Fog Related Crashes

Statewide Study of Fog Related Crashes in North Carolina

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July 2013

Executive Summary

The state of North Carolina was cast in the national news spotlight on Easter Sunday, March 31, 2013 as reports of a 95-vehicle pileup left 3 people dead and injured 25 others on I-77 at the Virginia-North Carolina state line. Heavy fog was the major contributing factor that ignited a series of crashes that began around 1:15 p.m. One motorist described the crash scene as "way too foggy and cars were going way too fast. You couldn't see but about 30 feet in front of you. A car in front of us stopped and it piled up from there. I rolled by window down and you could just hear car after car crashing behind us" (Worrell 2013).

While initially reported as having occurred at the Virginia-North Carolina state line, it was determined that the 95-vehicle pileup actually occurred in Fancy Gap, Virginia. In an effort to be proactive instead of reactive and to determine the exact magnitude of fog related crashes in North Carolina, the Traffic Safety Unit which is a part of the Transportation Mobility and Safety Division of the North Carolina Department of Transportation (NCDOT) initiated a detailed analysis of fog related crashes.

DATA/INVESTIGATION

Crash analyses of reported fog related data contained in the North Carolina crash database was performed for the years of 2003 to 2012. As part of this statewide effort, a thorough data analysis of key issues was also reviewed. Issues analyzed included but were not limited to crash data, dense fog events throughout the state, weather prediction centers and fog detection systems. The results of the analyses showed that fog related crashes are a rare event, accounting for less than 1% of all reported crashes and less than 2% of all reported fatal crashes. The majority of the fog related crashes occurred on secondary routes (41%). While fog related crashes are most often associated with multi-vehicle pileups, the majority of these crashes involved single vehicles (59%). The highest percentage of fog related crashes occurred between the hours of 5:00 a.m. to 7:00 a.m. (49%). Data analyses also showed that the majority of fog related crashes occurred from Tuesday to Thursday (48%) and during the months of November to January (43%).

- From 2003 to 2012 there were 19,188 reported fog related crashes in North Carolina.
- Fog related crashes accounted for 0.8% of all reported crashes.
- Fog related fatal crashes accounted for 1.5% of all reported fatal crashes.
- 41% of fog related crashes occurred on secondary routes, followed by local streets (22%), NC routes (17%), US routes (15%) and Interstate routes (6%).
- 59% of fog related crashes involved a single vehicle, followed by two vehicles (37%), three vehicles (3%) and 4 or more vehicles (1%).
- The largest fog related multi-vehicle crash involved 13 units (C-Injury crash).
- 49% of fog related crashes occurred between the hours of 5:00 a.m. to 7:00 a.m. 45% of fog related fatal crashes occurred between the same hours.
- 48% of fog related crashes occurred during the week from Tuesday to Thursday.
- 43% of fog related crashes occurred during the months of November to January.

COUNTERMEASURES

Potential countermeasures are available to help reduce or prevent fog related crashes from occurring. These countermeasures include advance forecast maps from weather centers, simple warning signs, Variable Message Signs (VMSs) and active fog detection systems. While other states have experimented with some of these countermeasures with varying degrees of effectiveness, the biggest deterrent to implementing most of the applicable countermeasures is the feasibility based upon the cost of the countermeasure in conjunction with the very small number of fog related crashes that occur at random locations throughout the state. Even with the most advance countermeasures, driver behavior is critical in determining the overall effectiveness of the countermeasure. The fog detection system in the Fancy Gap Mountain area in Virginia was upgraded by approximately $5.3 million in 1997 (Casanova L. 2002). Prior to the 95-vehicle pileup, overhead message boards along I-77 had been advising motorists to slow their speed due to severe fog through the Fancy Gap Mountain area starting at 5:47 a.m. Sunday. Law enforcement indicated that the main cause of the crashes was motorists traveling too fast for the conditions (Worrell 2013).

As a state that continues to be proactive rather than reactive to safety concerns, existing initiatives are in place and continue to be expanded upon that should help address some of the areas of concern identified by this analysis. Our state currently has three Transportation Management Centers (TMCs) that help to coordinate and manage technological and transportation resources from a centralized hub. Existing technology that can be managed in the TMCs that are useful in preventing fog related crashes are Dynamic Message Signs (DMSs), Closed Circuit Television (CCTV) Camera Surveillance and Roadway Weather Information Systems (RWIS). The RWIS are especially important in that they can be used to monitor and identify weather-related events that could impact roadway traffic conditions.

CONCLUSION

The 95-vehicle pileup on I-77 near the Virginia-North Carolina state line brought fog related crashes to the forefront of the Transportation Mobility and Safety Division's transportation safety concerns. Analysis of the past ten years of fog related crash data has shown that these crashes are a rare event, accounting for less than 1% of all reported crashes and less than 2% of all reported fatal crashes. And while fog related crashes are most often characterized as catastrophic events involving multiple vehicles, 59% of these crashes involved single vehicles.

