads in Virginia. The agency has an annual maintenance and operations budget of over \$2 billion (Gregg 2024).

VDOT conducts careful surveys of its roads to ensure it has an understanding of all its assets. Contractor vans equipped with high-tech sensors drive all Interstates, primary roads, and secondary roads with annual average daily traffic (AADT) of over 3,500 vehicles every year to measure their conditions. 20% of secondary roads with AADT of less than 3,500 are assessed every year, meaning VDOT on average updates the condition of those roads every 5 years. Bridges are inspected, in general, every two years, and VDOT has targets on other roadway assets (Gregg 2024, 23). VDOT has its own pavement rating, and it considers any road with a Critical Condition Index above 60 (measured out of 100) sufficient. Its System-wide goal is to ensure at least 82% of high-volume roads are sufficient. According to VDOT's 2024 data, 88% of Interstate miles, 83% of high-volume primary roads, and 79% of high-volume secondary roads are considered sufficient; 97% of VDOT's structures system-wide are in good condition as well (Gregg 2024).

The State adopts a data-driven, systematic approach to ensure all of its assets are well-maintained. Every year, VDOT examines the existing condition data, trends, forecasts and quality targets, establishes a network-level need assessment, and then finds ways to properly distribute the budget based on those needs according to the State Maintenance Engineer. Detailed work plans are then drawn up, with spending and accomplishments tracked accordingly by the individual VDOT maintenance districts. The goal is to “treat...pavements as they first begin to deteriorate,” according to the Assistant State Maintenance Engineer, as it would cost a lot more and impact the traveling public more significantly if VDOT “lets every piece of pavement get to where it needs to be rebuilt or

largely rehabbed.” While maintenance efforts have the support of VDOT’s executive leadership, according to the Assistant Engineer, maintenance remains a difficult task. The majority of VDOT’s network was built in the 1960s and 1970s, meaning they are well beyond their design life of 30 to 50 years. While improvements have been made in maintenance, expanding traffic volume and vehicle size continue to strain the roadways, and there have not been corresponding increases in funding, resulting in only modest improvements in overall infrastructure conditions in the state.

The data-driven approach also aids maintenance funding. The Assistant Engineer says that according to Virginia's state law, maintenance should get funded first ahead of capital projects. However, he continues, “Practically speaking, if [one] really took that literally, [VDOT] could spend every dollar available...on maintenance.” According to the Engineer, being able to better understand its assets and their conditions with its asset management system and the comprehensive review in 2019 has helped VDOT become able to “much better articulate to the politicians, to everybody, the condition we have, the condition we all want, [and] the funding gap to get us there.” The Engineer says that VDOT has done a better job in the last 10 to 15 years telling their story:

Forever, we've always said, hey, we don't get enough maintenance money, but we've never been able to point to where does it need to go and why does it need to go there. I think we've finally been able to posture ourselves to be able to show, from a data driven, analytical aspect with bar charts and graphs and numbers and all kinds of bells and whistles, to reflect, ‘Oh, this isn't just folks being unhappy that they don't think they have enough money,’ that there's a tangible need that can be calculated. And I think that has probably been as effective as anything else for us to be able to make that.

The data-driven approach and the narrative such data creates gives maintenance staff at VDOT credibility. The Engineer says, “When you do have all that information and present that data, people understand that you're on top of managing your program and you

do have a plan and a strategy and you are managing that well.” This, the Engineer continues, builds an “emotional bank account” with upper management and the general public, so when the maintenance staff does go and ask for funding, there is a greater chance that their demand will be treated seriously and trusted.

When asked about the maintenance difference between P3 projects and VDOT projects, the engineers argue that it may not be fair to compare the two. P3 projects in Virginia, according to the engineers, tend to be new construction, allowing the owners and operators to focus on a very specific segment of the roadway and to start from a clean slate. VDOT, on the other hand, is responsible for a much larger, much more diverse, and much older set of assets. An interesting point was raised by the Assistant Engineer, who says that it has been “interesting to see on these P3 privately owned/operated-type roadways where they make business decisions to invest in maybe higher quality, longer lasting materials that we at VDOT may not make.” He goes on to say that because VDOT has to balance maintenance and capital needs, it simply does not have the resources to spend significant amounts of money upfront, and often chooses materials or equipment that meet “a minimum standard that is acceptable and at a lower cost.” The private investor, on the other hand, may say that if enough is spent upfront to build a higher quality infrastructure, that may be better financially in the long run. “It would be nice to design every project with the longest lasting...the Cadillac, highest standard of every material and every technique[, but] that's not going to be cost-effective upfront when you're trying to not only maintain what you have, but maybe add some capacity and other things,” says the Assistant Engineer, “Engineering [ultimately] becomes an economics problem.”

