Remote Sensing Enhanced Non-destructive Evaluation of Roadway Infrastructure
(Technical Topic)

Racially Biased Infrastructure Practices and the Perpetuating Impacts in BiPOC Communities
(STS Topic)

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

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Introduction

The challenge of maintaining roadway infrastructure at acceptable levels must be addressed through the utilization of a comprehensive performance monitoring process. Performance metrics must be created and evaluated at a sufficient rate to detect abnormalities in roadways that may cause systemic issues (Garza 2008). The state of Virginia is home to the nation's 3rd largest state roadway system but houses the 2nd worst region for roadway infrastructure, with most of the interstate systems being reported for condition and capacity improvements. This has caused issues with roadway congestion, traffic jams, long commutes, gridlock, and infrastructure-related injury. If the infrastructure problems existing in Virginia roadways persist, a huge toll will be taken on the environment, public health, and the economy. Low-income minority communities have been historically left behind with infrastructure developments, and too often have become the subject of racist infrastructure practices, especially in American cities. There are multiple examples of BiPOC communities having been destroyed or very tacitly separated to create new infrastructure in developing cities. Historically, these communities were targeted because of the race of the inhabitants, to create a separate space for white inhabitants. These differences can lead to gaps in quality of resources and quality of life, furthering the racial and economic divide in America by creating issues with generational wealth. An attempt at solving the infrastructure problems is made through the development of a method of Remote Sensing Enhanced non-destructive evaluation of roadway infrastructure in the state of Virginia. The benefits of mechanical solutions such as drone fleets, geosynchronous satellites, and ground systems or a combination of the three are analyzed for their success in meeting the requirements of scope and resolution of analysis imagery. The inequities in infrastructure and its evaluation and improvements will be investigated, especially

as it impacts communities of color. We will question how modern and historical infrastructure create and perpetuate the oppression of the Black community.

Technical

There are over 57,000 miles of roadways that need to be maintained by the state of Virginia and the Virginia Department of Transportation. These roadways are crucial to transportation efficiency and the daily lives of the public. Currently, national regulations only enforce the inspection of roadways every 5 years and the inspection of bridges every 2 years (Gee, 2007).

Current methods such as Visual Inspection, Acoustical Techniques, and Infrared/Thermal Imaging of roadway infrastructure inspection are inefficient and accomplished by only using a variety of ground-based systems. These ground-based systems have many drawbacks, including traffic buildups, lane closures, and the fact that they are labor-intensive (Vaghefi, 2012). Additionally, they each have limitations such as invalid assessment of interior infrastructure, inaccurate testing, and limited usage (McGuire, 2020, para. 1-3). To improve the inspection process, the solution must include remote-sensing enhanced nondestructive evaluation through the combination of the state-of-the-art that includes spacecraft and aircraft. A satellite could send data to VDOT and allow them to focus on maintaining worn roads instead of repairing broken roads. This would create a more efficient system for the state's roadways that would cost less, require less labor, and cause fewer transportation infrastructure delays.

Maintaining transportation infrastructure is vital for the well-being of the state and public. The collapse of bridges is extremely dangerous as shown by the death of 13 people when I-35W collapsed in Minnesota in 2007 (Vezner, 2007). Although the collapse has led to reform in how infrastructure is inspected, those methods are now dated and could be improved for more efficient and less costly methods of inspection. Research indicates that as road conditions deteriorate, there

are more collisions and accidents tend to be more severe (Alhasan, 2018). By sensing all transportation infrastructure continuously, it would be possible to identify which roads are deteriorating at faster rates and put more time and effort into these problematic areas.

Research indicates there are a variety of remote sensing options available with either drones or satellites that allow for remote sensing from air and space. A paper published by Devin Harris, a Civil Engineering Professor at the University of Virginia discusses the wide variety of sensors that is the focus of the technical project, including Synthetic Aperture Radar (SAR), Interferometric Synthetic Aperture Radar (InSAR) on satellites, and a sensor called Light Detection and Ranging (LIDAR) on drones (Ma, 2019). Another technique to assess infrastructure from space is three-dimensional optics, which is a technology that can provide depth and height information that cannot be obtained from only one image. This can be done by overlapping two images, taken from two different angles of an object, with at least 60% overlap when combined. As well as satellites, there are also several types of Uninhabited Air Vehicles (UAVs) that could be used for evaluation of infrastructure, such as the tethered blimp, small imaging quadcopter, a micro quadcopter, and a hexacopter. The hexacopter would be the best choice for this technical project as it needs to be able to carry more weight for the different kinds of sensors. However, it does have a short flight time of 30 minutes.

