

Improving Road Safety with Intelligent Transportation Systems



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Executive Summary

Goal and Objectives

The goal of our project was to propose current and future Intelligent Transportation Systems (ITS) solutions to decrease fatalities in areas with high crash frequency, or hotspots, in New Mexico. In order to accomplish this goal we addressed the following objectives:

1. Composed and analyzed a compilation of ITS solutions and their possible applications that would best benefit the NMDOT, referred to as a "toolbox"
2. Identified and Characterized Hotspots, or Dangerous Sections of Road, Where ITS Solutions Could Potentially be Applied
3. Develop a set of guidelines that the NMDOT could follow to increase traffic safety at hotspots

Background

Traffic related accidents make up 2.2 percent of the world's deaths. Even in affluent countries such as the United States approximately 32,000 people die in these accidents every year (Road Crash Statistics, n.d.). Of the fifty states, New Mexico is one of the most dangerous to drive in, with over 23 percent more fatalities for every 100,000 people per year compared to the national average (Wang et al., 2015).

In the state of New Mexico, the majority of accidents are caused by driver error. These incidents include driving under the influence, driver inattention, and excessive speed. Accidents can also be caused by factors outside of the vehicle, such as poor road conditions, weather, and wildlife. It is important to find adaptable solutions that are able to address these scenarios.

The New Mexico Department of Transportation (NMDOT) is aware of this problem and is working to reduce driving deaths within the state. The NMDOT does this by researching road safety technology and implementing it in locations where there have been a large number of crashes. These solutions range from simple traffic barriers to advanced information collection systems (ITS Bureau, n.d.a).

Intelligent Transportation Systems (ITS) is a form of improving traffic safety based on information. The ITS Bureau of the New Mexico Department of Transportation was put in place to develop new, innovative methods to improve existing roadways (Intelligent Transportation Programs. n.d.a). For our project, ITS solutions typically fall into one of two categories: collecting data for departments such as the NMDOT, or communicating information with the operator of a vehicle.

The idea for this project originated from the NMDOT's interest in future traffic safety technologies and how they can be applied to hotspots within the state. Over the course of this project we have worked with the NMDOT to find new ITS technologies that are being researched or implemented by other DOTs. We then identified hotspots within the state, and recommended ITS solutions to reduce fatalities at these hotspots.



Figure 1 WPI Team on Site Visit

Methods

Our team used scholarly articles and interviewed representatives from other state DOTs, such as Colorado and Utah to learn more about ITS solutions. We then used this research to develop a detailed list of solutions which we referred to as a ‘toolbox’. Next, we used a mapping program called ArcGIS to identify hotspots in NMDOT Districts 3 and 5. Using crash data provided by our liaison, we identified hotspots by looking for groupings of accidents with similar causes.

After determining the hotspots, our team, accompanied by our liaison Tim Brown of the NMDOT, visited a number of hotspot locations to visually analyze them. The goal of these trips was to determine the best solutions for each location (Figure 1). Lastly we addressed each hotspot by proposing an ITS solution from the toolbox.

Outcomes:

Our first deliverable was a toolbox that includes ITS solutions. Some examples include lane management systems, variable speed limits, and smart traffic signals. Lane management systems give drivers advance warning of the direction and congestion of the lane they are travelling in. Variable speed limits are adjustable speed limits that change based on the weather and congestion conditions of a road. Smart traffic signals are able to prevent

unnecessary stops at intersections by providing more or less green time to certain directions based on information gathered by sensors connected to the signal.

Using the data given to us by the NMDOT, we determined that there were a total of 17 hotspots in Districts 3 and 5. For each location, our team wrote a detailed description of the layout of the roadway and what types of collision occurred there according to ArcGIS. We also included the total number of fatalities at each location. Over the course of our project we visited ten of the 17 hotspots we identified in our analysis of the crash data.

Lastly, our team used the ITS solution toolbox we assembled to assign potential solutions to the hotspots we identified. We took into consideration the physical features of the road as well as the primary cause of accidents at each location to best match the spot with a solution. There were certain locations that we were unable to suggest solutions for because at this time, ITS solutions do not best address accidents caused by human error.

We determined that the NMDOT should implement variable speed limits at the intersection of Coors and I-40, I-40 mile markers 221-258, and Route 68 mile markers 32-33. We also recommended that the NMDOT apply smart traffic signals to the intersection of Rio Grande and I-40, as well as along Cerrillos Rd. Our final recommendation to a specific hotspot was to introduce a lane management system to the intersection of the I-40 and I-25, or the Big I.

Through our research, we found that ITS solutions are best applicable to accidents caused by weather and congestion. Over the course of our project, we gathered information about the future of ITS. We recommended that the New Mexico Department of Transportation begin studying the possibility of third-party partnerships with internet service providers. These partnerships would allow for the service providers to lay fiber optic cable along roads. In return, the DOT would be able to access the new cable. This contract would enable the DOT to place ITS solutions in areas where it is currently hard to communicate traffic information. We also recommended the NMDOT begin working with Colorado DOT to continue researching smart work zones, which use smart vehicles and sensors to gather and transmit data on cars approaching construction zones. Our final recommendation was that the NMDOT begin looking into partnerships with social media outlets such as Waze, which would permit them to access real time traffic information such as congestion and locations of accidents.

Conclusion:

Working with the ITS Bureau of the NMDOT provided our team with an opportunity to increase traffic safety in New Mexico. The methods used by our team to identify hotspots can be replicated by other organizations and state DOTs. Additionally, our ITS toolbox can be used by DOTs all over the country as a resource for ITS solutions. Traffic safety is an issue in the state of New Mexico. It is above the national average for traffic fatalities per 100,000 population. Our project will help the NMDOT to decrease that number, and make New Mexico a safer state to drive in.

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Abstract

Traffic incidents are one of the leading causes of death worldwide, and are responsible for about 40,000 fatalities each year in the United States. The goal of our project was to work with the New Mexico Department of Transportation (NMDOT) Intelligent Transportation Systems (ITS) Bureau to propose current and future ITS solutions to decrease fatalities in areas with high crash frequency, or hotspots, in NMDOT Districts 3 and 5. We accomplished this by utilizing ArcGIS maps to locate hotspots, interviewing professionals, and visiting these locations. We composed and analyzed a compilation of ITS solutions the NMDOT could potentially utilize in the future to improve traffic safety within the state, as well as recommended specific solutions that would best address the hotspots.

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Chapter 1 Background

Traffic accidents are one of the leading causes of death worldwide. Every year, road traffic crashes account for 2.2 percent of the world's fatalities, making them the ninth leading cause of death globally. Individuals between the ages of 15 and 44 account for more than half of these deaths (Road Crash Statistics, n.d.).

In 2015, approximately 32,000 individuals in the United States died as a result of motor vehicle accidents. During the year 2014, there was an increase of over seven percent in fatalities directly related to car collisions. Over 40,000 traffic related fatalities occurred in 2016, the highest number in the last decade (Auto Crashes, n.d.). Traffic congestion can be linked to higher frequencies of automobile accidents. Efforts to make roads safer and cut down on road congestion have been made in the past, but even with the solutions implemented today, traffic safety is still an issue.

New Mexico consistently has a high number of automobile related deaths, with a 23 percent higher proportion of fatalities caused by traffic accidents per 100,000 people per year than the national average (Wang et al., 2015). This puts it among the bottom ten states in regards to traffic safety (Morretti, 2017).

In our project, we worked with the New Mexico Department of Transportation to investigate “hotspots”, or sections of road that have an above-average number of fatal accidents with similar causes. We recommended Intelligent Transportation System (ITS) solutions to increase traffic safety in these hotspots. In this chapter, we discuss common causes of car accidents, the history of ITS solutions, and how they can help to prevent accidents. We also discuss what ITS solutions our sponsor, the New Mexico Department of Transportation, is currently utilizing.

1.1 Causes of Car Accidents

Accidents can be caused by a number of factors, the most common of which can be classified as human error. While the majority of accidents in New Mexico are caused by driver error, many are also caused by conditions outside of the vehicle, such as bad weather, unsafe roads, or wildlife.

1.1.1 Human Behavior

The leading cause of traffic incidents resulting in fatalities in New Mexico is Driving While Impaired, or DWI. Alcohol is the most common intoxicant, involved in more than forty percent of all traffic-related deaths (DWI Penalties, n.d.). The second leading cause of car accident deaths in New Mexico is driver distraction. The most common type of distraction is cell phone use (Zhang, 2015). The third leading cause of fatalities from car accidents is excessive speed. All together, these three causes of traffic fatalities account for over 60 percent of driving-related deaths in the state of New Mexico. Therefore, it is pertinent that these causes are addressed (Department of Health, n.d.).

Another dangerous behavior is aggressive driving. Aggressive driving often leads to accidents that are caused by drivers cutting off other vehicles, weaving through traffic, and running red lights. These behaviors often put all vehicles on the road in danger. Aggressive driving is often caused by frustration, which is a product of congestion (Shinar, 1998).

Congestion occurs when there is an excess of cars on a particular roadway, and traffic slows down or comes to a near standstill. While this can be caused by construction or an accident, it often occurs when there are too many cars on the road. Reducing congestion could reduce aggressive driving and accidents caused by the behavior.

1.1.2 Road Features and Conditions

New Mexico has one of the most poorly maintained rural road systems in the US, currently ranked 44th (Morretti, 2017). With over 73 percent of the roads falling into the “rural roads” category it is concerning that 25 percent of them are considered to be in poor condition (Warren, n.d.). This is a concern because rural roads have a significantly higher rate of fatalities per 100 million vehicles than urban roads, 1.67 compared to 0.77 in 2015 (Hall, 2015).

Rural roads often have narrower and fewer lanes, making distracted driving and drifting out of lanes much more dangerous. US 491 between Gallup and Shiprock was once the most deadly stretch of rural road in the United States. This problem was addressed by expanding the road from two lanes to four lanes (Matlock, 2015).

Urban roads are often better maintained and therefore less dangerous than their rural counterparts, however, they have much more traffic. Many of the solutions that are effective in rural areas are less effective when used on busy roads or inside cities. For example, it is not possible in many circumstances to add lanes to urban roads as there are often structures bordering the roadways. The causes of accidents also vary greatly in cities when compared to rural areas because many of the problems associated with urban areas, such as traffic, do not apply to the majority of rural roads.

In metropolitan areas, such as the cities of Albuquerque and Santa Fe, road features such as intersections and roundabouts are often where crashes occur. For example, if a yellow light is not long enough, a driver trying to clear the intersection before the light turns red has greater chance of getting into a side traffic collision or a “T-bone” (Intersections and Safe Driving, n.d.). In areas where roundabouts replaced traffic signals, there was a 38 percent drop in car related deaths and injuries. However, during the first few months after the installation of a roundabout, the total number of crashes in the given area increased by 12 percent. This sudden increase in accidents is believed to be due to drivers learning how to deal with an unfamiliar road feature (Metcalf, 2017).