With regards to contracting out services, VDOT has a mixed approach. The Engineer says that in more rural areas, VDOT has employees that have different skill sets, and are able to self-perform some more difficult and complicated tasks. In more urban areas, by contrast, workers have more general skills, and more outsourcing is done there. Ultimately, local field managers make the decision with regard to what to keep in-house. Pavement resurfacing is outsourced to contractors entirely as according to the Engineer, “[VDOT] just [doesn’t] have the staff, the equipment to be able to do [that].” Staffing has been another challenge according to the Assistant Engineer, who says that “[VDOT] cannot do anything without [their] industry partners” and that everyone has challenges in terms of finding people to work in maintenance.

Two additional challenges are mentioned by the engineers. First, there does not exist a reliable funding model for weather-related emergency repairs. The Engineer says that in the past three fiscal years prior to the current one, the state did not experience major snow events or hurricanes. However, in the current fiscal year, the state was hit with a major flood, a major hurricane, and three to five major storm events. All the emergency response money has to come out of the maintenance budget, and when VDOT “overspend[s] [its] emergency response budget, it has got to come from somewhere,” according to the Engineer. This overspending eats into general maintenance and capital improvement funds, and is a hard piece to manage. Second, VDOT is constrained on material choices between asphalt and concrete pavement. The Engineer says that VDOT wants to make the best decision for investments for the road network, but has to be aware of the decision’s impact on the local industry as there does not exist “a very strong concrete pavement industry in

Virginia because we haven't historically invested in it,” and “at the same time, [the state’s] asphalt industry employs a tremendous number of people across the Commonwealth.”

The Assistant Engineer concluded the conversation by arguing that if maintenance is budgeted more specifically and strategically rather than being a simple lump sum in the budget, everyone will get a better sense of the maintenance backlog, which leads to better maintenance:

What's the backlog? I don't know. What's that? How big is it? How much does it cost? We kind of got an idea of it, but it's hard [to state it] in a cogent, defensible, documentable way. You can put it on somebody's desk and say, you may not choose to fund it, but here is the reality of it. I think that could drive, over time, maybe some decisions to make more investments not to Cadillac standards, but maybe to longer life standards when we build things or reconstruct things.

4.5.1 Analysis

VDOT’s maintenance work again shows the link between visibility and funding. Before developing plans and executing surveys to collect asset conditions, VDOT could not calculate and present precisely to legislators how much the infrastructure maintenance gap is. New data and planning have allowed VDOT to better explain their work to, and build more trust with, politicians, increasing maintenance’s visibility and being able to better articulate a funding strategy to return its assets to a state of good repair.

VDOT’s work also shows the difficulties government agencies have to balance when considering maintenance works in a situation of insufficient funding. Unlike a P3 project, which is given a blank slate to build and maintain new assets, VDOT has to allocate resources to maintain its large and progressively older infrastructure stock, to add capacity to meet new demands, and to navigate unpredictable emergency situations – a perfect illustration of crowding out of maintenance by other capital spending priorities. This means

that it is not at the luxury to invest more up-front capital, build to higher standards, and reduce life-cycle costs for its assets as the immediate capital and maintenance demand is overwhelming. This creates a vicious cycle – low up-front spending will require even greater amounts of spending in the future to maintain.

4.6 State of Michigan

While Michigan's DOT does not manage all local roads like North Carolina or Virginia, it still has an extensive profile of assets under its care. It is responsible for maintaining over 9,895 route miles of roads totaling 27,864 lane miles. Over half of the route miles and almost two-thirds of lane miles under MDOT control are National Highway System miles, which represent some of the most highly trafficked roads in the nation. MDOT is further responsible for over 2,700 bridges along with ancillary assets in its rights-of-way (MDOT 2022b). More recently, the state has been increasing its roadway spending with the influx of federal funding as well as a recognized need to improve its roadways. In 2023, the state roads and bridges are allocated over \$2 billion in maintenance, repair, and rebuilding. Over \$1.2 billion was allocated for road rehabilitation, reconstruction, preventive maintenance and resurfacing. \$337 million was allocated for bridge-related work, and \$466 million for routine maintenance (MDOT 2022a).

MDOT's primary measure of roadway quality differs from North Carolina and Virginia. Instead of using a direct metric that reflects road quality, MDOT measures the condition of its roads primarily through Remaining Service Life (RSL). RSL estimates the number of years a pavement can continue to serve before major repairs or reconstruction becomes more cost-effective than preventive maintenance. MDOT's document suggests that