Based upon the data analyses and review of the safety initiatives that are currently in place, our state continues to be proactive in implementing countermeasures that have proven to be effective in reducing fog related crashes. Due to the random nature of these crashes that occur on an annual basis, there are only a few potential candidate locations that the identified countermeasures specifically targeting fog related crashes may be suitable for. With the three TMCs which are strategically located within the major transportation hubs in our state and the technology that currently exists within each center and throughout the divisions, there currently may not be a need to invest additional funds to address fog related crashes. In lieu of

spending funds, perhaps more coordination of our existing resources is the way to go. Lessons learned from other states provide further evidence of the benefits of weather integration with TMCs. Based on the Federal Highway Administration's (FHWA) Road Weather Management Program review of four TMCs, the following observations were made: "Each TMC established new partnerships, both internal and external, to their agency that served to enhance their overall operations, provide benefit to the traveling public, and chart a pathway to improved relationships in the future. In particular, stronger relationships were established with maintenance counterparts to encourage active sharing of weather information. More effective weather integration depends on a seamless sharing of information and decision making across operations and maintenance, but the historical arrangements in TMCs often present major institutional and cultural barriers that hinder information sharing. Continued awareness at all levels of the DOT organizations involved of the potential value of weather information to enhance the quality and content of traffic operations is necessary" (RITA Intelligent Transportation Systems). With the continuation of information sharing across all of the NCDOT departments and the news media outlets on the existing weather related forecast maps/centers and the technology that exist within our TMCs and Divisions, the traveling public will see the benefits by further reducing the number of fog and other weather related crashes.

I. Background Information

1.1 Study Initiation

The state of North Carolina was cast in the national news spotlight on Easter Sunday, March 31, 2013 as reports of a 95-vehicle pileup left 3 people dead and injured 25 others on I-77 at the Virginia-North Carolina state line. Heavy fog was the major contributing factor that ignited a series of crashes that began around 1:15 p.m. Although the crash did not actually occur in North Carolina, fog related crashes often raise the concerns of both state and local officials, the news media and the general public when they do occur.

In an effort to be proactive instead of reactive, North Carolina Department of Transportation (NCDOT) Traffic Safety Systems Engineer, Brian Mayhew requested that the Traffic Safety Unit initiate a statewide study of fog related crashes.

The purpose of the study is to:

1. Identify the magnitude of multi vehicle fog related crashes in North Carolina,
2. Identify common characteristics (if any) of these crashes,
3. Determine if there are clusters of these crashes,
4. Examine existing data sources for predicting fog conditions, and
5. Examine potential countermeasures for fog related crashes.

This study examines reported fog/smog/smoke related crashes that occurred on a roadway within North Carolina during the last ten full years of available data (2003 – 2012).

1.2 Definition of Fog

According to the weather glossary on The Weather Channel website, fog is defined as a visible aggregate of minute water droplets suspended in the atmosphere at or near the surface of the earth, reducing horizontal visibility to less than 5/8 statute miles. It is created when the temperature and the dew point of the air have become the same, or nearly the same and sufficient condensation nuclei are present (TWC Weather Glossary). The National Oceanic and Atmospheric Administration's glossary defines fog as water droplets suspended in the air at the Earth's surface. Fog is often hazardous when the visibility is reduced to ¼ mile or less (NOAA Glossary).

1.3 Investigation of Multi Vehicle Fog Related Crashes

Upon review of the crash data for the time period of this study, the following is a summary of the reported multi vehicle (more than 5 vehicles) fog related crashes:

- **December 7, 2004:** A male driver on NC 147 in Durham struck the vehicle in front of him that was slowing down due to traffic ahead, which caused a chain reaction. This property damage only crash involved 7 vehicles.
- **October 19, 2006:** A female driver on US 19/US 23 in Woodfin struck the vehicle in front of her that was stopped for traffic, which caused a chain reaction. This property damage only crash involved 7 vehicles.

- **June 14, 2008:** Two vehicles were involved in a prior crash and one vehicle was stopped due to the collision. One sheriff vehicle was parked while the deputy directed traffic through heavy smoke covering the roadway and two other emergency personnel were providing assistance. A male driver maneuvering his tractor/semi-trailer in the northbound lane of US 17 near Jacksonville was exceeding a safe speed for the conditions when he swerved to miss a vehicle and caused an 8 vehicle pileup. One emergency personnel was killed.

- **July 29, 2009:** 13 vehicles were traveling west on I-40 near Durham in fog and rainy conditions. The traffic stopped suddenly and all the vehicles were involved in the crash. The investigating officer was unable to determine the cause of the C-injury crash.

- **October 3, 2009:** A disabled vehicle was stopped on I-40 near Canton across the eastbound lanes due to a prior crash. A male driver collided with the disabled vehicle causing a chain reaction. Later reports show that the driver was intoxicated at the time of the collision. This A-Injury crash involved 6 vehicles.

An additional review of literature for multi vehicle fog related crashes prior to 2003 yielded the following results:

- A National Transportation Safety Board highway accident report investigation (NTSB Number: HAR-76/03) titled "Automobile Collision with and Collapse of the Yadkin River Bridge" recorded the following synopsis: About 9:25 p.m. on February 23, 1975, an automobile struck a vital structural member of the Yadkin River Bridge near Siloam, North Carolina. The collision occurred in heavy fog. Following the impact, the bridge collapsed and both the automobile and the bridge fell into the river. Six more vehicles vaulted into the collapse zone within a 17-minute period. Four-persons were killed and 16 were injured.