Weather-related car accidents are responsible for more fatalities per year than weather disasters such as tornados and hurricanes (Dolce, 2016). These accidents led to approximately 5900 deaths a year nationally from 2005-2014. New Mexico is susceptible to many different weather patterns such as dust storms and snowfall. These conditions along with heavy rain and fog can cause sudden reduced visibility on roads. Cold weather can form ice over roadways, reducing the amount of traction between the road and a car’s tires. Under these conditions, a driver has less control of their vehicle (Weather-Related, 2016). Wildlife also contributes to the number of car accidents on many rural roads because animals can cross suddenly, posing a risk to fast moving automobiles. In the United States, there are approximately 730,000 annual collisions with deer alone (Ueno, 2014). These accidents can be dangerous because large animal collisions often cause serious injury such as cuts to the face and head along with spinal trauma (Ueno, 2014).

1.2 Intelligent Transportation Systems

While conventional solutions such as stop signs and changes to the shape of roads have helped improve traffic safety, there is a need for newer and more advanced solutions. The concept of Intelligent Transportation Systems (ITS) is a form of improving traffic safety based on information. According to our liaison, Tim Brown, and for the purposes of our project, in order for a solution to be considered ITS, it must fall into one of two categories: collecting data for departments such as the NMDOT, or communicating information with the operator of a vehicle. Another requirement for ITS is that it must be able to change to apply to specific circumstances; for example, a simple road sign which has the speed limit printed on it is not an ITS technology, but a sign that tells drivers the speed limit and their current speed is.

1.2.1 History of ITS

ITS can be traced back to the first instance of a three color traffic light in 1914, but became truly relevant in 1970 with the Highway Safety Act, which introduced the National Highway Safety Administration (Hamilton, 2016). Some early ITS technologies include the Driver Aided Information and Routing System, which would send a message to emergency response teams in the event of a crash. Another early ITS technology is the Experimental Route Guidance System, which was able to communicate from the car to infrastructure using radio waves to inform drivers of their location (Hamilton, 2016). Even the most common examples of ITS trace their roots back to this era, such as electronic signs, which were first introduced in the 1960s (Hamilton, 2016).

In the 1980s, ITS projects became significantly more complex. This marked the beginning of research into autonomous vehicles, such as the DARPA Autonomous Land Vehicle shown in Figure 2, which began demonstrations in 1985. In the late 20th century, autonomous vehicle research moved forward quickly with the development of technologies such as Pathfinder and TravTec which allowed a vehicle to geolocate itself. With the 21st century came projects such as 511, a phone service allowing drivers to call in and report accidents they see on the road, and the Clarus, which gave drivers access to information on adverse driving conditions (Hamilton, 2016).



Figure 2 The Darpa Autonomous Land Vehicle (Hamilton, 2016)

ITS has progressed along with communication technology. This trend continues into today with phone applications that show congestion and crashes, and camera networks that monitor roads for unusual car behaviors (Hamilton, 2016).

1.2.2 Gathering Information

Communication is a large component of ITS. In order for organizations such as the Department of Transportation to relay information to drivers and smart communication systems, they must first obtain information themselves. There are several ways this can be done.

A Vehicle Detection System (VDS) consists of a sensor, often using radar. VDS can detect vehicle statistics, such as occupancy and volume, for up to ten lanes of traffic. They can also be used in traffic light systems, because they can detect the presence of cars at an intersection (Jefferis, 1994).

Roadside Weather Information Systems (RWIS) can be used by the DOT to observe both weather and road conditions, such as moisture, snow, ice, and dust storms (Boselly, 1993). Using information gathered from this system, if weather conditions on a road are considered unsafe, the road can be shut down. This information could also be used to notify drivers if the road is icy or slippery.

Closed-Circuit Television (CCTV) is a system that uses cameras to observe traffic conditions. Monitors display information such as number of vehicles, types of vehicles, and even license plate numbers. The video collected from cameras can be viewed in real time and are monitored by DOT employees. The system sends notifications to the observers when a car pulls to the side of the road or an accident occurs so that they are able to monitor the correct cameras (Kurdi, 2014). Cameras and sensors can also be programmed to detect specific behaviors, such as wrong-way drivers (Monteiro, 2007).

1.2.3 Dispersing Information

Connecting drivers with information is an ITS solution because it makes drivers more aware of dangerous situations. This helps drivers to be more aware of situations such as wrong

way drivers or stopped traffic. Informing drivers of traffic information that could help them make better decisions improves the safety of every driver on the road. There are multiple ways to output traffic information to drivers. One of these is Highway Advisory Radio, or HAR. Drivers can tune into these radio stations to hear about current traffic information and road conditions. Another is the 511 Road Conditions Hotline, where drivers can call in to hear recorded messages about traffic conditions (ITS Bureau, n.d.a).

Digital Message Signs (DMS) are an on-road information system used to convey messages to drivers. These electronic signs are placed on highways and can be changed to display messages that alert drivers of upcoming traffic conditions (ITS Bureau, n.d.b). The signs are also used to report delays and estimated arrival times for select destinations.

Cell phone applications, such as Google Maps, have made improvements that mitigate travel times and congestion. Google Maps, Apple Maps, and Waze are a few applications that distribute real time information to drivers. When a cell phone user enables location services with companies such as Google, the user's cell phone communicates small amounts of GPS information to the company. The company then processes the information gathered from this communication and obtains information on driver speed and traffic flow (Palmer, 2014). The traffic information could then be quantified and posted onto a mapping application. Additionally, companies can access any of this stored information allowing them to determine the fastest travel routes for the application users.

While these ITS solutions are important and can still be used in the field today, it is necessary to understand where the field of ITS is headed. The future of ITS is autonomous and smart vehicles. These will replace many of the existing ITS solutions. However, it will be several years before smart vehicles are widely available so it is important to implement these ITS solutions (Overview of Autonomous Vehicle Technology, 2017).

1.2.4 ITS and Social Media

While many organizations have the ability to gather information, it is often hard to communicate the data to drivers. Professionals in the ITS field are currently exploring solutions for this time discrepancy. One of the leading solutions includes social media. Social media allows users to share information almost instantaneously. This application, when applied to transportation safety, allows users to upload and receive traffic-related data using an app on their phones.

Applications such as Waze or Here.com are already in place and give directions using Google-based maps. Using the social aspects of these applications, users are able to input locations of crashes and other dangers such as closures and hazardous weather into the app. This information can then be shared to other users in the form of an audio warning from the phone, or a recommended alteration to their route (Hind, 2014).

Use of social media in this way would reduce the number of rear end accidents from cars stopping abruptly because drivers would know about traffic and other backups before they encounter them. It could also reduce the number of crashes caused by drivers who are unaware of conditions such as icy roads. The disadvantage of this technology is that it would require the user to interact with a mobile device while driving, which may lead to an increase in distracted driving accidents (Butler, 2011).

1.2.5 The Future of ITS

The focus of ITS is shifting toward assisted driving technology. The automotive industry has already taken steps to implement vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication. As of November 2016, the National Highway Traffic Safety Administration proposed Federal Motor Vehicle Safety Standard (FMVSS) #150. Once passed, the FMVSS will require all newly manufactured light vehicles, or vehicles under 10,000 pounds, to have a dedicated short range communication (DSRC) radio included in the automobile (Vehicle to Vehicle Communication, 2016).

DSRC radios are used for V2V communication, but their signals can also be utilized by roadway infrastructure for V2I communication. V2I technology is extremely versatile and can be used to increase traffic signal efficiency, gather data about vehicle density and volume, and even relay suggested speed information to the vehicle itself. V2I technologies have also displayed the ability to detect lane changes and the lane position of vehicles on a highway (Cao, 2015). Data can be transferred from vehicles to infrastructure or from vehicle to vehicle quickly and efficiently through DSRC. However, this radio technology has a limited range, which makes communication when a vehicle is travelling at high speeds less reliable.

An alternative to DSRC technology is already included in cell phones, Long Term Evolution (LTE) radio. LTE technology is a different type of radio wave that offers communication at greater distances than DSRC. The disadvantage of LTE is that the technology has latency issues (Dey, 2016). Latency is the response time from when data receives instruction to transfer to when it actually begins to transfer. Safety technologies require less than 200 milliseconds of latency in order to convey information quickly enough to be usable by the car. As of today, LTE technologies currently have a latency of several seconds (Dey, 2016).

One dilemma in the advancement of V2V and V2I communication is the security threats associated with the technology. DSRC technology relies on open network communication, which means that anyone would be able to connect to the vehicles network pretending to be road infrastructure. For example, a hacker could attempt to collect information stored in a private vehicle's GPS, and potentially gain access to the user of that vehicle's common locations (Yağdereli, 2014). To protect against such attacks and maintain the integrity of the radio communications, numerous countermeasures are being developed. Additionally, private DSRC users will have access to options that would prevent the technology from communicating with other signals that are not verified (Hasrouny, 2017).

1.3 The New Mexico Department of Transportation

The ITS Bureau of the New Mexico Department of Transportation was put in place to develop new methods to improve existing roadways (Intelligent Transportation Programs. n.d.a). The ITS bureau has developed many applications that they have already applied to maintained areas. They are now expanding on their current projects and developing new ones.

1.3.1 Current Technologies

The NMDOT already has several ITS projects in place within their department, including traveler information systems. Information for these systems is obtained through both ITS and conventional sources. The NMDOT ITS Bureau obtains information from Vehicle Detection Systems (VDS) and Closed Circuit Television (CCTV), as well as utilizing two Roadside

Weather Information Systems (RWIS), which are used primarily to detect dust storms. The ITS Bureau also obtains information from APB and state radio transmissions (ITS Bureau, n.d.a).

The Traveler Information Systems NMDOT employs include Highway Advisory Radio (HAR), 511 Road Conditions hotline, and Digital Message Signs (DMS). The newest addition to these systems has been the website and app NMRoads (NMRoads, 2017)

1.3.2 NMRoads

The ITS Bureau created NMRoads which keeps drivers up-to-date on traffic and road conditions. NMRoads can be accessed via both nmroads.com and as an app on iOS and Android devices. NMRoads can provide drivers with information on road conditions, weather, and construction. NMRoads also gives direct access to live-stream road cameras in different major areas so they can view conditions live. The application displays a map of the state with different widgets indicating backups and their causes all over New Mexico. Drivers are able to select what kind of information they would like displayed. For example, they could choose to see current weather and weather advisories, view construction zones, accidents, or a combination of these options (ITS Bureau, n.d.a; NMRoads, 2017).

1.3.3 Our Project

Our project was to provide the New Mexico Department of Transportation ITS Bureau with information to help them improve traffic safety through the use of ITS solutions. We identified some of the most dangerous areas to drive in New Mexico, or hotspots, which will ensure efforts to increase traffic safety are focused on the areas that need it most. By providing the NMDOT with a list of general ITS solutions, they will have a “toolbox” to choose from when they are needed in the future. We also used the toolbox in conjunction with our identified hotspots to propose ITS solutions for the NMDOT. Our project will increase traffic safety at dangerous intersections within districts 3 and 5 in New Mexico, as well as help to prepare New Mexico for the future of ITS. The steps we took to identify hotspots and potential solutions can be replicated for future use by the NMDOT and other state organizations.