as RSL estimate “considers the structural integrity of the pavement, along with contextual data regarding the pavement’s history,” it is a “dynamic, detailed, and tactical measure that evaluates the long-term health of pavement” to allow MDOT to make informed decisions (MDOT 2022b, 16). According to the Transportation Planning Supervisor, the state has contracts that send vans along its roads to collect information about pavement distresses. The Transportation Planning Supervisor compares the RSL measure to a countdown clock – a year goes by and the RSL on a road segment decreases. The system, however, allows for modification based on engineering judgment. If engineers deem the road to be in better or worse condition than the RSL measure suggests, its RSL can be adjusted accordingly. For more local roads, MDOT uses the Pavement Surface Evaluation and Rating (PASER) system, which is a visual survey method that rates pavement surface conditions on a scale from 1 to 10. Both measures are accompanied by forecasting programs that can help maintenance officials project the trends of the state’s roads. Bridges are inspected using the National Bridge Inventory Condition Rating. The state’s goal is to ensure 95% of its Interstate roads and 85% of its other roads are of good or fair condition (RSL greater than 3 years). As of 2020, 78% of its Interstates and 70% of its non-Interstate roads are in good or fair condition. The quality of MDOT’s roads, according to its internal measures, has been trending downward in the decade between 2010 and 2020, with both sets of measures being above 85% in 2011 (MDOT 2022b, 24). MDOT approaches maintenance proactively to ensure “the right fix at the right time in the life cycle to maximize the life of the asset and minimize the cost to maintain it (MDOT 2022b, 37).” It hopes to balance routine maintenance, capital preventive maintenance, rehabilitation, and full reconstruction depending on asset condition.

Funding is a significant challenge for MDOT. In its 2022 Asset Management Plan, MDOT states that “[c]hronic underfunding poses a significant risk to MDOT’s ability to develop its highway capital program,” and rates the likelihood that the agency will not have sufficient funding levels to reach state of the good repair goals as “almost certain (MDOT 2022b, 29–31).” Both the Transportation Planning Supervisor and the Administrative Manager agree that insufficient funding is the biggest challenge. The Administrative Manager states that maintenance funding depends on the political climate, and states that under the current Governor Gretchen Whitmer, who ran on a platform of fixing roads, maintenance issues have gotten more attention. She argues that MDOT has “done a very good job of showcasing [its] priorities across the state as it relates to maintenance” – it knows that it cannot do everything with the money it has, and it will continue to “[make sure] that [MDOT is] voicing what [it] can or cannot get done with that funding and making sure that the right folks up on the Capitol hear.” The Transportation Planning Supervisor says that it is difficult to explain the different types of maintenance activities and their purpose to the public. The public expects a road that is stated to last 20 to 30 years will require no maintenance work whatsoever in the interim, so when crews show up to perform routine crack sealing, which is a good maintenance practice to ensure water does not get into developing stresses, the public thinks MDOT did a poor job with the initial paving.

The funding challenge is made more acute every year as Michigan has to contend with a harsh and unpredictable winter climate. According to the Administrative Manager, MDOT distributes its roughly \$450 million of routine maintenance money based on 5-year average regional winter weather patterns and holds a certain amount back to cover for worse-than-predicted winter conditions. Whatever money is left is rolled over to address

non-winter priorities. However, if there is not enough money left, which the Administrative Manager says is “most years,” “anything that can get deferred gets deferred.” With insufficient funding to start and bad winter conditions, deferred maintenance can become a chronic problem.

Michigan has limited exposure to public-private partnerships, having used the arrangement only to modernize a 5.5-mile stretch of I-75 and update roadway lighting in the Detroit area (FHWA, n.d.-a; n.d.-b). The Transportation Planning Supervisor says that P3 arrangements have “strict, highly enforceable scopes, schedules and fees with a predetermined performance and penalty structure.” At the same time, she says that P3 partners may have less commitment to public welfare as they require financial gain, and that P3’s long-term contracts can “bind agencies and governments in a way that can be politically unpalatable” since they reduce the government’s ability to protect the public via policy changes. Further, she argues that while P3 arrangements help take assets off MDOT’s balance sheet and reduce its maintenance responsibilities, MDOT had to pay for the cost of the project upfront. Either way, there is a cost to MDOT.

The philosophy underlying MDOT’s decision to outsource specific tasks is simple: it comes down to cost and efficiency. If a task can be done cheaper internally, it will be kept in-house; otherwise, it will be outsourced, says the Administrative Manager. She further states that as certain positions can get paid better in the private sector and it is difficult to fill these positions in-house, the related tasks would have to be contracted out. Tasks that require special equipment, such as applying pavement marking, add additional strain to the department’s budget and the equipment may not be used to its full capacity. In these cases, the tasks are outsourced. Ultimately, MDOT actively examines its resources and the costs of

different tasks, and makes decisions accordingly. This has resulted in tasks that are sometimes contracted out and sometimes brought back in-house.