- A Transportation Research Board record from *The Asheville Citizen* dated January 21, 1996 and titled "Fog Warning Systems Working Elsewhere: After Another Big Pileup Near Canton, N.C. Officials Will Take Another Look" offered the following abstract: There have been at least six multi-car accidents on Interstate 40 in the Canton, North Carolina area since December 1977 that are attributed to fog. Although a $450,000 fog system was installed in the Canton area in 1974, North Carolina officials removed the system in 1986 after it performed poorly. Following a recent 46-car accident, the North Carolina Department of Transportation is now considering a more state-of-the-art system that will detect fog and inform motorists to lower their driving speeds.

- A review of the National Oceanic and Atmospheric Administration's Storm Events Database provided the following Dense Fog event on April 13, 2000 in McDowell County: Dense fog caused or contributed to a 43 car pile-up on Interstate 40 about 3 miles west of Old Fort. The pile-up began when a driver parked his car on the shoulder to fix a flat tire and other drivers could not see more than 15 to 20 feet. Fourteen injuries and one fatality were the result of this weather-related accident.

II. Data Analysis

In an effort to determine the magnitude of fog related crashes in North Carolina, analyses of crash data contained in the North Carolina Crash Data base was performed for the last ten years (2003 – 2012) of available data. The data was broken out into several categories and is discussed below.

2.1 Crash Severity Data

	Reported Crashes in the State of North Carolina (2003-2012)				***Reported Fog Related Crashes in the State of North Carolina* (2003-2012)**			
	Total Crashes	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**	**Total Crashes**	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**
2003	**248,024**	1,405	83,541	163,078	**2,174**	27	721	1,426
2004	**248,503**	1,421	83,437	163,645	**2,239**	34	774	1,431
2005	**233,990**	1,421	78,530	154,039	**1,991**	22	686	1,283
2006	**235,986**	1,430	76,247	158,309	**2,370**	24	802	1,544
2007	**241,989**	1,541	76,431	164,017	**1,610**	24	516	1,070
2008	**235,453**	1,352	71,905	162,196	**2,399**	22	731	1,646
2009	**231,838**	1,237	69,677	160,924	**2,415**	14	670	1,731
2010	**238,469**	1,225	69,218	168,026	**1,139**	11	307	821
2011	**234,026**	1,137	68,039	164,850	**1,048**	9	300	739
2012	**239,941**	1,188	70,141	168,612	**1,803**	14	530	1,259
	2,388,219	**13,357**	**747,166**	**1,627,696**	**19,188**	**201**	**6,037**	**12,950**

On average, fog related crashes account for less than 0.8% of all reported crashes on our roadways within North Carolina. In the past ten years, there have been a total of 19,188 reported fog related crashes. One hundred twenty (120) of these resulted in a fatal crash, accounting for 1.5% of all reported crashes. Approximately 67% of fog related crashes resulted in property damage only, which is consistent with the statewide data of all reported property damage only crashes average of 68%.

From 2003 – 2012, all reported crashes decreased by 3% along with decreases in fatal and injury crashes also by approximately 15% and 16% respectively. However, property damage only crashes have increased by approximately 3%. During this same time period, fog related crashes decreased by 17% along with decreases in the number of fatal, injury and property damage only crashes also by approximately 48%, 27% and 12% respectively. The decline in all reported crashes and fog related crashes can likely be contributed to an ever growing awareness of traffic safety initiatives/campaigns as well as advances in intelligent transportation system technologies and motor vehicle occupant protection systems.

Road Classification on Which the Reported Fog Related Crashes Occurred in the State of North Carolina (2003-2012)				
Road Classification	**Total Crashes**	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**
Interstate	**1,077**	9	309	759
US Route	**2,829**	48	946	1,835
NC Route	**3,170**	45	1,034	2,091
Secondary Route	**7,829**	79	2,490	5,260
Local Street	**4,283**	20	1,258	3,005
Total Crashes	**19,188**	**201**	**6,037**	**12,950**

Normally when the news media reports a major fog related crash involving multi vehicles, these crashes are most often reported as occurring on an interstate. However, of the 19,188 reported fog related crashes, the majority occurred on secondary routes (41%). In terms of the ranking order by road classification on which the fog related crashes occurred, secondary routes was followed by local streets at 18%, NC routes at 17%, US routes at 15% and finally Interstates at 6%.

Time of Day of the Reported Fog Related Crashes in the State of North Carolina (2003-2012)				
Time of Day	**Total Crashes**	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**
Midnight	**563**	6	178	379
1:00	**521**	9	176	336
2:00	**641**	14	204	423
3:00	**684**	16	219	449
4:00	**947**	13	259	675
5:00	**1,974**	23	550	1,401
6:00	**3,455**	37	1,046	2,372
7:00	**3,913**	31	1,370	2,512
8:00	**1,705**	10	568	1,127
9:00	**486**	4	154	328
10:00	**242**	1	70	171
11:00	**177**	1	51	125
Noon	**141**	1	42	98
1:00	**96**	0	33	63
2:00	**107**	0	31	76
3:00	**131**	2	38	91
4:00	**159**	3	57	99
5:00	**283**	0	86	197
6:00	**403**	5	123	275
7:00	**417**	1	117	299
8:00	**422**	4	124	294
9:00	**590**	6	186	398
10:00	**563**	8	166	389
11:00	**568**	6	189	373
Total Crashes	**19,188**	**201**	**6,037**	**12,950**

Approximately 49% of all reported fog related crashes occurred between the hours of 5:00 a.m. and 7:00 a.m. Forty five percent (45%) of the fatal fog related crashes also occurred during this same period of time. Mid-week (Tuesday-Thursday) occurrences accounted for the majority (48%) of these crashes.

