Prospectus

Real-Time Weather Data to Improve Roadway Safety
(Technical Topic)

The Different Actors Contributing to Roadway Traffic
(STS Topic)

By

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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

In 2019, 827 deaths occurred on Virginia's roadways, and 180 people were injured every day from traffic crashes. Further, according to the Center for Disease Control, motor vehicle crashes are the leading cause of death for people aged 5-19 years ("Annual Report", n.d.). At the national level, on average there are over 5,891,00 crashes each year, and 21% of the cases are weather related. Weather-related crashes are defined as crashes occurring in adverse weather, such as rain, sleet, snow, fog, or crosswinds, or on slick pavement (wet, snowy/slushy, icy). These result in nearly 5,000 people killed and over 418,000 injured each year on US roads during adverse weather ("How Do Weather Events Impacts Roads?", 2020).

In addition to these health risks, there are significant economic costs associated with congestion and safety lapses, which are prevalent in Northern Virginia and Hampton Roads. With that in mind, it is appropriate to conclude that transportation is key to Virginia's quality of life and economic development, and weather can greatly affect transportation (MITRE).

Various technologies exist currently that collect real time data, such as the Geostationary Operational Environmental Satellite (GOES) System, or the doppler radar, both employed by the National Weather Service (NWS) subset of the National Oceanic and Atmospheric Administration (NOAA). Despite these accurate technologies providing information through weather apps and channels, very few traffic algorithms currently include weather data in predictions (Xu et al., 2016). Furthermore, despite satisfaction with available weather data, many people underestimate adverse weather severity, and do not change their plans based on it (Barjenbruch et al., 2016).

As aforementioned, approximately 1/5 of road accidents are weather-related, and, on average, 20 percent of state DOT maintenance budget consists of winter road maintenance.

Further, 23 percent of highways delays across the nation are due to snow, ice, and fog. In Metropolitan DC (and Northern Virginia) travel time delay increases by 14 percent with adverse weather, and 24 percent during precipitation ("How Do Weather Events Impacts Roads?", 2020). This imposes important economic tolls as well as socio-cultural costs, while raising political and ethical questions.

In this paper, a technical solution to this problem will be presented, proposing a new spacecraft design as well as an improved method of data delivery to roadway users. The technical solution is a result of a collaboration with MITRE, as well as other UVA Engineering groups also working towards improving transportation in Virginia. While this group is focusing on weather data, other groups specialize in non-destructive roadway infrastructure evaluation, and management and tracking of truck parking. This problem will also be analyzed from a social perspective, using a Science, Technology, and Society (STS) approach. STS Actor-Network Theory will be used to analyze the different actor groups involved in the socio-technical problem, such as roadway users, meteorologists, weather apps, economy, public policy and engineers.

Technical Project

The Virginia Department of Transportation (VDOT) operates one of the largest state-maintained highway systems in the United States, just behind North Carolina and Texas, with almost 60,00 miles ("Virginia's Highway System", n.d.). The size of the road systems results in high maintenance costs, as well as losses related to congestion (lost time, increased fuel consumption, and accidents). In 2018 the economic cost of traffic crashes in Virginia amounted to $6.4 billion ("Virginia Transportation by The Numbers", 2020). Because weather greatly impacts safety and throughput of the roadway system, MITRE tasked UVA students with designing a spacecraft that will acquire real-time weather data to improve weather safety.

Currently, the National Weather Service uses both satellite and radar technologies to gather weather data, such as the GOES System and the doppler radar. GOES data helps the NWS solve for numerous weather conditions (winds, moisture, cloud cover, etc.) at both surface and different layers of the atmosphere. The new GOES-R, latest generation of geostationary weather satellites, uses Advanced Baseline Imagery (ABI) as a primary instrument for imaging. The ABI technology will provide more spectral information, greater spatial resolution, and temporal coverage, equaling the GOES Imager & Sounder data from 1975 to 2015 in less than 4 years ("GOES-R Series Satellite", n.d.). Conversely, the doppler radar can detect the precipitation in a thunderstorm as well as the motion of the precipitation along the radar beam. Both these instruments are used by meteorologists to provide weather forecasts.

Although weather forecasts are what roadway users usually rely on, VDOT uses different measurements, as road conditions could differ significantly from meteorological data. An example of this is the difference in atmospheric temperature and roadway temperature, the road could be a couple degrees colder which could result in ice (this usually happens on bridges). Therefore, VDOT employs about 90 roadway sensors across Virginia, mostly on main highways (I-81, I-95, I-64), which collect a large variety of weather conditions. VDOT also contracts Vaisala to track snow and ice across the state (Fontaine, 2020).

Despite the wide availability of weather data and the various sources, roadway user information is extremely fragmented. Very few traffic algorithms integrate weather data in predictions, and there is no centralization in data so different channels such as Waze, Google Maps, and 511 will all offer different information. Further, although VDOT consistently shares information with local media, the forecast news is not followed unless considered catastrophic or sensational (Fontaine, 2020).