Designing a system that will be able to see all the roads of Virginia and accurately determine which roads and bridges have damage will come with various challenges. Satellites are limited in what resolution they can detect, so current and affordable technology might not be within reach and an outside company may be required to fund the project. Drones are also limited by Virginia laws requiring them to be manually piloted, which greatly decreases the range they can cover in a day. Camera systems installed in vehicles through companies like

MobilEye and Tesla could provide intel into transportation infrastructure usage and quality, but it may be difficult to gain access to the data. The most effective solution the project team has decided upon is to design a system with an overarching satellite that collects information on all roadways daily with a few drones or UAVs that can be sent to analyze the problematic areas in more detail.

STS Topic

American infrastructure development plays a complex role in the poverty and the physical destruction of minority communities. The displacement and segregation of minority citizens was and continues to be government-sponsored and purposeful. A major reason for this separation is due to public policy. From the implementation of "Manifest Destiny" to systematically displace Native Americans to racist post-slavery policies used to alienate Black communities (with the destruction of Black Neighborhoods to create Centennial Olympic Park in Atlanta and Central Park in New York), the nation's history of BiPOC displacement is dark and extensive. It is important to acknowledge the role that infrastructure development plays in this destruction. (Costa 2018). Highways, roadways, and other large physical barriers specifically play a large role in the development of poverty in BiPOC American communities.

A disturbingly under-analyzed component of this problem is the historical implementation of the National Interstate system. During the initial rise of intra-city transportation infrastructure development, the funding was provided by state coffers, offering a more culturally sensitive input to the construction. However, with the 1965 Highway Act, federal funding and input led to a much more generalized implementation system that did not acknowledge cultural and regional implications (Sherman 2014). Thus, the construction of these highways could often lead to the destruction of BiPOC communities and separation from White

communities. The Interstate Highway System had a noble purpose in solving multiple nationwide issues. These include congestion, loss of time, loss of productivity, inaccessibility of rural areas, and lack of preparedness for transportation-related to National defense. However, the problems that arose were unavoidable.

The Freeway Revolts were a direct result of the opposition to construction in major cities. The protestors were wary of the destruction of neighborhoods, uprooting of history, and private land speculation among other things. The concerns of the protestors were proven valid, as is highlighted by the case in Nashville, Tennessee. Interstate 40 was planned and routed through a predominantly Black neighborhood. Community members gathered, concerned, and filed a lawsuit. Their concerns included the possibility of property value lowering, the separation of Black business owners from their clientele, and racial implications surrounding the decision. The courts ruled against them, essentially citing an exaggeration of the impacts of construction. Following the construction though, property value did in fact decrease, Black Business owners did see profits drop, and many speculated that it was an intentional attempt to undermine the Brown vs. Board of Education ruling by creating a physical separation between Black and White communities (Karas 2015). There are many such examples with similar outcomes to those experienced in Nashville, which have lasting impacts on Black communities including school segregation, lack of equal access to resources and necessities, and infrastructure neglect in non-white communities. These observations lead to the question: How do we evaluate the impact of infrastructure on BiPOC communities and work to a technical solution? The research on this topic is mostly conceptual and qualitative, which will make it difficult to develop a quantitative solution that can be integrated into the technical solution. However, understanding the complex

and lasting impacts of highways on historically and presently Black communities is the first step in developing a solution.

Conclusion

After comparing the benefits, risks, and costs of a technical solution to remote sensing for Virginia infrastructure evaluation, our team will likely pursue the design of a low-earth orbit InSAR satellite with subsystems on the ground to detect smaller imperfections with the potential to become hazardous. This will improve the monitoring abilities of the Virginia Department of Transportation, leading to more efficient use of manpower and location of hazardous defects to improve Virginia's poorly rated infrastructure.

I will also develop a greater understanding of the implications of infrastructure improvement and development and its impacts on BiPOC communities. Specifically, with the use of highways as a means of segregation.

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