When asked about what would make their jobs easier, the interviewees suggest having a crystal ball that projects and controls weather, but quickly focused to stress again the need for sustainable funding. The Transportation Planning Supervisor said that “[MDOT] just have never really had the sufficient resources to maintain the network that [it has], ...and [MDOT has] never really been able to do true asset management and maintain the system in the way that [its] pavement management engineers and bridge engineers would like to, where [they are] actually doing the most cost-effective treatment at the time that that treatment is needed in order to get the maximum amount of life out of the pavement or bridge structure.” The Transportation Planning Supervisor hopes for adequate resources, that politicians have trust in the agency, and that they trust MDOT’s data and forecasts that show the maintenance shortfall. While the state has made progress in plugging the funding gap with a recent short-term cash infusion from additional bonding and inflation-indexed gas tax, material and labor costs have also risen quite significantly over the past half-decade, which eroded the funding increases. Politics and earmarks also distract from the asset management plan – The Transportation Planning Supervisor states that MDOT may be told to do a project in some area because there was an earmark, but that earmark may not pay for the whole project, so funding originally designated for other projects has to be diverted to shore up the gap created by the earmark.

The most interesting finding of the interview came when the Administrative Manager said that MDOT may be too good at penny-pinching to the extent that it struggles to justify asking for more. She says:

And I think one thing that Michigan does really well is being able to complete its goals with the resources it has. And so I think a lot of outside folks and even politicians will sometimes say, well, why do you need more money? You seem to be doing fine with what you have. I think it's hard to get the message across that we could be doing better when from somebody who's well removed from it, they think we're doing just fine with what we have.

So I think it better comes down to just making sure that we're being visible with what's not getting done. Because I think we do such a good job of emergency response and safety concerns that some politicians, I think, look at it and go, you guys do just fine with what you have. I don't see why you need more. And I think that is one thing that, you know, I hate to say that we're too good at our jobs, but to some extent, I think we are... I think Michigan is just very good at what we do and we're very good at getting the job done regardless of the challenges that we have. And that almost sends the wrong message sometimes.

4.6.1 Analysis

MDOT's maintenance work clearly demonstrates a link between visibility and funding. As politicians only have visibility on the road conditions today, but not how good the roads could be if MDOT had more money for maintenance, they choose not to fund MDOT since according to their observations the road conditions are acceptable. Having a Governor that is concerned with maintenance raises the visibility of related issues, and helps the department get more funding. But ultimately, maintenance is always political.

OVERALL ANALYSIS AND DISCUSSION

This section draws from the literature review and case studies and examines key themes that emerged. It confirms theories regarding why infrastructure maintenance remains persistently underfunded due its invisibility. This section also analyzes strategies that can be used to raise maintenance's visibility, and offers discussion on interesting themes, including second-order impacts of increasing visibility.

5.1 Invisibility of Infrastructure Maintenance, and Associated Funding Issues

It is clear through the interviews that infrastructure maintenance is relatively invisible, and all the reasons previous literatures suggest contribute to its invisibility. First, maintenance activities are often removed from view. Madison County's Superintendent says, for example, that his workers are not typically seen. All six government entities interviewed have asset condition monitoring programs of various degrees and these programs are crucial to maintenance planning, but the act of visually surveying roadway quality is very difficult to notice. Second, maintenance requires specialized knowledge that is not understood outside the maintenance circles. Rockland County's inventive salt spraying techniques are extremely effective at snow build-up prevention and removal, but hardly anyone outside the maintenance department pays attention to such details. The Director of Highway Operations at NCDOT similarly stated that explaining maintenance to legislators is challenging as they are not transportation practitioners, and focus more on stemming potholes and traffic instead of advancing proactive maintenance. Third, infrastructure is considered a means to an end – everyone's attention is on the travel destination and the tasks that need to be completed once arrived. Little attention is paid to the road they use to get there, and even less to how these roads are maintained. The

Highway Superintendent of Rockland County said it best: Everybody uses the road, but “most people don’t acknowledge it, [and] they take it for granted.” While the invisibility of the state of infrastructure assets themselves – stemming from the difficulty of keeping track of asset conditions across a large inventory and the difficulty of precisely examining complicated built structures – is argued to be a further reason for maintenance’s invisibility, no one interviewed commented on the effectiveness of their condition surveys.

When maintenance is seen, it is either because the activity itself is visible, or something is broken. The Director of Highway Operations at NCDOT noted that trash and unmowed lawns tend to attract complaints – these are visible aspects of maintenance that are easily observable. The Highway Superintendent in Madison County remarks that while no one notices the missing maintenance work from staff reductions, when bridges started to be closed due to a lack of maintenance and people were forced to detour, the general public started to take note and the politicians began inquiring.

Because maintenance, as well as the consequence of the lack of maintenance, is invisible in the short term, politicians and decision-makers often opt to spend available funding in more visible ways instead of spending on maintenance. In Madison County, individual legislators request projects in their constituency, and prioritize police department funding. In Rockland County, the Superintendent reports that local officials funded more visible political projects and are always looking to reduce maintenance funding. In Chautauqua County, the Director works hard to advocate for highway maintenance to state officials in the hopes of obtaining more state funding. In North Carolina, the maintenance budget is the one that suffers when belt-tightening is required. VDOT has struggled in the past to demonstrate the exact maintenance needs, and suffered from low maintenance

funding. Last but not least, as it is hard for the legislature to perceive how much better the roads could be with proper maintenance as MDOT does a good job taking care of the more visible emergency repairs, politicians question why MDOT needs additional funding. These cases also combine to show the complicated ways maintenance and its invisibility induce principal-agent problems. Local maintenance officials act as agents of elected politicians and plead for maintenance funding as they understand the importance of maintenance, but the principals often choose to spend the money in more visible ways. When politicians are viewed as the agents responsible to the general public, their decisions to underfund maintenance are a perfect example of the moral hazard problem associated with agents' actions.