Month of the Reported Fog Related Crashes in the State of North Carolina
(2003-2012)

Month	Total Crashes	Fatal Crashes	Injury Crashes	PDO Crashes
January	**2,929**	21	882	2,026
February	**1,725**	17	563	1,145
March	**1,497**	13	474	1,010
April	**761**	15	239	507
May	**764**	10	262	492
June	**692**	11	219	462
July	**708**	10	251	447
August	**1,227**	21	427	779
September	**1,473**	14	505	954
October	**2,070**	26	637	1,407
November	**2,113**	20	588	1,505
December	**3,229**	23	990	2,216
Total Crashes	**19,188**	**201**	**6,037**	**12,950**

The three consecutive month period in which the highest number of reported fog related crashes occurred between the typical winter time period of November through January (43%).

2.2 Locational Data

Top 10 Routes on Which the Reported Fog Related Crashes Occurred in the State of North Carolina
(2003-2012)

County	Road On	Total Crashes	Fatal Crashes	Injury Crashes	PDO Crashes
Watauga	**US 421**	**88**	3	31	54
Mecklenburg	**I-77**	**61**	0	17	44
Watauga	**US 321**	**52**	0	14	38
Mecklenburg	**I-485**	**50**	0	13	37
Caldwell	**US 321**	**49**	2	19	28
Gaston	**I-85**	**45**	0	16	29
Iredell	**I-77**	**44**	0	15	29
Mecklenburg	**I-85**	**44**	0	13	31
Wake	**NC 55**	**39**	1	7	31
Burke	**I-40**	**36**	1	8	27

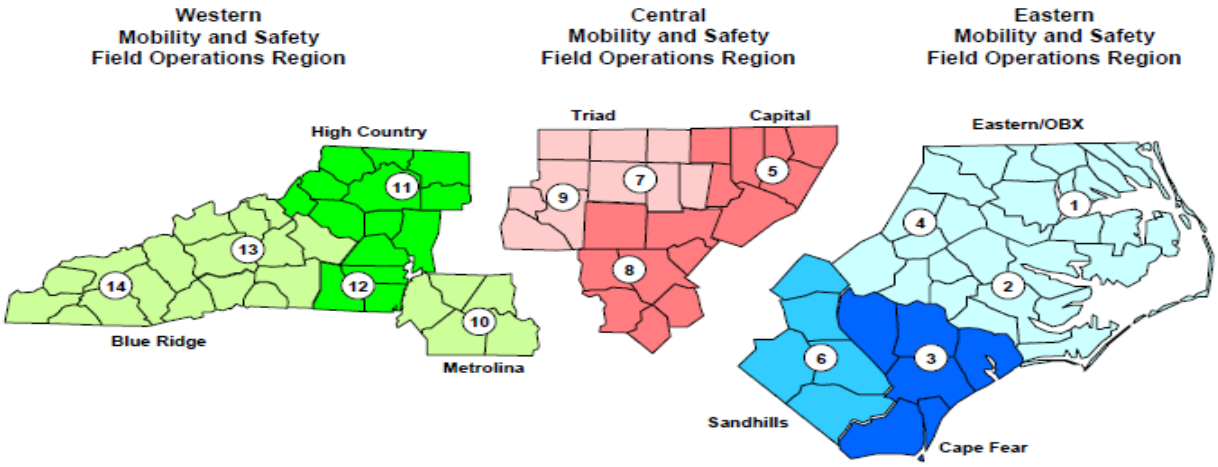
Based on a review of the Top 10 Routes on Which Reported Fog Related Crashes Occurred, 60% of the crashes occurred on interstates. Four out of the six identified interstate routes ran through neighboring counties (i.e. I-77 through Mecklenburg - Iredell County and I-85 through Mecklenburg – Gaston County). Thirty percent (30%) of the top 10 routes were US routes, with

two out of the three routes running through neighboring counties (i.e. US 321 through Caldwell – Watauga County). In addition, interstate routes in Mecklenburg County accounted for 30% on the top 10 routes listing.

Top 20 Counties in Which the Reported Fog Related Crashes Occurred in the State of North Carolina (2003-2012)				
County	**Total Crashes**	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**
Mecklenburg	**1,043**	6	349	688
Wake	**886**	3	225	658
Guilford	**708**	7	235	466
Forsyth	**529**	4	173	352
Catawba	**472**	4	146	322
Randolph	**402**	5	119	278
Iredell	**401**	4	128	269
Robeson	**397**	11	169	217
Cumberland	**395**	7	118	270
Davidson	**385**	3	150	232
Buncombe	**373**	4	127	242
Gaston	**373**	1	128	244
Johnston	**363**	3	136	224
Rowan	**350**	4	117	229
Cabarrus	**346**	3	101	242
Union	**345**	2	104	239
Pitt	**327**	2	97	228
Rockingham	**285**	3	92	190
Nash	**281**	4	88	189
Watauga	**281**	3	77	201

Mecklenburg County was the top county in which reported fog related crashes occurred. The top 20 counties accounted for approximately 47% of all reported fog related crashes. In addition, 41% of all the fog related fatal crashes occurred within the top 20 counties.

The North Carolina Department of Transportation's Division of Highways is spread across 14 division offices within the state.



For the purposes of this study, the regional classifications are based on the areas defined by the Mobility and Safety Field Operations section within the Traffic Safety Unit.