Chapter 2 Methods

The goal of our project was to propose current and future Intelligent Transportation Systems (ITS) solutions to decrease fatalities in areas with high crash frequency, or hotspots, in New Mexico. In order to accomplish this goal we addressed the following objectives:

1. Composed and analyzed a compilation of ITS solutions and their possible applications that would best benefit the NMDOT, referred to as a "toolbox"
2. Identified and analyzed hotspots, or dangerous sections of road, where ITS solutions would best be applied
3. Develop a set of guidelines that the NMDOT could follow to increase traffic safety at hotspots

2.1 Objective 1: Composed and analyzed a compilation of ITS solutions and their possible applications that would best benefit the NMDOT, referred to as a "toolbox"

The first stage of our project was to compile a "toolbox", or annotated list, of ITS solutions based on methodical research and structured interviews with professionals in the field of ITS. All solutions we found in our study that could potentially be applied by the NMDOT are included in this toolbox.

2.1.1 Interviews

One way we gathered information for the toolbox was by interviewing several out-of-state DOT officials to gain more knowledge on ITS initiatives outside of New Mexico (Appendix A). We contacted these professionals by using state directories to email individuals whose job title included or was related to ITS. Many of the individuals we contacted directed us to others within their department. Because of its proximity to New Mexico, we first contacted the Utah DOT and conducted a phone interview with Blaine Leonard, Technology and Innovation Engineer. We also contacted the Colorado DOT and met with John Williams, Technology Manager - Information Technology Professional V. We asked these professionals questions such as "What are some of the larger issues your state has encountered in regards to traffic safety?" and "What types of ITS programs have you implemented, or thought about implementing, in response to these issues?" These questions helped us to learn more about potential solutions that could be applied in the state of New Mexico. We also tried to contact other state DOTs through email, but several of these states, such as Arizona, Oklahoma, and Nevada, never responded or were not available.

In addition to this, we interviewed a Principal Engineer at the Southwest Research Institute to gain more information on research being conducted in the field of ITS (Appendix B). We interviewed Jesus Martinez at the recommendation of our liaison John DiRuggiero, who gave us Martinez's contact information. We asked Martinez questions such as "What type of ITS solutions do you see being researched right now?" in order to ensure that our recommendations to the NMDOT included cutting edge ITS technologies.

2.1.2 Internet Research

In addition to interviews, we also conducted research on the internet. The purpose of this was to find information on state of the practice ITS solutions that had already been implemented elsewhere. To find this information we first used Google Scholar to search for key terms such as "ITS Solutions" and "Intelligent Transportation Systems". This yielded several articles that described research or projects relating to ITS. Our liaison's definition of ITS included "technology that focused on communication" so we only further researched projects with communication technology.

We researched several other state DOT websites, focusing on states with large rural areas, a few large cities, and terrain such as desert and mountains. We directed our research to the Arizona, Oklahoma, Nebraska, Colorado, and Utah DOTs. On these state websites, we looked for departments related to "traffic safety", "research", and "intelligent transportation systems".

We directed our research based on references found in papers. Many of the articles about ITS solutions we read discussed ITS development in Europe. This led us to research international

solutions in countries such as Denmark and Spain. Many articles were being published by universities, which led us to research being done in the field of ITS by institutions such as the Massachusetts Institute of Technology and the University of New Mexico.

2.2 Objective 2: Identified and Characterized Hotspots, or Dangerous Sections of Road, Where ITS Solutions Could Potentially be Applied

We identified areas with a large number of accidents of the same type in a small area within Districts 3 and 5 as shown in Figure 3. To do this, we used ArcGIS to map each crash resulting in a fatality between 2010 and 2015. With this information, we went over state maintained roads, or roads that the NMDOT has jurisdiction over, looking at the causes of each crash. The first step of our process was to limit the roads to those which had over 8000 average annual daily traffic (AADT). This was a basic way of filtering out low traffic, non-state maintained roads which tend to be smaller than roads that are within the state's jurisdiction. On the remaining roads we noticed irregular clusters of crashes. We then investigated each one of these clusters to see if they were potential hotspots by inspecting if there was a common theme regarding the causes of crashes. We would then determine how far apart these accidents were spaced. We chose 2.5 miles per crash to be the threshold for determining hotspots because most of the locations with high concentrations of similar accidents fit within this range. This means that each location had to have at least one crash every 2.5 miles to be considered a high crash frequency location. However, we also determined a stretch of I-40 to be a hotspot even though it did not fit this definition. I-40 Mile Marker 221-258 is influenced by large patterns of similar crashes and were pointed out to us by our liaison. One additional location, the intersection of Rio Grande and I-40, was selected to be a hotspot based on interviews with Nancy Perea. During the last few weeks of our project, we implemented a different method of hotspot identification which used the number of crashes divided by the amount of traffic recorded over the course of a day (Appendix C). This method displays smaller spots and tends to prioritize low traffic non state maintained roads. We did not use this method to identify the hotspots as we discovered it near the end of our project.

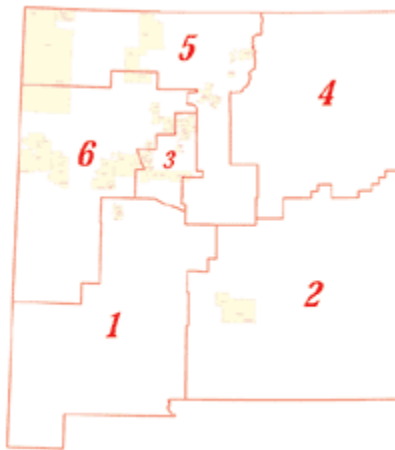


Figure 3 Map of NMDOT Districts (NMRoads)

2.2.1 ArcGIS

To identify hotspots, we used ArcGIS Online, a geographic information system (GIS) program, which was already being utilized by the NMDOT for similar location identification purposes. Prior to our project, data for crashes between 2010 and 2015 were uploaded to ArcGIS by our sponsor. This data included the location, number of injuries, number of fatalities, and cause of crash such as in Figure 4.

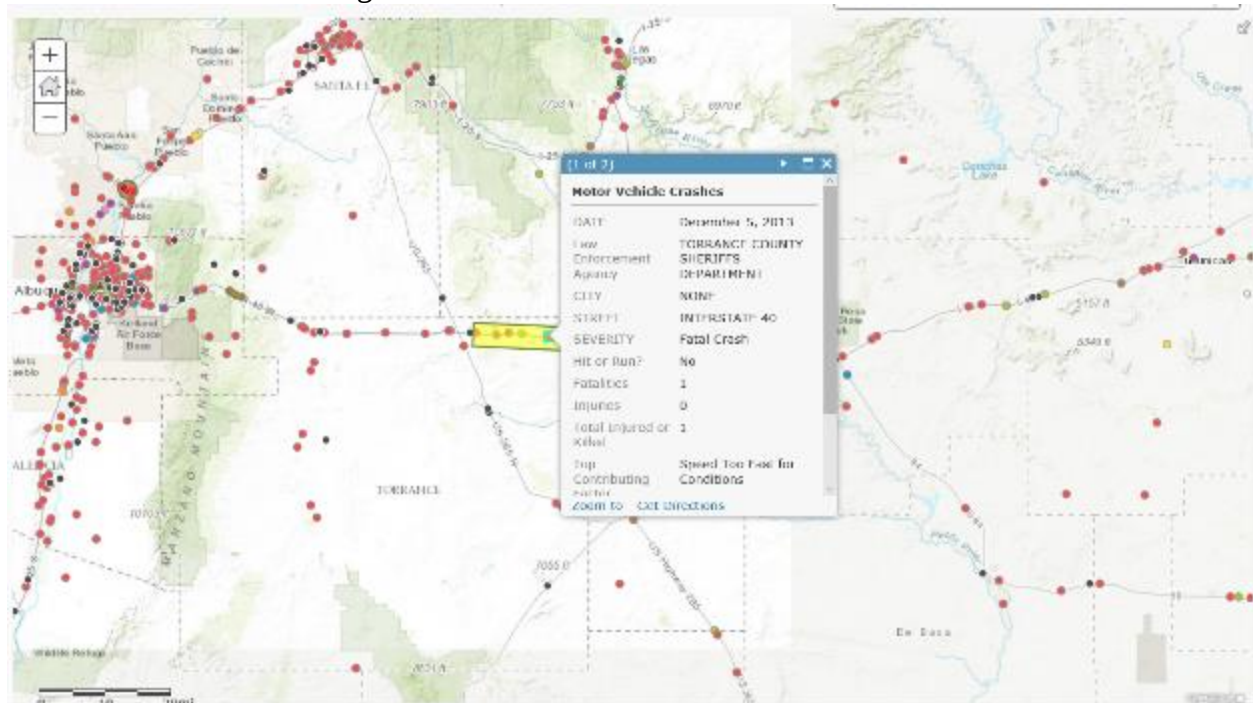


Figure 4 hotspot on Interstate 40 With Detail of a Fatal Crash

ArcGIS has multiple “layers” which allowed us to manipulate data being viewed on the program. These are data sets displayed on a map that can be turned on and off. Layers are a way of grouping data points so they can be filtered and interpreted. These can be posted publicly or created in a private group. Public layers can be searched for and added by any ArcGIS user. A private group was formed for the purpose of our project, which allowed for all information relevant to our analysis to be accessible in one location. The account created for us by the NMDOT was private so any personal information, such as crash data, would not be accessible to public users.

In order to begin identifying hotspots in Districts 3 and 5, we selected the crash report layer on ArcGIS that populated the map with every accident in the state from 2010-2015. Crashes are represented on ArcGIS as dots, and displayed on the map at the location the accident occurred as seen in Figure 3.

We utilized the ArcGIS filter option when accessing the data. The filter application was only accessible on some of the individual layers, for example, the 2015 crash data could not be filtered. This is because the 2015 data was made available to the DOT a few days before the start of our project. This data was input as a Comma Separated Value (CSV) file instead of a feature layer similar to the rest of the data. The difference between CSV files and feature layers is the

ability to perform analysis within ArcGIS. On the 2010-2014 data, filtering allowed for information such as “top contributing factor” of the accident to be sorted and displayed. Since we were initially working with non-paid versions of ArcGIS, we did not have the ability to create feature layers, however, we were able to perform similar analysis within Microsoft Excel.

After we identified a hotspot on the ArcGIS map, we used the “Map Notes” tool in the software to mark the location for future reference. Map Notes allowed us to place a semi-transparent geometric shape over a hotspot location, and save the shape on the map. An example of this is the yellow rectangle in Figure 3. We were also able to add comments to the location, which included information that was important about that specific spot such as the number of fatal crashes and the primary causes.

2.2.2 Interviews with NMDOT Engineers and Traffic Safety Experts

We interviewed experts in the field of traffic safety (Appendix D). The first person we interviewed was Mike Knodler, the Director of the Traffic Safety Research Program at UMass Amherst. We contacted him through email and conducted an over the phone interview. We also conducted an in-person interview with Ken Martinez, the Director of the Regional Emergency Communication Center (RECC) in Santa Fe County, at our liaison Tim Brown’s recommendation. We contacted him through email which we found on the RECC website. We asked these experts questions such as “Are there any trends in accidents that result in a fatality? I.e. collisions from behind, disregarding a stop light, etc.” in order to understand what types of accidents we needed to most focus on preventing so we could search for solutions that best addressed those crashes.