5.2 Strategies to Increase Visibility of Maintenance

All maintenance professionals interviewed were acutely aware of the lack of visibility in their work and the consequence invisibility has on funding. Therefore, they have devised strategies to increase the visibility of maintenance.

The first strategy maintenance officials employ is elevating maintenance as a way of ensuring more immediate and basic human needs of safety are met. Infrastructure and roads are more frequently thought of as the backbone of the economy as they facilitate the transportation of goods and people (Puentes 2025). However, the human desire for economic safety is not as strong for physiological security, as proposed by Maslow and his work on the Hierarchy of Needs (Maslow 1943). Maintenance officials would therefore utilize safety as a lens to elevate maintenance and press for attention and funding. In Chautauqua County, the Director argued that if the infrastructure is not maintained,

emergency services cannot get to where they need to be. Similarly in Rockland County, the Superintendent argues that highways are a critical safety concern without well-maintained roads children and first responders cannot get to their destinations safely. Government officials and legislators constantly make decisions that affect the economy – job creation, tax credits, and supporting local businesses, to name a few – but decisions regarding safety are rarer and they would be clearly of a higher importance and may receive more careful consideration. This mindset may benefit maintenance as it is advocated as providing safety enhancements.

The second strategy is using data, new technology, and analysis to increase maintenance’s visibility. More and better data collection using advanced equipment aids the understanding of the current state of the system, and can help “bring forward” the consequences of ignoring maintenance. All six places have various forms of road and asset inventory systems that allow relatively up-to-date monitoring of the status of the entire system. This itself can help maintenance professionals identify areas of deficiencies and facilitate longer-term planning. Having data and the ability to perform analysis on the data also allows maintenance officials to visibly illustrate the future consequences of lack of maintenance – in essence “bringing forward” the negative political and economic impact associated with poor maintenance to influence present decision-making. In Rockland County, the Superintendent tries to be proactive and keep local decision-makers informed about possible changes in road conditions. For NCDOT, the Director says that a key part of the agency’s role is to supply information and data that can support the legislature’s decision-making and communicate clearly to all stakeholders. Better data and analytics aid this effort, and the state has ongoing efforts to better incorporate them into maintenance

efforts. For VDOT, the Engineer says that with data, the agency is able to “much better articulate to the politicians...the condition we have, the condition we all want, [and] the funding gap to get us there.” At MDOT, officials recognize the need to use data to support narratives that better illustrate to politicians and the general public the maintenance funding shortfall. In general, data has helped maintenance officials better convey maintenance needs to politicians.

A third and equally important tool for maintenance professionals to increase the visibility of maintenance is to build trust with elected officials. In all the cases interviewed, having the trust of the legislature, maintaining a credible reputation and professional relationship, and having the persistence to keep advocating have helped elevate maintenance work in the eyes of the politicians. Having this trusting relationship with elected leaders elevates the visibility of maintenance officials themselves, and thereby elevates maintenance’s visibility. Naturally, some of the trust comes with the time maintenance professionals and politicians spend working alongside each other. In the case of Virginia, North Carolina, Madison County and Rockland County, this trust is built on decades of relationships. However, it is also clear that time is not the only factor in enhancing trust – having clear data and delivering results can enhance the trust as well.

A fourth aspect of enhancing the visibility of maintenance may be through the use of contracts. This is not universally reflected in the interviews as entities use contracts for a wide variety of reasons. Chautauqua County engages contractors primarily due to state requirements, and VDOT leaves the choice of whether to contract to individual divisions. However, in Madison County, the Superintendent said that work that can be scheduled in advance to fit in contractors’ timelines can be contracted out, and in North Carolina the

philosophy behind contracting out is “If you can plan it, you can contract it.” By virtue of the nature of contracts, the timelines, costs, and quality standards associated with the scope of work need to be clearly stated, as stated by officials at MDOT. The process of writing and administering contracts necessitates planning in advance and continuous monitoring. This process may help maintenance professionals better understand how and when to allocate resources, and showcase the different components, costs, and timelines of maintenance more visibly to politicians compared to work done by internal crews.