Regions in Which the Reported Fog Related Crashes Occurred in the State of North Carolina (2003-2012)				
Region	**Total Crashes**	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**
Eastern	**5,917**	83	1,883	3,951
Central	**6,009**	62	1,788	4,159
Western	**7,262**	56	2,366	4,840
Total Crashes	**19,188**	**201**	**6,037**	**12,950**

The number of reported fog related crashes was evenly distributed when looking at the regions in which the crashes occurred. The Western Region was the top region with approximately 38% of the reported fog related crashes occurring within this region.

Divisions in Which the Reported Fog Related Crashes Occurred in the State of North Carolina (2003-2012)				
Division	**Total Crashes**	**Fatal Crashes**	**Injury Crashes**	**PDO Crashes**
1	**738**	7	231	500
2	**1,107**	17	333	757
3	**1,264**	10	378	876
4	**1,445**	23	450	972
5	**1,781**	20	445	1,316
6	**1,363**	26	491	846
7	**1,394**	15	440	939
8	**1,305**	15	393	897
9	**1,529**	12	510	1,007
10	**2,050**	16	638	1,396
11	**1,338**	11	416	911
12	**1,843**	15	600	1,228
13	**1,060**	9	347	704
14	**971**	5	365	601
Total Crashes	**19,188**	**201**	**6,037**	**12,950**

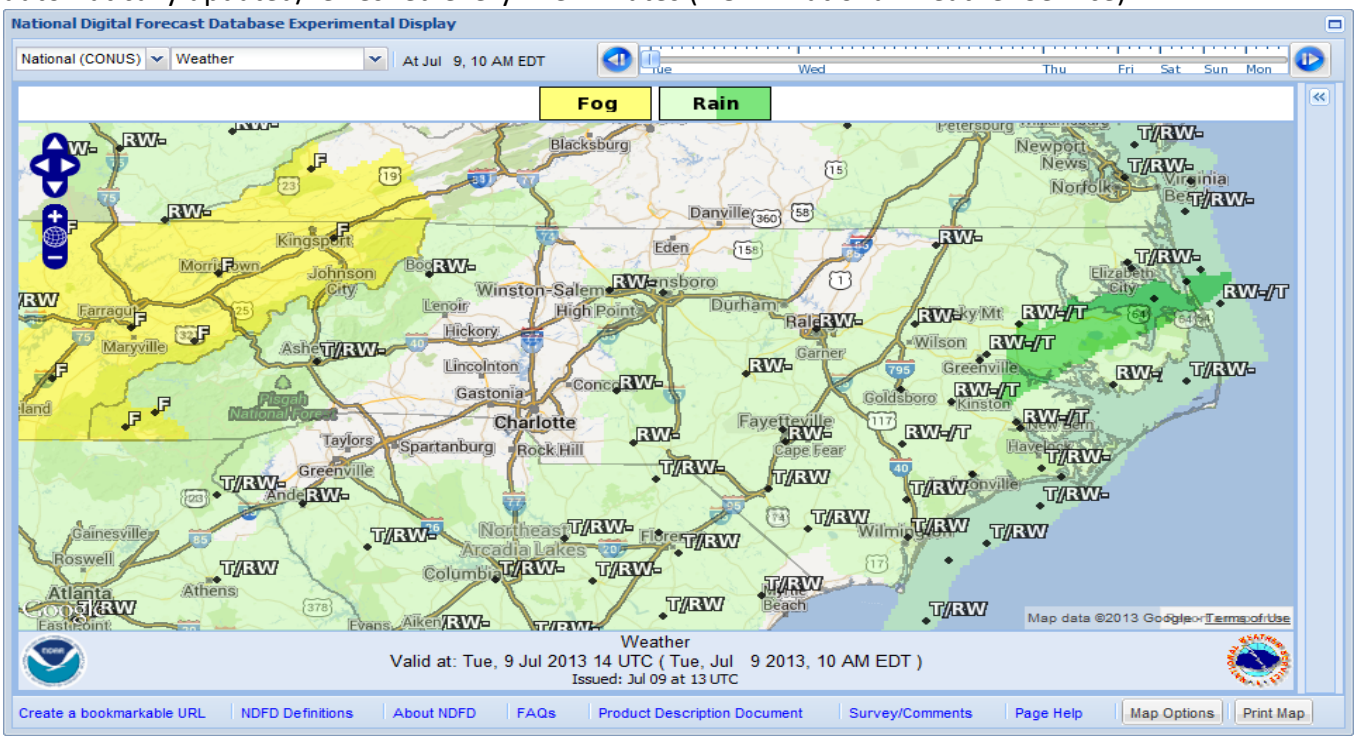
Division 10 was the top division in which reported fog related crashes occurred accounting for approximately 11% of the crashes. It should be noted that Mecklenburg County, the top county in which reported fog related crashes occurred, is within Division 10.