In order to learn about hotspots within Albuquerque we conducted an in-person interview with Nancy Perea, the Head Traffic Engineer of District 3, as well as Margaret Haynes, the Assistant Traffic Engineer of District 3, and Jill Mosher, the Assistant District Engineer for District 3 (Appendix E). In this interview, we asked questions such as “where do you often see accidents within the city?”, “what areas are you addressing right now?”, and “what are the common causes of accidents in the city?” We wanted to gain information about where crashes had been happening, if the causes of these traffic incidents had already been addressed, and what caused certain locations to have a high accident rate.

2.2.3 Site Visits

After we identified the hotspots, we visited nine of the seventeen sites within Districts 3 and 5 that were near Santa Fe and Albuquerque. During these visits, we talked with our liaison, who was accompanying us, about the common causes of accidents at the location, what was currently being done, and what solutions would be most effective. We chose not to visit some areas due to their distance from either Santa Fe or Albuquerque. We did not visit one hotspot between Coors and Don Felipe road because we located it after we conducted our site visits in District 3. Our goal for these visits was to identify common problems and evaluate the possibility of implementing ITS solutions in each area.

2.3 Objective 3: Develop a Set of Guidelines That the NMDOT Could Apply to Hotspots

Using the toolbox in conjunction with the list of hotspots, we attempted to identify ITS solutions that best addressed each location. We based our choices on group discussions, and

conversations with our liaison, Tim Brown. We took into consideration where these ITS solutions had been previously implemented, and how effective these solutions were at their respective locations. We used information from CDOT, UDOT, and NMDOT engineers to propose our recommendations.

Chapter 3 Results and Discussion

The final product of our project was a completed ITS solution toolbox, a list of analyzed hotspots, and a list of proposals on how to use ITS solutions to address the hotspots in NMDOT Districts 3 and 5. In this chapter, we will detail our results in regards to these three deliverables as well as explain our findings on the quality of ArcGIS data, future of ITS technologies, and other recommendations for the NMDOT.

3.1 Objective 1: ITS Solution Toolbox

Over the course of our research, we generated a list of ITS solutions and their possible applications. Each entry includes a summary of the solution's application. Below is the list of solutions that we have collected. Our list is split into two parts, the first details solutions that could be used to help prevent accidents, while the second focuses on data collection. Although the solutions in the second section do not reduce a specific type of accident, they help organizations such as the DOT collect data. This data provides them with a better understanding of traffic incidents in the state. A summary of the solutions can be found in Appendix G.

3.1.1 Crash Prevention Methods

Radio Notices

Radio stations provide regular traffic reports to communicate information on congested roads and other hazards along with possible routes to avoid these delays. Drivers can tune in to a specific AM radio station to receive information about these delays or road closures. This is already being used by the NMDOT and most other DOTs around the country. While this does not prevent any one type of accident, it helps drivers make more informed decisions (Highway Advisory Radio, n.d.).

Digital Message Sign

A digital message sign displays messages to drivers about hazards on the road ahead of them. They can either be mobile or permanent, and messages can be changed to address different situations. This is already being used by the NMDOT and many other DOTs around the country. While this does not prevent any one type of accident, it helps drivers make more informed decisions. This system requires a fiber optic network (Brudny, 2013).

Red Light Cameras

Red light cameras take pictures of the front and back of a car after a sensor detects it running a red light. First responders are notified if a crash results from a vehicle running a red light. This improves response time and decreases the chance of an accident caused by congestion resulting from the initial crash (Benefits of Intelligent Transportation Systems, n.d.). These are being used by other state DOTs across the country. One limitation of this is that New Mexico laws prevent individuals from being convicted based on license plate recognition pictures. This system requires a fiber optic network.

Wrong Way Driving Cameras

Wrong way driving cameras use infrared technology to detect vehicles travelling in the wrong direction. Digital message signs can be used in concert with these cameras to notify other drivers of the potential hazard ahead. This helps minimize head on collisions due to wrong way driving. This is currently being used by the Arizona DOT. The system requires a fiber optic network. (Detection and Warning Systems for Wrong-Way Driving, 2015).

Ramp Metering

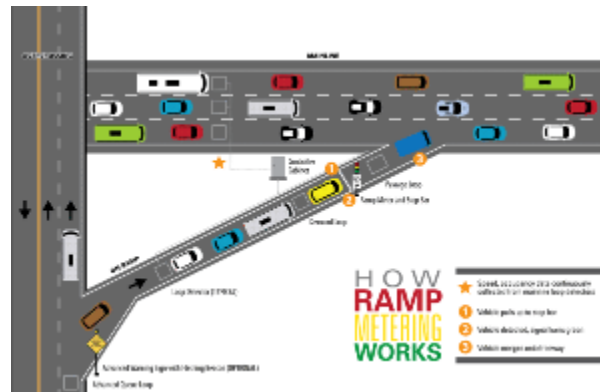


Figure 5 Example of Ramp Metering (Ramp Metering, n.d.)

Ramp metering uses traffic signals installed on freeway on-ramps to help control the rate at which cars enter the freeway based on the volume of traffic as seen in Figure 5. This helps to decrease congestion on the interstate. Ramp Metering helps to limit the number of rear end collisions, accidents that occur because of crowded merging lanes, and accidents caused by failing to yield to the right of way. While this method reduces congestion on the freeway, it often causes stopped traffic on the onramp. This is preferable as any collisions that happen there are at a much lower speed and are less dangerous. This solution is currently being used by the Colorado DOT. It does not require connection to a control system but it can be connected so that traffic engineers can change the amount of red and green time (Ramp Metering, n.d.).

Variable Speed Limits

Variable speed limits are digital speed limit signs that can be changed from a control station to help drivers adapt to road conditions such as rain or snow. Some of these systems use technology like section speed to calculate the average speed of cars and adjust the speed limit to decrease speed variance between vehicles. It can also be paired with roadside weather information systems (RWIS) to change the speed of roads during extreme weather conditions. This helps decrease accidents due to excessive speed. It is currently being used by the Colorado and Utah DOTs (Leonard, 2017). One limitation of this technology is that for this solution to have any effect, the reduced speed limit has to be enforced by local authorities. Communication between law enforcement and the Department of Transportation would play a significant role in the effectiveness of these technologies. John Williams of the Colorado DOT stated that variable speed limits are currently just suggestions in the state of Colorado, and it is illegal for police officers to enforce them (Williams, 2017). Laws may also have to be passed in the state of New Mexico in order for variable speed limits to be enforced.

Radar Speed Monitor



Figure 6 Example of a Radar Speed Monitor (Bloch, 1998)

Radar speed monitors are signs that show the fixed speed limit as well as the speed of an approaching driver as seen in Figure 6. If a vehicle is speeding, lights on top of the monitor will flash to alert the driver. The monitors help to minimize accidents due to excessive speed. This is currently being used by the NMDOT (Bloch, 1998).

Lane Management

Lane management is a system of overhead digital signs that indicate whether a lane is open or closed depending on road conditions and congestion. It can display a suggested speed for each lane. The shoulder of the road can be opened using a digital sign to provide additional capacity during times of congestion. These signs can be controlled from an operating center. They help to break up congestion at busy hours of the day, such as morning and afternoon commutes. This is currently being used by the Colorado DOT. This system requires a fiber optic network (Williams, 2017).

Smart Traffic Signals

A smart traffic signal is a traffic light that utilizes V2I communications to detect approaching vehicles. This improved signal would optimize traffic flow by eliminating unnecessary stops and reducing congestion. It would also reduce the likelihood of a collision due to an improper turn. Because this solution would require smart vehicles which have not yet been made widely available, this solution is not currently being used anywhere in the United States. This solution will not be available until further development of V2I technology (Silva, 2015).

3.1.2 Data Collection

Bit Carrier

A bit carrier is a sensor that can detect Bluetooth signals. These signals transmit data such as the number of vehicles and their average speed. It provides real time traffic and road monitoring and can immediately inform officials of traffic jams due to accidents. The bit carrier does not help prevent accidents, but does improve response time in the event of an accident by relaying accurate data to the DOT. They are not currently being used in the United States but have been applied in Spain (Traffic Technology in Spain, n.d.). There have been some concerns about the security of bit carriers because they use Bluetooth, which has poor security, to communicate.

Density Monitor

A density monitor is a device capable of determining traffic density on a roadway. The monitors could help provide accurate AADT numbers for the DOT. They are currently being used in Turkey (Ozkurt, 2009).

Section Speed

Section speed operates by capturing the position of a vehicle at two locations on a roadway. It then uses this information to calculate the speed the vehicle was going between these two points. Section Speed, when paired with a variable speed limit sign, can help to regulate the speed of traffic by decreasing congestion and reducing accidents caused by excessive speed. Alone, section speed could be used to collect data on the number of cars on a road and give the DOT accurate AADT numbers (Traffic Technology in Spain, n.d.). This technology is currently being used by the NMDOT.

RWIS

Roadside weather information systems, or RWIS, measure weather conditions in a given area. This information is then sent to the DOT for use in conjunction with technologies such as variable speed limits. RWIS has been implemented by the NMDOT as well as other state DOTs. This technology requires fiber optic cable to convey the information to the DOT (Boselly, 1993).

Smart Work Zones

Smart work zones include portable Bluetooth sensors and non-intrusive traffic sensors to collect real time data. These sensors can be found in objects such as traffic cones. The purpose of this is to collect traffic data surrounding work sites for the DOT. They are currently being researched by the Colorado DOT (Revision of Section, 2017).

Remote Traffic Microwave Sensor

A remote traffic microwave sensor is a traffic sensor that uses microwaves to detect vehicles. This differs from normal sensors because it is able to detect stationary vehicles by continuously modulating a transmitted frequency. It can be used to collect data such as the number of cars and their average speed, which could provide the DOT with accurate traffic data. It is currently being used by the New Mexico and Colorado DOTs (RTMS, n.d.).

Social Media Applications

Social media can be used to gather information about accidents and crashes faster than is currently possible. Applications such as Waze collect user submitted data in order to inform drivers about crashes along the driver's route. It is possible to partner with Waze, gaining access to this information under the condition that the DOT submits the crashes it detects to the Waze system (Butler, 2011).

Cellular Partnerships

Many of the above solutions require the communication of information to the DOT to be effective. Much of New Mexico does not have cellular service which restricts the types of ITS solutions that are implementable. One way to fix this is to form partnerships with third party cellular network providers. This contract would require the DOT to give permission to a cellular provider to build along the side of the road. In exchange for this the DOT would have access to any fiber optic cable the company installs. This has already been done by the Colorado DOT (Williams, 2017).

Transit Signal Priority

Transit signal priority would include sensors placed on stop lights that detect public transportation vehicles approaching an intersection and adjust signal times to allow the vehicle through. This solution does not stop accidents from happening, but helps to minimize congestion due to large transit vehicles and makes public transportation more efficient (Benefits of Intelligent Transportation Systems, n.d.). This could also be applied to emergency response vehicles to decrease response time and the chance of a secondary accident. This requires V2I technology and is currently being used by USDOT.

3.2 Objective 2: Hotspots

The second objective of our project was to identify and analyze hotspots. We found 17 hotspots in Districts 3 and 5 in New Mexico. We visited ten of these 17 hotspots. The other seven we were not able to visit because of their distance from both Albuquerque and Santa Fe. At the end of our project, we developed a new method of identifying hotspots using an ArcGIS map. This map identifies hotspots based on the number of crashes and AADT statistics. We have provided this map to the DOT as a deliverable (Figure 7). An explanation of this map can be found in Appendix C.