There are certainly drawbacks to the different strategies, and none is perfect. Elevating maintenance’s importance to physiological levels may increase its visibility, but this strategy runs the risk of taking attention away from more immediately critical projects. Additionally, there is nothing stopping other government agencies from justifying their mandates on the basis of safety and demanding funding and attention – the playing field would be leveled, only with a more urgent tone to every government action, which may not be helpful to anyone. While contracting may increase visibility and facilitate better long-term planning, it is not universally applicable. The administration of contracts itself costs resources, and the process takes time. This approach is not suitable for smaller tasks or emergency tasks at a minimum, and contracts, especially long-term contracts, can suffer from humans’ general inability to predict the future and unforeseen changes in conditions as warned by MDOT – the City of Chicago’s municipal parking concession, which is widely studied, is such a case in which the municipality grossly underestimated the value of its parking assets (Spielman 2022). However, the strategies, implemented at the right time and in conjunction with each other, may help bring visibility to maintenance and obtain more associated funding allocation.

5.3 Regarding Standards and Life-Cycle Costs

A particularly interesting point on standards was made by the maintenance engineers at VDOT: because the state is responsible for building and maintaining a massive set of road assets and its budget is never as plentiful as required, VDOT cannot spend significant amounts of money upfront to ensure higher quality construction that may reduce life-cycle costs. Instead, VDOT makes the conscious decision that it needs to balance new capital needs with existing maintenance needs in the short term, so it chooses materials or equipment that meet “a minimum standard that is acceptable and at a lower cost.”

Design and engineering standards for roadways have no doubt come a long way, and roads today are designed to safely handle traffic volumes and speeds the Romans would only be able to dream about. However, design standards also introduce the question of planned obsolescence. Absent minimum standards, perhaps roads would be constructed to higher initial quality like reportedly in P3 projects if transportation authorities make investments based on life-cycle cost considerations. The existence of minimum standards, however, provides transportation authorities with a bar above which may seem excessive, and the minimum standard would allow lower immediate spending so money could be used for other projects. The minimum standard becomes the target to achieve, and functions like a planned obsolescence goal as there is no need to exceed it. Politicians and even maintenance professionals may have strong incentives to set low internal standards: a low standard would require less maintenance spending in the short term, and both politicians and maintenance professionals can claim easy credit for maintaining roads “up to standard.” Given infrastructure’s immediate quality is invisible and its deterioration process also invisible

until failing, the public would have little ways to monitor the effect of minimum standards on infrastructure quality.

Setting a minimum standard can certainly be useful in many respects as the minimum standards can eliminate low-quality construction and design. Enforcing a higher standard can also be extremely costly as it would require a systematic rethink of all existing infrastructure. However, the effect of standards on infrastructure maintenance activities remains unclear.

5.4 Is Doing Too Well Actually Harmful?

While not explicitly stated in other interviews except the Michigan case, it is interesting to consider the consequences of penny-pinching too well. In the case of MDOT, it appears to do a very good job taking care of immediate safety concerns or emergency situations. These events could serve as potentially visible signals of infrastructure breakdown and be used to draw attention to maintenance issues. Successfully and timely handling these situations takes away the first strategy identified in *section 5.2*, and leads to, as the Administrative Manager at MDOT describes, politicians questioning why additional maintenance funding is needed since they perceive MDOT as doing “just fine.” Without these visible examples, MDOT has to shift to a strategy of attempting to highlight “what's not getting done,” but this is much harder as humans presumably have a much harder time conceptualizing things that have not yet happened. MDOT’s predicament introduces an interesting conundrum: if infrastructure can be maintained at a level of good repair, how can maintenance officials prevent funding decreases since the infrastructure system can no longer be perceived as in need of improvement?

This conundrum is another manifestation of the principal-agent problem associated with infrastructure maintenance's invisibility. As the maintenance workers, acting as agents, perform successful emergency maintenance, they create information asymmetry whereby politicians, acting as principals, can no longer visibly understand the quality of the roads. Although, interestingly from this perspective, agents are not able to use this information asymmetry to their benefit and are instead punished via reduced funding. When politicians are viewed as agents to the general public, however, MDOT's case shows another instance where the agent shirks its responsibility to ensure infrastructure upkeep in order to advance their own interests of using the money that would have been allocated to maintenance elsewhere. This would presumably help the politicians with reelection by focusing on more visible projects.

5.5 Regarding American History and Culture

Beyond all the factors and aspects discussed above, perhaps another reason that inhibits proper consideration of maintenance in the American context is America's relatively short history. Compared to developed European counterparts or developing East Asian countries, America does not carry significant amounts of physical historical luggage. It took Greece's second-largest city, Thessaloniki, two decades of construction to open its first metro line because of the constant discoveries of historical artifacts (S. Anderson 2024). When London was expanding the Westminster Tube station during the 1990s, it had to think about how to preserve the station itself, which was built in 1859, as well as how to preserve the Palace of Westminster, which was close to a thousand years old (Rabey 2025). In these projects, preserving and maintaining history is part of the consideration of designers and

engineers because the built environment in these places embodied thousands of years of history. Politicians, designers, and engineers in these contexts are familiar with questions of, and comfortable making decisions regarding, maintenance and preservation because they have been dealing with similar topics for perhaps centuries. America, in comparison, has a much shorter physical history, and its people are comparatively inexperienced in contemplating such questions.