III. Potential Countermeasures

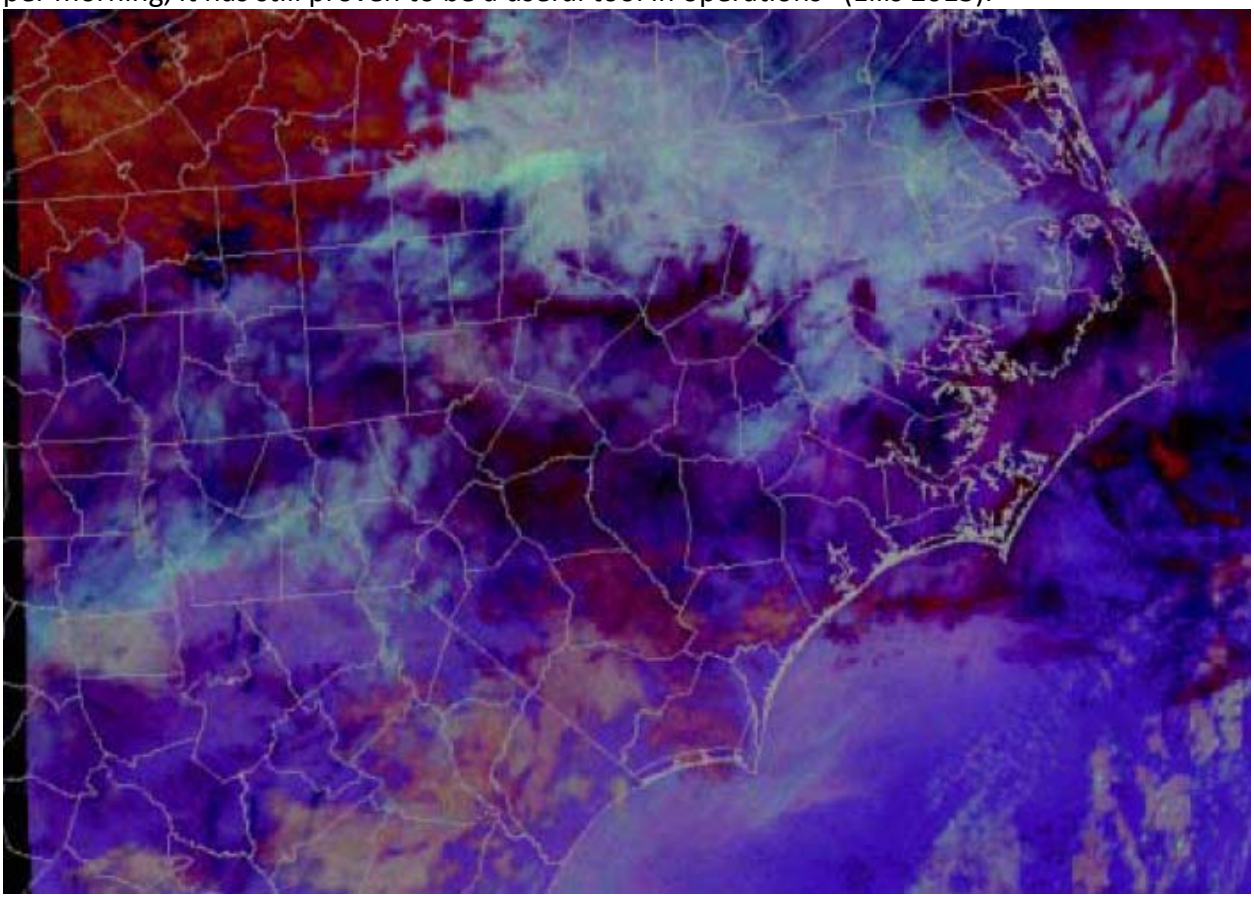
Potential countermeasures are available to help prevent/reduce fog related crashes from occurring. While other states have experimented with some of these countermeasures with varying degrees of effectiveness, the biggest deterrent to implementing most of the applicable countermeasures is the feasibility based upon the cost of the countermeasure in conjunction with the very small number of fog related crashes that occur at random locations throughout the state. Within this section are some of the countermeasures that are available, a review of the technologies some other states are currently utilizing and the existing technologies that exist within our state.

3.1 Advanced Forecast Maps from Weather Centers

One potential countermeasure are advanced forecast maps that are available through weather centers. By using advanced forecast maps, drivers are made aware of the current driving conditions and can make necessary adjustments to their travel plans. One map that is currently available and is currently being updated to include a roadway map is provided by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service. The map displays active watch, warnings, advisories and short term forecasts in the lower 48 U.S. states and are automatically updated/refreshed every five minutes (NOAA National Weather Service).



Another advanced forecast map that is currently available is provided by the Short-term Prediction Research and Transition Center (SPoRT). SPoRT is a NASA project to transition unique observations and research capabilities to the operational weather community to improve short-term forecasts on a regional scale. However, the forecast maps are not continuously updated within SPoRT. One weather forecaster gave SPoRT a glaring review for its usefulness in forecasting a dense fog event over Central North Carolina on January 12, 2013. "The fog is clearly indicated with a blue color. This is the first opportunity we have had to see fog with the micro physics imagery with a warm surface. As a forecaster if was helpful to know which interstate corridors had the worst conditions. This turned out to be the I-85 corridor north of Raleigh and the northern half of the I-95 corridor. This was a great situational awareness tool to let us know that these two interstates in particular were in more danger than some of the other high traffic corridors. While this imagery is only available a couple of times per morning, it has still proven to be a useful tool in operations" (Ellis 2013).



3.2 Fog Warning/Detection Systems and Technologies in Other States

In an effort to prevent/reduce the number of fog related crashes, other states throughout our country have installed fog warning/detection systems and utilized various technologies. The following is a review of some of the systems that other states have installed.