Figure 7 Example of Heatmap Generated in ArcGIS

3.2.1 Intersection of Coors and I-40



Figure 8 Picture from Google Earth of the Coors and I-40 Intersection (Google Earth, 2017)

There are nine fatal crashes in and around the intersection of Coors Blvd and Interstate 40. Five of these accidents were caused by DWI, two were caused by pedestrian error, one was caused by swerving, and one was caused by excessive speed. We determined the cause of these accidents to be similar because more than half of them were caused by DWI which may indicate a larger problem with the roadway. From our interview with Nancy Perea, we learned that this intersection is located near one of the major river crossings that links the residential and business districts of Albuquerque. Both roadways contain heavy traffic in the mornings and evenings as people commute from the western residential communities of Albuquerque to the eastern business districts. During our site visits with our liaison, we learned that the lanes leading to the Coors Blvd exits back up onto the highway as seen in figure 6. The highway already contains a large number of cars attempting to pass through the area, so the ramp backups coupled with vehicles attempting to pass through the intersection result in congestion. Because of the traffic congestion, another problem arises. When drivers attempt to move out of congested lanes into faster moving leftmost lanes, failure to yield to the right of way accidents are more prevalent. These accidents are often severe due to the relative speed difference of the vehicles.

3.2.2 Intersection of I-25 and I-40, “The Big I”



Figure 9 Intersection of I-25 and I-40 (Google Earth, 2017)

The intersection between Interstate 25 and Interstate 40, nicknamed the “The Big I”, has the highest average daily traffic of any road in Albuquerque. Spanning only one and a third of a mile on I-40 and a third of a mile on I-25, there have been 11 fatal crashes resulting in fifteen fatalities at this intersection. Six of these were caused by a DWI, two were caused by drivers disregarding a traffic signal, one was caused by excessive speed, one was caused by a failure to yield, and one was caused by driver inattention. We determined the cause of these accidents to be similar because over half of them were caused by DWI, which may indicate a larger problem with the roadway. From our site visit, we learned that there was a large number of lanes merging onto the highway over a short distance on I-40. The merging traffic has to navigate through five congested lanes in order to integrate into the traffic flow. Traffic already on the freeway is attempting to merge onto I-25 southbound, a single lane exit, and traffic entering the freeway must navigate through, creating a dangerous traffic weave.

3.2.3 Intersection of Rio Grande and I-40



Figure 10 Intersection of Rio Grande and I-40 (Google Earth, 2017)

This hotspot was identified during our interview with the District 3 engineers. While it contains only one fatal crash, caused by driver inattention, there are 163 non-fatal injury crashes.

Similar to many of the other hotspots in this area, the road is congested during the morning and evening rush hours. The on ramp often becomes backed up during these times going so far as to impede traffic on Rio Grande. There is a traffic light managed intersection at the bottom of the off ramp for Rio Grande Blvd. This traffic signal causes stand-still traffic to back up onto Interstate 40. The traffic overflow cuts off the rightmost lanes on I-40, limiting the capacity of the interstate.

3.2.4 Route 68 Mile Markers 32-33, “The Horseshoe Curve”



Figure 11 Route 68 Mile markers 32-33 (Google Earth, 2017)

This hotspot encompasses a large, horseshoe shaped curve on Route 68. The roadway increases and decreases in relative elevation as it proceeds through a small valley. Although ArcGIS did not indicate any weather related accidents, the curve is marked with a traffic sign warning drivers about ice. According to ArcGIS, two fatal accidents occurred on this stretch between 2010 and 2015. During our site visit, we took note of multiple memorials for individuals involved in fatal crashes, some of which were from before or after our data set. We also noted alcoholic beverage containers on the side of the roadway, which we assumed was litter from passing cars.

The curve is well marked with standard roadway signs, but if navigated carelessly, the roadway becomes dangerous. One of the fatal accidents on ArcGIS was a head-on collision. A vehicle travelling southbound had travelled over the center line, striking oncoming northbound traffic. The second fatal crash listed the top contributing factor as “none,” so a cause for the accident could not be determined from the software.

Our team drove through the location during poor weather conditions, and the safest speed we felt comfortable travelling was 15 mph under the speed limit. During this trip, several other cars passed us despite the low visibility due to rain and fog.

3.2.5 Route 68 Mile Marker 6-8



Figure 12 Route 68 Mile Marker 6-8 (Google Earth, 2017)

This hotspot is located adjacent to Alcalde, NM. The median of the roadway, between the north and southbound lanes, is characterized by a significant grade change. The two northbound lanes are about two feet higher than the southbound lanes. Tim Brown informed our team that the roadway was originally the same grade. Over time, repaving the roadway led to the significant grade difference.

One of the six fatal accidents recorded in this hotspot was caused by failure to yield to the right of way. Based on the design of the roadway, this accident could have occurred because of a driver trying to enter the highway from a side street or cross the southbound lanes. We investigated the intersection of NM-68 and State Highway 389, and found that cars obeying the stop sign and stopbar had an obstructed view of traffic travelling southbound on NM-68. The roadway signs on NM-68 create a blind spot for traffic trying to merge onto the highway. The blind spot could cause a failure to yield to oncoming traffic.

The rest of the six fatal accidents were caused by DWI. The close proximity of the six fatal accidents, although DWI related, led our team to believe that there was a problem in the roadway itself. Upon visiting the hotspot, we noticed the Okhay Casino was located about four miles south of the location. We cannot determine the role that the Casino played in any of the DWI crashes at this time.

3.2.6 Route 291 Mile Marker 2-3



Figure 13 Route 291 Mile Marker 2-3 (Google Earth, 2017)

The hotspot on Route 291 is a one mile long, single lane section of road located between Espanola Valley High School and the Okhay Casino. There were four fatal accidents on the road between 2010 and 2015. All four of these accidents were drug or alcohol related. While visiting the hotspot, we noted the large number of “descansos”, or roadside memorials, along the road. All four fatalities are listed as drug or alcohol related accidents.

The pavement of the roadway is in poor condition, but is not inherently dangerous. There is a large, gravel shoulder on both sides of the road. We do not believe this to be a contributing factor to the cause of the accidents at this location. The speed limit is posted at forty-five miles per hour, which Tim Brown considered suitable for navigating the roadway during the daytime.

Route 291 is a rural road, lacking streetlights and signage around curves. Drivers navigating the roadway at an unsafe speed after dusk may have difficulty staying on the road.

3.2.7 Route 599 Mile Marker 6-7



Figure 14 Route 599 Mile Marker 6-7 (Google Earth, 2017)

This hotspot is located on NM-599 near the South Meadows Road overpass. The two fatal accidents recorded at this location took place prior to the construction of the overpass. Originally, NM-599 was at grade with South Meadows Road, resulting in an intersection. According to Tim Brown, the construction took place recently, within the time period of our crash data.

After reviewing the hotspot during our site visit and learning about the construction that altered the intersection, we revisited the hotspot on ArcGIS and found that the dates of the fatal accidents that occurred on the roadway took place in 2011, and no fatal accidents have occurred at the location since that year. Additionally, both of the fatal accidents were caused by a failure to yield to the right of way. These accidents took place at the intersection of South Meadows Road and NM-599, which no longer exists due to the construction of the overpass.

3.2.8 Cerrillos Rd Mile Marker 50-52 (NM-14)



Figure 15 Cerillos Road Mile Marker 50-52 (Google Earth, 2017)

Cerrillos Road, also known as NM-14, is a busy roadway in southern Santa Fe. The road is predominantly a three lane divided highway, but both the northbound and southbound directions have additional turning lanes to access businesses along the roadway. The northbound side of the roadway also has a bicycle lane integrated with the three traffic lanes. NM-14 is intersected by four roadways. In the one mile long hotspot we located, there are four traffic lights managing four-way intersections located at Siler, Camino Carlos Rey, Camino Consuelo, and Calle del Cielo. All four fatal accidents in this location were caused by DWI, which may indicate a problem with the roadway.

During the work commute, NM-14 becomes a very congested area. We visited the hotspot at approximately 2 P.M. on a weekday, and traffic had already begun to back up. We noted a rear-end accident within the hotspot that occurred during our visit.

3.2.9 I-40 Mile Marker 221-258



Figure 16 I-40 mile Marker 221-258 (Google Earth, 2017)

This hotspot is unique because it is much larger than the other hotspots, covering a total of thirty seven miles of I-40 and containing eighteen fatalities. These crashes are split fairly evenly between DWI, mechanical failure, inattentive driving, and excessive speed. However, ten of these accidents are listed as weather-related. During a conversation with our liaison, we confirmed that the section of I-40 in question often had weather related accidents. From our online research we found that the section of freeway was long and straight with few noticeable problems. We did not visit this hotspot because of its distance from both Albuquerque and Santa Fe.

3.2.10 US 550 between NM 528 and I-25



Figure 17 US 550 Between NM 528 and I-25 (Google Earth, 2017)

The hotspot located on US-550 is one of the eight bridges crossing the Rio Grande. The hotspot is 2.2 miles in length and was the site of six fatal accidents, resulting in a total of six deaths. Two of these were caused by failure to yield, two were caused by DWI, one was caused by swerving to avoid, and the cause of one is unknown and marked as ‘other’. We determined the causes of accidents were similar because half of them were a result of drivers attempting to change lanes.

The location is currently under construction to alleviate the problems on the roadway. The construction does not include any installation of ITS technology, but includes significant geometric fixes to the roadway. The bridge on the roadway will be demolished and replaced by a new bridge with two additional lanes, relieving the congestion resulting from the morning and afternoon work commutes. The shared turning lane in the middle of the roadway will be removed to eliminate potential head-on collisions.

3.2.11 Coors Blvd between Kirsten Road and Don Felipe



Figure 18 Coors Blvd Between Kirsten Road and Don Felipe (Google Earth, 2017)

This hotspot is located on Coors Boulevard between the intersections of Kirsten and Don Felipe and is 0.19 miles long. Two fatal accidents were identified at this location, resulting in a total of two deaths. One of these was caused by failure to yield and the other by an improper turn. We determined the cause of these accidents to be similar since they both are the result of drivers turning and impeding normal traffic flow.

The location is a two lane divided highway with a turning lane separating the opposing directions. It has a speed limit of 55 mph. We did not visit this location because we located it after we had completed our site visits in Albuquerque and did not have time to go back.

3.2.12 Historic Route 66 (NM-333) Mile Marker 14-16



Figure 19 Historic Route 66 Mile Marker 14-16 (Google Earth, 2017)

NM-333 is a two mile long stretch of roadway on which four fatal accidents occurred from 2010-2015. The roadway consists of a single lane in both directions, and contains a four way intersection managed by a stop sign. Only three accidents at this location had a top contributing factor listed in ArcGIS, and the fourth was marked as “other”. The causes were excessive speed, DWI, and driver inattention.

Upon visiting the location, we could not determine a common hazard that would have caused the hotspot. A driver’s vision would not be hindered in any way while at the intersection, and visibility on the roadway was excellent. There are no curves or other dangerous features within the hotspot.