5.6 Second-Order Impacts of Increasing Visibility

Overall, increasing visibility appears to have a positive effect on infrastructure maintenance – at least in the short run. This is seen through previous research as illustrated in *section 2.4*, as well as through the case studies in which maintenance officials overwhelmingly believe increasing maintenance’s visibility can lead to increased funding, and constantly performs actions to increase maintenance’s visibility.

However, the previous discussion sections also raise questions with regard to the impact of increasing maintenance’s visibility in the long run. Data can help maintenance professionals better understand the state of their systems, but data require more resources to store and analyze. Data also provides politicians with a clear view of the infrastructure’s state, which allows politicians to draw their own conclusions as to what levels of funding may be appropriate. This may reduce the influence of maintenance professionals to advocate for more funding. With regard to standards, it has been shown that building codes and the minimum standards that they set have made buildings safer in general by ensuring that the structures remain standing during disasters (Chapman-Henderson and Rierson 2021). Yet, setting a minimum standard can also provide maintenance officials and politicians with an

easy and visible benchmark to hit. Simply building or maintaining to the standard is good enough, and there is no reason to go above and beyond even if that could result in long-term benefits. Timely emergency maintenance is good, as it eliminates immediate threats to public safety, but it also lowers the visibility of maintenance issues, which may result in reduced maintenance funding. Contracts can be used to ensure the government continuously commits a certain level of resources to certain maintenance projects, increasing maintenance's visibility and theoretically reducing government entities' ability to divert funds away from maintenance. Yet, as no one can predict the future, government operations require a degree of flexibility to accommodate the unexpected – contracts reduce this flexibility.

While these second-order impacts of improving visibility on infrastructure maintenance may appear threatening to future maintenance, the pursuit of perfection in the long run should not be the enemy of the good in the short run. These second-order impacts are listed here in the hopes of inspiring future policymakers and maintenance professionals to think more carefully and strategically about their actions and policies, and the potential unintended consequences different actions may have. Given the state of America's road infrastructure, efforts should be focused firmly on increasing the visibility of infrastructure maintenance and raising the quality of roads. These second-order impacts are more likely to occur as a result of improved maintenance, and can be more closely debated then.

POLICY RECOMMENDATIONS

Based on the interviews and analysis, it is clear that roadway infrastructure maintenance has a visibility issue which creates a funding issue. This section outlines a few broad aspects of policy consideration that may help policymakers and maintenance professionals better address the maintenance challenge in roadway infrastructure.

1. Improve asset management systems and enhance the use of data

In all the cases discussed, asset management systems provide tremendous aid to maintenance efforts. However, as acknowledged by the interviewees, many improvements can be made. Having a more complete inventory of assets, being able to more frequently and objectively update their conditions, incorporating related financial planning abilities into the asset management system, and using more sophisticated analytical methods to predict and forecast future conditions could all serve to increase the visibility of maintenance and enable it to compete for funding. However, with more data comes the greater cost of collecting and managing the data, and such efforts must be done in a well-planned and well-coordinated fashion to ensure resources are not wasted on collecting data or performing analytics that are not used productively.

2. Offer training and diverse pathways into the maintenance profession

Many professionals interviewed spoke about the difficulty of retaining and recruiting knowledgeable workers to perform maintenance tasks. As maintenance plays such a crucial role in ensuring everyday life can continue as is, it is critically important that the workforce is well-staffed. Creative recruitment strategies, systematic on-the-job training programs and

apprenticeship programs, and enhanced working conditions and wages may help attract people to the industry. Additionally, the industry and policymakers need to consider how advanced data analytics can be used, and how to attract talent who can perform such analysis to the industry.

3. Continued advocacy for maintenance

The interviews show that many maintenance professionals advocate for maintenance in different ways – from establishing trusting relationships with politicians through daily work to attending advocacy sessions. As America’s roadway infrastructure is aging, it is important that the public as well as legislators in charge understand the importance of maintenance. Continued advocacy is important to ensuring maintenance’s visibility.

4. Rethinking minimum engineering and design standards

As illustrated earlier, minimum standards may play a negative role in ensuring the lowest life-cycle cost for projects and roadway systems. Raising the standards, clarifying the goals of the standards, and reviewing the standards to ensure that they truly reflect the state goals would be great places to begin unwinding the effect of standards, maintenance, long-term quality and costs.

5. Develop ways to effectively utilize contracts to increase visibility

While contracts are complicated, they may have the benefit of bringing visibility to specific parts of the maintenance operation. Contracts can also ensure that certain tasks receive ongoing and stable funding commitments. It would be worthwhile for agencies and

legislatures to examine how contracts can be used effectively to monitor, allocate, and facilitate planning of maintenance work.