California

A recent fog detection and warning system along a 13-mile section of the California Highway 99 corridor in the central part of the state was completed in 2009. The system alerts motorists automatically of dangerous weather conditions and slow speeds by using changeable message signs (CMSs) and highway advisory radio (HAR). When slower speeds are detected downstream, the CMSs warn drivers of the slower traffic ahead. If an incident has occurred, the CMSs will warn drivers of slower traffic ahead in order to prevent chain-reaction collisions. Presently the system only employs CMSs and HAR to communicate road conditions to travelers. Both of these methods are effective. The addition of the 511 system addresses the shift to mobile data devises and increased reliance by the motorist on receiving this information while traveling. Once the fog detection data is integrated with the 511 system, it will help reduce the impact of severe fog by minimizing the number of vehicles on the roadway (FHWA Road Weather Management Program).

Georgia

An augmented fog/smoke detection and warning system in Adel, Georgia was initiated in 2001 along a 19 mile segment of the highway to reduce the likelihood of crashes due to impaired visibility distance caused by fog and smoke. At the heart of the system's data collection operation is a set of 19 commercially available fog sensors. Each sensor has a transmitter and a receiver. The system's software analyzes data from the fog sensors, notifies Georgia Department of Transportation officials at the TMC in Atlanta of potential problems and automatically decides what message to post on four changeable message signs on the north and southbound outskirts of the fog zone. The 36-foot-wide and 9-foot-high signs are attached to metal structures built over the highway (GTRI Case Study).

Maryland

In 2003, the Maryland State Highway Administration (SHA) developed a plan to install an automated fog-warning system in fog prone areas of I-68 near Big Savage Mountain. The warning system was designed to use existing environmental sensor station (ESS) visibility sensors and wireless communications equipment to activate flashers on roadside message signs during periods of limited visibility. When fog was detected, the contact enclosure triggered a transmitter and activated the warning signs. The ESS sensor data, including surface, subsurface, and atmospheric data were sent to the central RWIS at the District-6 operations center via a telephone landline (RITA Intelligent Transportation Systems).

South Carolina

As a result of a federal court decision the South Carolina Department of Transportation (DOT) was required to incorporate fog mitigation technologies during construction of the Interstate 526 Cooper River Bridge. The DOT deployed a low visibility warning system on seven miles (11.3 kilometers) of the freeway to inform drivers of dense fog conditions, reduce traffic speeds, and guide vehicles safely through the fog-prone area. The warning system components include an ESS, five forward-scatter visibility sensors spaced at 500-foot (152.4-meter) intervals, pavement lights installed at 110-foot spacing (33.5-meter), adjustable street light controls,

eight CCTV cameras, eight DMSs, a Remote Processing Unit (RPU), a central control computer, and a fiber optic cable communication system. The central computer's decision support software predicts or detects foggy conditions, correlates environmental data with predetermined response strategies, and alerts traffic managers in the district office (FHWA Road Weather Management Program).

Virginia

The Fancy Gap and Afton Mountain interstates have a long history of fog-related, multivehicle crashes. The Virginia Transportation Research Council created an expert panel of decision makers from the Virginia Department of Transportation and the Virginia State Police and with the help of the Virginia Tech Transportation Institute staffed the panel. The panel issued the following recommendations: (1) Install variable message signs "immediately prior" to the most fog-prone areas to warn drivers of detected incidents or fog-related vehicle stops or slowdowns ahead. Use high advisory radio within the fog zone to communicate with drivers. (2) Install video cameras in the Afton and Fancy Gap fog areas. Explore the use of ultra-low-temperature, infrared video cameras to penetrate fog. (3) Increase police visibility, including increased patrols and possible staff assignments to I-77 at Fancy Gap and I-64 at Afton. (4) Seek authorization for experimental use of advisory and regulatory variable speed limits on I-77 as part of the new Fancy Gap fog mitigation system. (5) Conduct research to improve the legibility and visibility of variable message signs in fog. Study the effectiveness of static signs augmented with strobes and lasers to warn drivers of detected incidents and slowdowns in the fog zone. Because the panel included experts from numerous levels of the Virginia Department of Transportation and Virginia State Police and had extensive knowledge and experience with the fog problems under consideration, they were able to discuss their disagreements and come to a consensus on how to proceed (TRB Abstract).

3.3 Current Fog Detection Systems/Technologies in NC

Within our state, a lot of the technologies mentioned in the states above that are used to prevent/reduce the number of fog related crashes already exist. TMCs help coordinate and manage technological and other transportation resources from a centralized hub. By collecting and analyzing real time information, changes to the transportation system can be made as necessary, including coordinating responses to real time events. The three TMCs that are strategically located within major transportation hubs within our state are the Triangle TMC (serves Division 5), the Piedmont Triad TMC (serves Divisions 7 and 9) and the Metrolina TMC (serves Divisions 10 and 12). The remaining Divisions operate various permanent or portable Intelligent Transportation System (ITS) field devices either through an office in a NCDOT facility or in a satellite/mini-TMC. The variety and quantity of field devices includes DMSs (portable and / or permanent), HAR, CCTV cameras, video detection equipment, RWIS, and fog detection systems (NCDOT Smartlink).