In order to provide accurate weather information using remote-sensing, my team will design a CubeSat. The CubeSat will use imagery to monitor on-road precipitation accumulation, as well as precipitation intensity. Further research will culminate in a high-resolution Low Earth Orbit (LEO) satellite design, which will provide cheaper and more accurate weather data. To validate the design, the precipitation data collected by the CubeSat will be compared to that of local observers and sensors at ground level. The design will also be tested by comparing its effectiveness (in terms of congestion rates and weather-related accidents) to that of existing technologies employed by VDOT. The information collected by the new CubeSat will be distributed to VDOT as well as directly to roadway users through navigation apps. The improved technology will better inform drivers about road conditions, resulting in a decrease of weather-related accidents and traffic.

STS Project

Transportation is key to Virginia's quality of life and economic development, with the road-system being the backbone for commuting and commerce. Every year Virginia drivers spend a total of $9.5 billion dollars on additional vehicle operating costs (VOC), safety, and congestion costs. Virginia drivers can lose up to $2,015 and 102 hours per year due to high traffic caused by congestion ("Virginia Transportation by The Numbers", 2020). When first considering this problem, one might think that the easiest, and perhaps most effective, solution would be to increase roadway traffic capacity – such as building new lanes and/or parallel roadways. In theory this could help solve the issue, as both I-81 and I-95 were built in the late

19050s, when Vehicle Miles Travelled was around 700 billions. As of 2018, VMT was 3,240 billions, almost 5 times as much ("National Highway Traffic Safety Administration", n.d.). However, building new/expanded roadways to increase road capacity is not viable solution as we will illustrate.

Expanding roadways is incredibly costly, and finding physical space to do so would be difficult. When looking at the location of I-81, one of the major transportation arteries in Virginia, it is almost entirely surrounded by National and State Parks. Most notably it is near Shenandoah National Park, Appomattox Court House National Historical Park and George Washington and Jefferson National Forest, in what is known as the Great Appalachian Valley. The precious (and largely protected) nature drastically limits constructions along the route. On the other hand, other areas of focus such as Northern Virginia (I-395, I-495, I-66) and Hampton Roads (I-664, I-264) are densely populated. This makes it difficult to construct new lanes due to the lack of space. Further, it has been found that building bigger roads actually make traffic worse (Mann, 2014). In a study conducted at the University of Pennsylvania, researchers found that if a city had increased its road capacity by 10 percent between 1980 and 1990, then the amount of driving in that city went up by 10 percent, showing a linear, one-to-one relationship. Although correlation doesn't always mean causation, it is highly unlikely that road engineers have consistently predicted driving demand just coincidentally (Mann, 2014).

The problem can be analyzed from a STS perspective, using the Actor-Network Theory (ANT) initially described by Michel Callon, Bruno Latour, and John Law in the 1980s (Muniesa, 2015). According to ANT, engineers exercise influence and power by practicing heterogeneous engineering through building and maintaining successful actor-networks. Here engineers are defined as network builders, and engineering is the activity of associating different entities (“actors”) into a stable system (“network”) to solve a problem or accomplish a goal. The technological artifact, in this case a spacecraft to provide accurate weather data to roadway users, is just a complex network of diverse actors. The actors at work in this network are many, but we will focus on economy, weather apps, public policy, roadway users, engineers, weather, and the natural environment. As aforementioned the natural environment and the economy are constraint on the network, as they do not allow the construction of more lanes to alleviate congestions (due to the Parks and costs). Another economics aspect is the theory of supply and demand, which underlines the induced demand phenomenon. This, also known as induced traffic, refers to the increased roadway capacity leading to more people driving, failing to improve congestion (Schneider, 2018). Weather apps, and how weather data is received and interpreted by roadway users also greatly impact the network, as it is ultimately up to drivers to take advantage of the technology created.

The January 2016 United States blizzard is a prime example of how these different actors contribute to road congestion. On January 21st 2016, the Greater Washington DC area (including Northern Virginia) was hit by about 1-2 inches of snow, a usually insignificant amount, which turned how to be catastrophic as the roads had not been prepared for it. I will use the events of that night, and the following days, to show how different actors can contribute to a network (Barbash, 2016).

In Actor-Network Theory every single one of the actors needs to contribute in a specific way in order for the network to operate successfully, resolving the issue of weather-related congestion and road accidents in Virginia.

Conclusion

In this paper, a solution to the issue of weather related traffic and roadway accidents was proposed, offering a technical view, as well as a STS perspective. A new technology was proposed to improve remote sensing, and provide better data to weather channels. Further, a new method of communicating weather data to roadway users is proposed. As far as the STS approach, Actor-Network Theory can be applied to this problem. Determining the various entities involved in the development of the technological system will result in a better understanding of the issue.

The remote sensing spacecraft will bring real-time weather data to roadway users, allowing them to make informed decisions about the best way to operate (or not) the vehicle, and the best route to take. This will result in an overall decrease in weather related congestion as well as road accidents. First and foremost, many lives will be saved as a result. Additionally, this will result in much less money spent on roadways, and time freed up as people don't spend as much time stuck in traffic.

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