6. *Reconsider the government funding structure for maintenance*

There are clear issues with the way infrastructure maintenance is funded in the U.S. right now. The federal government's continued support for capital projects over maintenance burdens state and local governments with ever-increasing maintenance bills, and the current separation of capital and maintenance spending is not helpful from a life-cycle perspective. It is clear from the interviews that capital and maintenance often come from the same pot of money, and capital spending often crowds out maintenance spending. Available funding should be allocated in ways that enhance life-cycle efficiency. For example, maintenance costs for projects should not be considered separate from capital costs, but should be included in comprehensive reports that look at how one relates to another. Capital projects should be reviewed to ensure that the responsible agency has sufficient funding to operate and maintain the project before they are greenlit, and earmarks should be used more responsibly. A more asset-centric approach may be more helpful. Additionally, as argued in *section 2.5*, infrastructure maintenance does not always receive its dedicated funding source. Developing stable, long-term funding sources for maintenance operations separate from capital project funding can partially shield maintenance from political forces and mitigate its lack of visibility. In devising such schemes, scholars and policymakers should consider carefully the principal-agent problem at various levels to minimize moral hazards.

7. *Learn from international experiences*

There are many countries in the world that operate and maintain complex infrastructure systems with different approaches. The U.S. may benefit from exploring how different models have worked in other countries, and borrow from the best to ensure that its maintenance quality can increase.

8. *Increase maintenance funding*

While there are certainly ways to improve the efficiency of roadway maintenance, such improvements will not solve the substantial maintenance funding gap that has accumulated over the years due to its relative invisibility. To truly address the maintenance shortfall, more funding support should be considered.

CONCLUSION

Infrastructure maintenance plays a critical but often overlooked role in ensuring economic productivity, public safety, and overall quality of life in society. This thesis explores the reasons behind infrastructure maintenance's neglect, particularly emphasizing its invisibility and subsequent implications for funding and political support. Through literature review and interviews with roadway maintenance professionals from state and local governments in the U.S., several insights emerged.

Infrastructure maintenance remains invisible primarily because its effectiveness is only noticed when failures occur. Daily maintenance tasks and preventative maintenance rarely attract public attention or political interest, unlike the more visible ribbon-cutting of new infrastructure projects. This invisibility reduces maintenance's political visibility, resulting in chronic underfunding as politicians prioritize projects with immediate political rewards.

Interviews with maintenance professionals revealed specific strategies to combat invisibility, including reframing maintenance as a critical safety issue, leveraging advanced asset management systems and data analytics, building trust with legislators, and strategic use of contracting to improve transparency and accountability. Agencies that effectively employ these strategies appear more successful in securing funding and maintaining higher-quality roads.

Nonetheless, challenges remain. Maintenance is chronically underfunded, lacks dedicated funding sources, and there is not enough discussion on how maintenance can improve despite highway infrastructure beginning to reach the end of its expected life. Addressing these challenges requires a shift in both policy and public perception. Key

recommendations include enhancing asset management practices, improving training and workforce pathways, redefining engineering standards with lifecycle costs in mind, restructuring infrastructure funding to include dedicated maintenance sources, and learning from successful international practices. Ultimately, increased funding combined with greater visibility and strategic policy interventions is essential for overcoming infrastructure maintenance challenges and safeguarding America's infrastructure resilience and reliability for the future.

This thesis is written as a broad qualitative exploration of America's infrastructure maintenance issue with the hopes of raising awareness and questions. Naturally, it has many limitations. While the cases here are good examples of some problems in infrastructure maintenance, they may not be representative in every circumstance. The research does not include qualitative elements that can more objectively correlate maintenance levels to various factors that may impact it. There are many aspects that this thesis also does not explore, including but not limited to the impact of various maintenance techniques, the influence of organized labor and industry lobby on maintenance decisions, and how contracts and standards affect maintenance performance.

There are many ways to extend this thesis. As maintenance data are difficult to collect in the U.S. and various public entities have different standards to measure maintenance, research into ways that can more objectively showcase the state of infrastructure across the nation would significantly aid conversations regarding infrastructure development and maintenance. As the world embraces digitization and automation, the impact of new technology and data analysis on maintenance should be examined further. The second-order impacts of visibility with regards to minimum

standards, existing good maintenance, and contracts, as broadly stated in this thesis, can be extended and studied more closely, and should provide for interesting debate regarding different approaches to enhance maintenance. The effectiveness of recent comprehensive asset management plans and strategies, as well as new funding models (including PPP), on maintenance would also generate valuable insight into the interaction between policy and maintenance. America's maintenance challenge cannot be resolved if it is hidden – robust discussion can only result in creative ideas that can ensure the long-term stability of the nation's infrastructure, and by extension, its economy at large.

May the things we build last.

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