3.2.13 Shiprock Intersection of US 491 and US Hwy 64



Figure 20 Shiprock Intersection of US 491 and US Highway 64 (Google Earth, 2017)

This hotspot is located near Shiprock at the intersection of US 491 and US Highway 64. It is three miles long and was the location of six fatal accidents resulting in seven total deaths. Four of these accidents were caused by DWI, one was caused by pedestrian error, and one was caused by an improper lane change. While most of the accidents at this intersection were caused by DWI, we still considered it a hotspot because the concentration of fatal accidents in one location may be an indication of a larger issue with the roadway.

The intersection is a two lane divided highway with two stoplights. We were not able to visit this location because of its distance from both Santa Fe and Albuquerque.

3.2.14 Route 64 Mile Marker 24-30, Shiprock Intersection



Figure 21 Route 64 Mile Marker 24-30 (Google Earth, 2017)

Route 64 between mile markers 24 and 30 near Shiprock was the site of six fatal accidents resulting in a total of seven deaths. It is 5.6 miles long. Four of these accidents were DWIs, one was caused by following too closely, and the cause of one is unknown and marked as

“other”. Like the other Shiprock hotspot, while a majority of the accidents at this location are DWIs, we believe it may indicate a larger problem with the roadway.

Route 64 is a two lane divided highway. We were not able to visit this location because of its distance from both Santa Fe and Albuquerque.

3.2.15 Farmington Pinon Hills Blvd between N Dustin Avenue and Daybreak Drive



Figure 22 Farmington Pinyon Hills Blvd Between North Dustin Avenue and Daybreak Dive (Google Earth, 2017)

This section of Pinon Hills Blvd in between North Dustin Avenue and Daybreak Drive is 0.72 miles long and is the site of three fatal accidents resulting in a total of three deaths. All three of these accidents were caused by failure to yield to the right of way.

This road transitions from one lane to two lanes and vice versa depending on the direction. There are also several significant intersections controlled by only stop signs on this 50 mph road. We were not able to visit this location because of its distance from both Santa Fe and Albuquerque.

3.2.16 W Broadway Ave between Church St and 3rd St, Bloomfield



Figure 23 West Broadway Ave Between Church Street and 3rd Street (Google Earth, 2017)

The area around mile marker 64 on West Broadway Avenue in Bloomfield is a 0.56 mile stretch that is the site of three fatal accidents resulting in three total deaths. Two of these accidents were caused by failure to yield and the other was caused by pedestrian error. We determined these accidents were similar because two out of the three of them were caused by failure to yield.

Two of these accidents occurred prior to the road being out under construction. We did not visit this location because of its distance from both Santa Fe and Albuquerque.

3.2.17 I-40 Mile Marker 192-198, Moriarty



Figure 24 I-40 Mile Marker 192-198 (Google Earth, 2017)

I-40 between mile markers 192-198 is the site of seven fatal car accidents resulting in seven total deaths. Four of these accidents were caused by driver inattention, one by excessive speed, one because of a DWI, and the cause of the last accident is unknown. We decided that the accidents were similar because half of them had the same cause: driver inattention.

This section of I-40 is a two lane divided highway with an overpass and on ramps. It is the intersection of I-40 and Howard Cavazos Blvd. We were not able to visit this location because of its distance from both Santa Fe and Albuquerque.

3.2.18 Considerations

A common theme we noticed throughout our project was that some of the data on ArcGIS was not sufficient to allow us to identify causes and potential solutions for all hotspots. Many of the accidents we encountered on ArcGIS had their main cause listed as ‘other’, so we could only speculate as to why the accident occurred. Additionally, the cause of the accident would change depending on which individual was killed in the collision. For example, consider the case of a drunk driver making an improper left hand turn and causing an accident with a vehicle travelling along the roadway. While both cases would indicate in ArcGIS that alcohol was involved, if the drunk driver died in the collision the cause of the accident would be listed as ‘DWI’, and if the other driver died the cause would be ‘failure to yield’. Cases such as this made it difficult to determine what the primary cause of the accident actually was.

We also noticed other discrepancies with ArcGIS data. For example, we only identified two fatal accidents on NM-68 MM 32-33, but a quick google search of the location had showed a news article that stated, “the "horseshoe" curve, located between mile markers 32 and 33 – which has recorded approximately 15 fatalities since 2010” (Matlock, 2017). While we only have data recorded through 2015 and this article was published in 2017, it is unlikely that 13 fatalities happened in the past two years after only two occurring in the previous five. We are unsure of the reason for this discrepancy.

The data on ArcGIS also does not always tell the entire story. We believe this is the case for the NM 291 mile marker 2-3 hotspot. This location was the site of a significant number of DWI accidents, but the road itself did not seem to have any immediate problems with it. In researching this location further, we found that one of the accidents was caused by a heroin-induced police chase, and that the location has been reported for instances of drag racing (Grammer, 2010). We would have never known this information about the site based on DOT resources alone.

At this time, we cannot provide any recommendations on how to resolve this lack of information. The DOT gets their traffic reports from the state police, who recently updated the way they report crashes. The 2015 data already provided much more detail than the 2010-2014 data, for it includes information about the crash such as time of day it occurred, more accurate location data, information on the road grade, lighting, weather, and crash direction. We believe that new data the NMDOT receives will be more complete than the data that we worked with for this project.

3.3 Objective 3: Recommended Solutions

Part of our third objective was to pair hotspots with ITS solutions. For each hotspot we considered all of the information we had gathered about each location, including the common causes of accidents in the area as well as information we gathered from our liaison. We only recommended ITS solutions for locations we visited with the exception of I-40 mile markers

221-258. Hotspots that we visited but did not recommend ITS solutions for are also explained below.

Some accident types are better addressed by ITS solutions than others. ITS solutions work best when applied to hotspots caused by traffic congestion or weather. Accident types such as failure to yield or swerving are indicative of these causes, as they often would not have happened without outside influences such as congestion or weather.

ITS solutions do not work for all causes of accidents. ITS solutions are less effective when dealing with causes such as driver inattention or DWI. The current method for addressing these situations is to try to provide information to other drivers on the road so they may avoid the impaired driver. The problem with this solution is that it is difficult to inform drivers soon enough that they have time to adjust for the anomalous vehicle. In the future these notices can be projected directly into the car, giving much earlier access to safety information.

As of right now, these issues are best addressed by law enforcement, and initiatives such as ENDWI (End DWI). In the 2015 fiscal year, a total of 1,532 DWI arrests were made by state police during ENDWI Winter Superblitz, and several Miniblitz activities. These programs are overtime enforcement initiatives, which take place during holidays such as the Fourth of July. Although these programs are specifically designed to crackdown on DWI, participating State Police officers also issue citations for violations such as speeding and cellphone use (Hall, 2015). These programs are successful in addressing accident-causing driver behaviors that are not currently addressable via ITS technologies.

For our project, we only recommended solutions for sites with accident causes that would be resolved through the implementation of ITS.

3.3.1 Intersection of Coors and I-40

We determined that the cause of accidents in this area was excessive speed in through lanes during times with high congestion, making it dangerous for cars to leave the backed up lanes. This decision was based on the types of crashes in the intersection as well as our interviews with District 3 traffic engineers. Since we deduced that the main cause of accidents at this location was congestion, we chose to recommend variable speed limits. A variable speed limit connected to sensors on the highway would allow the NMDOT to control the speed of cars, adjusting the speed limit during peak traffic. This will make it safer to change lanes in this intersection. In order for the variable speed limit sign to work properly, a section speed and density monitor would also need to be installed as well. These sensors will help to determine how congested the road is and if the speed variance between vehicles.

1. We recommend the NMDOT apply a variable speed limit, section speed, and density monitor to the Coors/I-40 location.

3.3.2 Intersection of I-25 and I-40, “The Big I”

At the intersection between I - 40 and I - 25, also known as “The Big I,” we found that there was a large number of new lanes merging onto the highway over a short distance, making it difficult to cross from one side to the other safely. Since most of the accidents were congestion related, we determined that an overhead lane management system would address this location. The system would show the following information for each lane: Its destination, how congested

it was expected to be, and a recommended speed. This would help drivers to make more informed decisions. However, it is possible this solution would cause drivers to be less accommodating to cars attempting to merge, leading to even more problems. Another concern is that drivers may be distracted by the signs and not focus on driving. Another possible solution would be to implement ramp metering which would decrease the number of cars in the intersection at any given time.

2. We recommend the NMDOT apply a lane management system and/or ramp metering to the Big I location.

3.3.3 Intersection of Rio Grande and I-40

From our visits and research, we determined that traffic on I-40 was heavily congested near the Rio Grande exit, while the traffic from Rio Grande was at a standstill trying to get access the interstate. To solve this, we propose implementing ramp metering to decongest I-40, along with smart traffic signals that give more or less green time depending on the time of day to reduce the backup of vehicles onto I-40.

3. We recommend the NMDOT apply ramp metering for I-40, and smart traffic signals on Rio Grande NW.

3.3.4 I-40 Mile Marker 221-258

Along I-40 there are several weather related accidents, which we believe would benefit from an adjustable speed limit sign connected to a weather station. In order for the smart speed limit to work, a section speed and roadside weather information system would also have to be installed so NMDOT officials could be informed about both the average speed cars are travelling and the weather conditions in the area. This has recently been applied in Colorado for the same reason.

4. We recommend the NMDOT apply a roadside weather information system, section speed, and weather-influenced smart speed limits to the I-40 MM 221 -258 location.

3.3.5 Route 68 Mile Markers 32-33, “The Horseshoe Curve”

Because of the sharp curves, shape of the road, and conditions we saw while driving, we believe that this section of road would benefit from weather influenced smart speed limits, supplemented by RWIS and section speed. An alternative solution would be to use a radar speed monitor, which would encourage drivers to slow down if they were speeding.

5. We recommend the NMDOT apply a roadside weather information system, section speed, and weather-influenced smart speed limits, or a radar speed monitor to the NM-68 MM 32-33 location.

3.3.6 Route 68 Mile Marker 6-8

Because of the nature of the accidents that occurred on this road and the state of the road itself, we do not believe we can recommend an ITS solution at this time. Five of the six accidents at this location were DWIs, and we believe that may related to the location's close proximity to a casino. Additionally, we observed that the road is not level in this location and believe that this is a contributing factor to the severity of these accidents, as one of them is marked as a rollover. While there are no ITS solutions that would significantly improve the road, we do believe that once the road is resurfaced at a level grade it will be safer to drive.

3.3.7 Cerrillos Road (NM-14) Mile Markers 50-52

Our team recommended smart traffic signals to address the congestion and associated accidents on Cerrillos Road. The signal timing along the roadway is inefficient, and our vehicle was stopped after short periods of driving, sometimes stopping at multiple red lights in a row. This many delays may cause driver aggression and road rage. Cerrillos Road has a significantly higher AADT than other side roads. Giving vehicles on this roadway priority would increase traffic flow with little effect on the intersecting streets. Cerrillos Road has an average AADT of about 40,000, and the highest AADT of any intersecting road is 14,000.

6. *We recommend the NMDOT integrate smart traffic signals along the Cerrillos Road location.*

3.3.8 Historic Route 66 (NM-333) Mile Marker 14-16

Since this location is a well maintained road with full visibility, we chose not to recommend an ITS solution for this location. All four of the accidents at this location were caused by human error. Although we cannot recommend an ITS solution for this location, we believe that the installation of rumble strips on the centerline as well as on the lane lines would help to prevent accidents at this location, because they would alert drivers when they begin to depart from their lane.

3.3.9 Route 291 Mile Marker 2-3

Our team was unable to recommend an ITS solution to this area, as we were unable to identify an underlying cause of accidents. With this in mind, we recommend installing a CCTV camera at this location to give the NMDOT a better idea of what is occurring at this hotspot. There have been reports of drag racing and drug use at this location. While the installation of a CCTV camera would not prevent any accidents caused by these factors, it would improve the response time to accidents that occur. Similarly, we recommend that the NMDOT alert the local police about this location so it can be more strictly patrolled, and dangerous behaviors can be stopped before they lead to a fatality. We also noticed that there were very few lights along the road. We believe that that installation of smart road lights, which increase intensity when a sensor attached to them detects the presence of a vehicle, would help light up the road and increase visibility.

3.3.10 Route 599 Mile Marker 6-7

Because of the recent construction and the lack of fatal accidents after the roadwork concluded, we did not see the need to recommend the installation ITS solutions at this location. We believe that the installation of an overpass, which eliminated the Rt. 599 and South Meadows Rd intersection, has resolved the hotspot.

3.3.11 Outside Influences on Accidents

Through our research and fieldwork, we discovered two addressable accident influences. These influences, weather and congestion, lead to increased crash frequency. For example, roadway congestion restricts a driver's ability to perform simple traffic movements that would be easily completed on open roadways. Movement on the roadway becomes more dangerous, and lack of communication between drivers leads to accidents.

Traffic congestion results in several specific types of crashes. Through our analysis of accidents using ArcGIS, we found that common causes of accidents in congested areas are following one another too closely, failure to yield to traffic travelling in adjacent lanes, and excessive speed. We addressed traffic congestion with ramp metering, variable speed limits, and remote lane management.

Our team's most common recommendation in regards to congestion related hotspots was ramp metering. This solution regulates the number of automobiles entering a freeway via an onramp at any one time, therefore limiting the number of vehicles attempting to enter the flow of traffic. Cars already on the freeway do not have to adjust their speed to allow a large number of automobiles to merge, which prevents slowdowns and allows the traffic to maintain a reasonable speed.

Variable speed limits are another solution to reduce congestion. The solution makes it possible for the DOT to adjust speeds on a roadway to better suit the current conditions. Since congested roadways often have large speed variance between vehicles, adjusting the speed limit would minimize the difference and reduce the potential for severe accidents.

Lane management is another ITS solution that allows a DOT to adjust the roadway to real time traffic conditions. The CDOT utilizes remote lane management to open roadway shoulders as additional lanes, increasing the capacity of the roadway (Williams, 2017). The solution improves traffic flow, reduces congestion, and allows for safer travel.

Weather also influences car accidents. Poor visibility on roadways due to conditions such as fog, rain, and snow increases the chance of an collision. The main accident types that result from these weather conditions are failure to yield to the right of way, excessive speed, and driving left of the center line. A some of the ITS solutions that can help prevent weather related accidents are variable speed limit signs, radar speed monitors and weather stations. A weather station in the area would help organizations such as the DOT warn drivers of incoming storms and give them the chance to avoid the storm all together. The DOT could also use these stations to adjust variable speed limit signs, lowering the speed limit in areas where road conditions are poor. This would give drivers more control over their vehicle in conditions such as ice and rain.

3.3.12 ITS and Human Error

As previously stated, a common theme we encountered throughout our project is that ITS solutions are not well suited to address accidents caused by human error. Specifically, out-of-vehicle ITS solutions cannot address DWIs and driver inattention. Ken Martinez, the director of

the Regional Emergency Communication Center in Santa Fe County, explained that he has seen an increase in the number of accidents caused by driver inattention in the past few years due to the rise of cell phone use (Martinez, 2017).

While many cell phone apps, including NMRoads, require users to click on an icon stating a phrase along the lines of, “I am not currently driving”, it is very easy for drivers to bypass this and is often simply done on an honors system. Apple is currently moving towards a system that discourages the use of cellphones while driving. The software update, iOS11, includes a “do not disturb while driving” feature, which allows users to turn off notifications while they are operating a motor vehicle. However, this requires drivers to voluntarily turn the feature on. One idea our team had for decreasing the amount of cell phone use while driving was a system that would involve a driver plugging their phone into their vehicle while it was in operation. The vehicle would “lock” the phone, so drivers would not be able to access it while driving.

We brought up this idea to Ken Martinez, who indicated that some individuals may see the locking of their cell phone while driving as an invasion of rights and their private property. We then adjusted this idea that these “cell phone locks” would only be required for repeat offenders caught using their cell phones while driving. Martinez believed more people would be open to this idea (Martinez, 2017). This is similar to the idea of alco-lock devices, or a device that will not allow the vehicle to operate until the driver passes a breathalyzer test. Alco-lock devices are sometimes required for repeat DWI offenders. A limitation of this suggestion is that the NMDOT would not be able to implement it alone. It would require collaboration with both lawmakers and vehicle manufacturers. For this reason, we are unsure of the feasibility of this suggestion.

We believe that the number accidents caused by driver inattention will dramatically decrease with the implementation of semi-autonomous and autonomous vehicles. However, until the use of these vehicles is widespread, this potential technology may be able to decrease the use of cellphones while driving and therefore the number of fatalities caused by driver inattention.

3.3.13 Recommendations for The Future of ITS

The future of road safety and Intelligent Transportation Systems is swiftly changing. The focus of the field is shifting from how we can use roadside technology to inform individuals about upcoming danger to how vehicles themselves can be used to inform drivers. Connected technologies, such as V2V and V2I, are predicted to be the next step in accident mitigation and avoidance. Soon, vehicles will be able to take part in two way communications via DSRC technology.

Estimates of when connected vehicle technologies will be effective vary between professionals in the field. The use of connected vehicles will vary by geographic location, and may be delayed depending on the passing of Federal Motor Vehicle Safety Standard #150. The longest time estimate from the individuals we interviewed was from Tim Brown, our liaison. He believes that it will be approximately 20 years until the technology takes hold in New Mexico. Given even the longest timeframe, we feel as though connected vehicles would be the most effective solution for the elimination of traffic accidents.

Connected vehicle technology is a very flexible solution to traffic accidents, and is capable of various uses. Vehicle to infrastructure (V2I) communication technology is most suitable for the DOT while vehicle to vehicle (V2V) technology does not require any preparation

from the DOT. V2I technology requires trusted DSRC transmitters to be installed along roadways, while V2V technology will use DSRC radios already installed in private vehicles. Connected vehicles are also able to provide data in real time about road conditions, traffic speed, and traffic density to any DOT who utilizes roadside collection technology. Through the use of V2I, DOT messages displayed on DMS would be transmitted directly to a vehicle's dashboard rather than projected over the roadway. Speed limits could be relayed from roadside units (RSU) to the automobile itself. According to the USDOT, connected vehicle technology has the potential to prevent 76 percent of automobile accidents (Narla, 2013).

Interactions between DOT DSRC infrastructure and the radio contained within vehicles on the roadway are critical in order to take advantage of data. Ideally, the infrastructure will already be in place when the optimal number of connected vehicles are active. This means that preparation for the technology advancement must commence in the coming years. At this time, we are not able to provide any information on the placement of DSRC RSUs. Through our discussion with John Williams, we learned that testing of the RSUs is currently underway, and one major result of the testing will be the determination of how far each unit should be spaced (Williams, 2017). However, he was not able to tell us the method of testing for legal reasons, and therefore we do not know how the DOT should determine where to place these units.

One key part of the future of DOTs around the country is the growing importance of third party partnerships. These partnerships can be made with a variety of companies in order to accomplish different goals. For example, UDOT has partnered with cell companies, allowing them to lay fiber along roads under the condition that UDOT could use the fiber once it was in place. This allows them to place cameras along sections of road that they did not have access to previously. Another example of a possible partnership is the work Colorado DOT is conducting with research companies such as RoadX. CDOT pays RoadX to research new ideas in ITS. They are currently working on infrastructure that will work with smart cars. Both of these partnerships provide services that the DOT could perform themselves, however, the partnership has the potential to save both money and time in the long term.

At the start of our project, we set out to provide a framework the NMDOT could use to bring their ITS department into the future. We learned about connected vehicle technologies, and heard from sources that multiple states were researching V2V and V2I. We attempted to contact those states, learn more about what specific research was being done, and bring that information to the NMDOT. However, it was not that simple. This research is often being done by contractors hired by state DOTs, and therefore it is the intellectual property of those contractors. This means that state DOTs were not at liberty to go into detail about the cutting edge technology being researched by their contractors. For this reason, we are not able to recommend a framework for the NMDOT as we do not have the information to do so.

7. We recommend that the NMDOT begin research into the placement of DSRC Road Side Units to prepare for the implementation of V2I technologies.

For solutions in the ITS toolbox such as smart construction sites, social media partnerships, and network partnerships, we recommend that the NMDOT begin research into the feasibility of these projects. We recommend they start with partnerships, as they have the potential to be the most beneficial for the NMDOT in the near future. While smart construction

sites are not currently fully implementable, it is important that the NMDOT begins to prepare for these new technologies by researching where and what kinds of transmitters are required before the advent of smart cars.

8. We recommend that the NMDOT begin research into the feasibility of smart construction sites, social media partnerships, and network partnerships to best prepare for the future of ITS.

3.4 Conclusion

Over the course of this project, we collected ITS solutions into a toolbox, identified hotspots using ArcGIS, and proposed solutions to these hotspots based on our research into ITS solutions. The methods used by our team to identify hotspots can be replicated by other organizations and state DOTs. Additionally, our ITS toolbox can be used by DOTs all over the country as a resource for ITS solutions. Traffic safety is an issue in the state of New Mexico. It is above the national average for traffic fatalities per 100,000 population. Our project will help the NMDOT to decrease that number, and make New Mexico a safer state to drive in.

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Appendices

Appendix A: Interview with Out-of-State DOT Employees

This is an interview conducted orally with representatives from Out-of-State DOT representatives. The purpose of this interview was to learn more about what other state departments are doing in the field of ITS and if any of their initiatives have been successful in increasing traffic safety in their state.

Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with DOT officials to get a more in depth understanding of the data that we will be analyzing. This is a collaborative project between the DOT and we as WPI students. Our goal is to propose new ITS solutions to increase traffic safety in hotspots in New Mexico and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

Would you mind if we recorded this interview? May we use your name in our paper?

1. What are some of the larger issues your state has encountered in regards to traffic safety?
2. What types of ITS programs have you implemented, or thought about implementing, in response to these issues?
3. Have these programs been successful? What are some of their pros and cons?
4. How does the DOT adjust applied solutions when dealing with rural roads compared to metropolitan areas?
5. How do you address rural areas with poor connection?
6. How do you address areas of with poor weather conditions?
7. Have you used social media to obtain data for your department?
8. Has your state implemented any programs to improve response times to accidents?
9. Do any of the ITS solutions you've applied in your state have the primary goal of reducing fatalities?
10. What other programs do you see your department implementing in the future? Where do you see your department headed?

Appendix B: Interview with ITS Professionals

This is an interview conducted orally with professionals in the field of Intelligent Transportation Systems. The purpose of this interview was to learn more about research being conducted in the field of intelligent transportation and where the future of ITS is headed, as well as what solutions that are commonplace today can be used for.

Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with ITS experts to get a more in depth understanding of the data that we will be analyzing. This is a collaborative project between the DOT and we as WPI students. Our goal is to propose new ITS solutions to increase traffic safety in hotspots in New Mexico and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

Would you mind if we recorded this interview? May we use your name in our paper?

1. What ITS solutions are the current common practice?
2. Where do you see the industry in 10 years?
3. What type of ITS solutions do you see being researched right now?
4. What are some common communications based ITS solution?
5. What ITS solutions can be applied to specific locations?
6. Are there any ITS solutions that have the specific goal of reducing fatalities?

Appendix C: Step by Step Process to Make Hotspot Map with ArcGIS

Requirements:

- A. A computer with an ArcGIS account capable of performing analysis
- B. An AADT layer (in this example 2013)
- C. A collection of crashes with locations

Process:

1. Using the “Analysis” menu (a small map icon) as seen in figure 7 and navigate to the “Summarize Data” drop down menu at the top of the list.

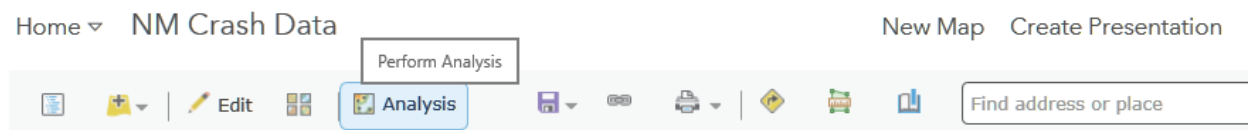


Figure 7 Location of the Analysis Function

2. From this list, open the “Summarize Nearby” option. This will add the number of incidents to the AADT layer.
3. The fields for this analysis are numbered 1-6 as seen in figure 8.
4. First set field 1 to the AADT layer.
5. Field 2 should be set to the crash information
6. Field 3 contains three parts part one should read “line distance” this will remain unchanged. The second and third will determine how far from the line the program will look for crashes, set values to “100 “and “feet”
7. Field 4 contains 2 fields the first should be set to “fatalities”, the second should be set to “counts”
8. Field 5 will remain blank
9. Field 6 will set the name of the new layer
10. Be sure to uncheck the small box at the bottom of the list, if you do not the analysis will only run for the portions of the map you can see now. A completed copy of this process can be seen in figure 8.


Summarize Nearby

1 Choose layer from which distances will be measured to features in the layer to summarize

New Mexico AADT 2013

2 Choose a layer to summarize

Motor Vehicle Crashes, New Mexico,...

3 Summarize nearest features using a


Line distance

100

Feet

To output multiple areas for each point, type sizes separated by spaces (2 3.5 5).

☒ Return bounding areas

4 Add statistics from the layer to summarize

☒ Count of points

Fatalities

Sum

Field

Statistic

5 Choose field to group by (optional)

Field

☐ Add minority, majority

6 Result layer name

New Layer

Save result in WPI 2016

☐ Use current map extent

[Show credits](#)

RUN ANALYSIS

Figure 8 Detail of the Summarize Nearby Form

11. Next, open the “Analysis” menu again.
12. Under the “Analyze Patterns” menu, open the “Find hotspots” entry.
13. This process has 4 fields.
14. The first field should be the layer you just made.

15. Field 2 is set to “count of points” with these points being the number of fatal crashes from the previous analysis.
16. Field three should be set to “AADT vn”. This will give the ratio between crashes and AADT
17. In the options drop down menu below figure 9 the distance band will determine how much distance from the road section is taken into account. This number should be very smallThis may be limited by the AADT layer. Experiment with values until you find the values that work best.
18. Field 4 sets the name of the new layer.
19. Again be sure to uncheck the box at the end of the list see figure 9 for example of completed process.

1

Choose layer for which hot spots will be calculated

i

New Layer

▼

2

Find clusters of high and low

i

Count of Points

▼

3

Divide by (optional)

i

aadt vn

▼

Options

i

Distance Band

i

100

Feet

▼

4

Result layer name

i

Hot Spots Count of Points

Save result in

WPI 2016

▼

☐ Use current map extent

Show credits

RUN ANALYSIS

Figure 9 Detail of Filled out Calculate Hotspot Form

Appendix D: Interview with Traffic Safety Experts

This is an interview conducted orally with traffic safety experts. The purpose of this interview was to determine what common causes of traffic accidents are and what behaviors lead to these causes of accidents, in addition to what solutions may help to eliminate these behaviors.

Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with traffic safety experts to get a more in depth understanding of the data that we will be analyzing. This is a collaborative project between the DOT and we as WPI students. Our goal is to propose new ITS solutions to increase traffic safety in hotspots in New Mexico and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

Would you mind if we recorded this interview? May we use your name in our paper?

1. What are the most common causes of fatal accidents?
2. Are there any trends in accidents that result in a fatality? I.e. collisions from behind, disregarding a stop light, etc.
3. What kind of roads do you most often see these accidents on? I.e. rural, metropolitan, etc.
4. What solutions can be put in place to eliminate these causes of accidents?
5. How does response time vary in areas that have poor connection? Are secondary accidents more likely to occur?
6. How long does it take to clear an accident on a rural road as opposed to a metropolitan one?

Appendix E: Interview with NMDOT ITS Engineers

This is an interview conducted orally with NMDOT Traffic Engineers. The purpose of this interview was to help us determine what traffic safety issues to focus on, as well as to learn what ITS solutions the NMDOT was already planning on implementing and what potential hotspots were already being addressed.

Preamble

We are a group of students from Worcester Polytechnic Institute in Massachusetts. We are conducting interviews with Traffic Engineers and New Mexico Department of Transportation's employees to learn more about the major causes of traffic accidents based on their experience on the roads. Our goal is to propose new ITS solutions to increase traffic safety in hotspots in New Mexico and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

If interested, a copy of our results can be provided at the conclusion of the study.

Would it be okay if we recorded this interview? May we use your name in our paper?

1. What are some common causes of fatal accidents in New Mexico?
2. What is NMDOT currently doing to alleviate these problems?
3. Do you have any ideas as to other ITS Solutions NMDOT should put in place?
4. Are there any areas within your jurisdiction that have a high number of fatalities?
5. Why do you believe these locations have such a high number of fatalities?
6. Is there anything you do in these locations to decrease the number of deaths?
7. What projects are being conducted in your district?

Appendix F: Interview Table

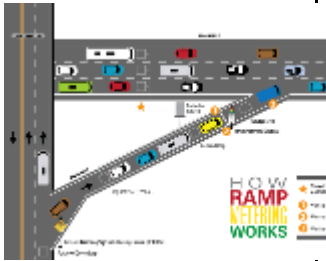
This table contains all of the people we interviewed over the course of the project as well as their title

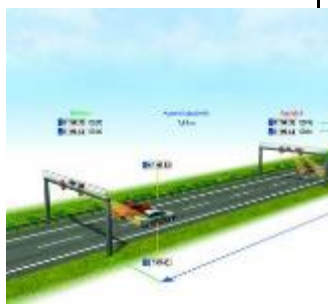
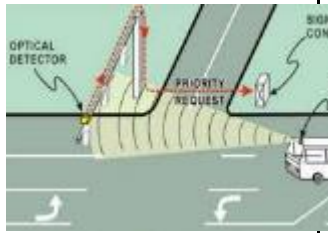
Interview Log

Interviewee Name	Date	Title of Person
Michael Knodler Jr.	9/8/17	Associate professor at UMass Amherst, Director of Traffic Safety Research Program UMass Amherst
Nancy Perea	9/11/17	Traffic Engineer District Three
Margaret Haynes	9/11/17	Assistant Traffic Engineer District Three
Jill Mosher	9/11/17	Assistant District Engineer District Three
Blaine Leonard	9/13/17	ITS program Manager for UDOT
Ken Martinez	9/14/17	Director of Santa Fe Regional Emergency Communications Center
Jesus Martinez	9/18/17	Principal Engineer of Transportation management systems section of Southwest Research Institute
John Williams	9/27/17	Technology Manager - Information Technology Professional V. for CDOT

Appendix G: ITS Toolbox

A compact list of all solutions researched in this project.

Radio notices		Radio stations give their regular traffic reports to communicate to drivers where traffic is and possible routes to avoid it, with the goal of reducing congestion in already busy area	Gives Driver More Information	NMDOT
Variable Message Signs		Digital signs that display messages to drivers about upcoming accidents or warnings about hazards ahead. Can be either mobile or permanent and messages can be changed to fit situation of road ahead.	Gives driver more information	NMDOT
Red light cameras		Cameras take front and back photo of car that sensor picks up running a red light.	Gathers information at red lights decreasing response time and secondary accidents	California DOT
Arizona Wrong Way Driving		Uses infrared cameras to detect wrong way drivers. After the automobile is identified travelling the wrong direction, the DOT would utilize other technologies to inform drivers and law enforcement. A supplemental technology would be DMS.	Wrong way driving collisions	Arizona DOT
Ramp Metering		Traffic signals installed on freeway on-ramps to help control the rate at which cars enter the freeway based on the volume of traffic in order to decrease congestion on the freeway.	Merging, congestion	Colorado DOT

Section Speed-		Technique works by capturing a car's position first at one location, then at a second down the road, calculating the speed the vehicle took to get from A to B.	congestion(when used alongside variable speed), speeding	NMDOT
Variable Speed Limits		Digital speed limit sign that can be changed from a control station to help drivers adapt to road conditions such as rain or snow. Certain systems use technology like section speed to calculate the average speed of cars on a stretch of road and make that the speed limit to avoid major differences in speed between drivers.	Speeding, congestion	Utah and Colorado DOT
Transit Signal Priority		Uses sensors to detect transit vehicles, such as a public bus, approaching an intersection and adjusts signal times to improve transit times and performance.	Congestion, response time	USDOT
Bit Carrier		Sensor can be hung from a traffic light that picks up Bluetooth signals, collect data on the number of vehicles and average speed. Can alert immediately a traffic jam due to accidents. Real time traffic and road monitoring	Helps to decrease response time in case of an accident and will give accurate data to DOT	Spain
Density Monitor		A device capable of determining traffic density on a roadway	Will give DOT accurate AADT Numbers	Turkey

Radar Speed Monitor		A sign that shows the fixed speed limit as well as the driver's current speed	Excessive speed	NMDOT
Lane Management		Overhead digital signs indicate whether a lane is open or closed depending on road conditions and congestion. Shoulder of road can be opened using a digital sign to open up another lane and provide additional capacity during times of congestion. There is a slight reduction in speed	Congestion	Colorado DOT
Remote Traffic Microwave Sensor		Also known as a side-fired radar, this device is capable of collecting information on volume, interval lane speed, occupancy, and class of vehicle.	Decrease response time, data gathering	Colorado DOT (researched)
Smart Work Zones		Help collect real time data and help to alert drivers of traffic delays or stopped conditions through the use of portable Bluetooth sensors and Portable non-intrusive traffic sensors.	Congestion	Colorado DOT (research)
Smart traffic signals		Traffic light which utilizes V2I communications, and can detect approaching vehicles. The signal would optimize traffic flow by eliminating unnecessary stops.	Congestion T-Bone	Currently being researched