There are currently two fog detection systems within our state. One of the systems is an Advanced Fog Incident System (AFIDS) in rural Haywood County (Division 14). This

mountainous area just west of scenic Asheville has a history of becoming dense with fog and creating a driving nightmare for those on I-40. The system includes CCTV, VMSs, RPUs, and field Visibility Sensors. The system polls strategically placed visibility sensors to determine the current distance that a driver can see and compares the values with threshold values that are stored in the RPUs. The RPUs execute the appropriate stored scenarios that match the current driving conditions. These actions include placing travel information on VMSs, sending alarms to the two central facilities, and paging personnel to respond to the incident. Upon receiving an alarm, the operators at the central control centers can verify the driving conditions by using the CCTV (Haywood AFIDS). The other fog detection system that is located on I-26 in Madison County (Division 13) is described as a standalone visibility system that can detect fog.

There are also technologies throughout our state that are/can be used to prevent/reduce the number of fog related crashes. DMSs which are situated above many of North Carolina's major arterial roadways, help to alert motorists of incidents and provides alternative routes (if available). CCTV surveillance allows real-time monitoring and evaluation of traffic conditions. North Carolina's 511 system which was implemented in the summer of 2004, allows travelers to check on traffic and weather conditions statewide via the telephone. HAR is also an additional source for travel information and conditions. One of the more advanced systems that can help to identify fog weather conditions is the RWIS that is located on I-95 in Halifax County (Division 4). RWIS is a collection of pavement and atmospheric sensors that monitor and identify weather-related events that could impact roadway traffic conditions. This sophisticated system can respond automatically by applying anti-icing chemicals to the roadway and activate other information devices (DMSs, etc.) (NCDOT ITS).

	Number and Type of ITS Field Devices by Division (early 2007) ***(NCDOT Smartlink)***								
Division	**CCTV**	**Video Detection**	**DMS**	**Fog Detection**	**HAR**	**Portable HAR**	**Portable VMS**	**RWIS**	**Total**
1	22	0	0	0	0	0	0	0	**22**
2	0	0	0	0	0	0	0	0	**0**
3	0	0	9	0	0	0	0	0	**9**
4	5	8	10	0	2	1	12	1	**39**
5	63	0	33	0	6	2	8	0	**112**
6	0	0	5	0	0	0	10	0	**15**
7	11	0	16	0	0	0	12	0	**39**
8	0	0	0	0	0	0	0	0	**0**
9	33	1	23	0	4	0	2	0	**63**
10	57	134	36	0	0	0	0	0	**227**
11	0	0	3	0	0	0	0	0	**3**
12	0	0	5	0	0	0	0	0	**5**
13	0	0	4	1	0	0	0	0	**5**
14	0	0	8	1	0	0	0	0	**9**
Total	**191**	**143**	**152**	**2**	**12**	**3**	**44**	**1**	**548**

With the exception of Divisions 2 and 8, every division within the state has available ITS systems/technologies that can be used to alert motorist when fog/smog/smoke weather conditions are present.

IV. Conclusions & Recommendations

As a state that continues to be proactive rather than reactive to safety concerns, existing initiatives are in place and continue to be expanded upon that should help address some of the areas of concern identified by this analysis. Our state currently has three TMCs that help to coordinate and manage technological and transportation resources from a centralized hub. Existing technology that can be managed in the TMCs that are useful in preventing fog related crashes are DMSs, CCTV surveillance and RWIS. Based upon the data analyses and review of the safety initiatives that are currently in place, our state continues to be proactive in implementing effective countermeasures that have proven to be effective in reducing fog related crashes. Due to the random nature of these crashes that occur on an annual basis, there are only a few potential candidate locations that the identified countermeasures specifically targeting fog related crashes may be suitable for.

However with the three TMCs which are strategically located within the major transportation hubs in our state and the technology that currently exists within each center, there currently may not be a need to invest additional funds to address fog related crashes. In lieu of spending funds, perhaps more coordination of our existing resources is the way to go. Lessons learned from other states provide further evidence of the benefits of weather integration with TMCs. Based on the Federal Highway Administration's (FHWA) Road Weather Management Program review of four TMCs, the following observations were made: "Each TMC established new partnerships, both internal and external, to their agency that served to enhance their overall operations, provide benefit to the traveling public, and chart a pathway to improved relationships in the future. In particular, stronger relationships were established with maintenance counterparts to encourage active sharing of weather information. More effective weather integration depends on a seamless sharing of information and decision making across operations and maintenance, but the historical arrangements in TMCs often present major institutional and cultural barriers that hinder information sharing. Continued awareness at all levels of the DOT organizations involved of the potential value of weather information to enhance the quality and content of traffic operations is necessary" (RITA Intelligent Transportation Systems). With the continuation of information sharing across all of the NCDOT departments and the news media outlets on the existing weather related forecast maps/centers and the technology that exist within our TMCs and Divisions, the traveling public will see the benefits by further reducing the number of fog and other weather related crashes.

V. Next Steps

The NCDOT will seek to create a research project that will explore the utilization of weather data for roadway safety applications. Through partnership with a university, the research would help to develop an implementation plan for integrating fog prediction into available NCDOT systems for alerting motorists.

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Appendix A

Fog Related Crashes Risk Map

Fog Related Crashes Risk Map

Criticality of Achievement	Decrease in the Number of Fog Related Crashes	Number of Fog Related Crashes Relatively Unchanged	Increase in the Number of Fog Related Crashes
Fog Prone Corridors Throughout the State	* Management awareness of identified fog prone corridors throughout the state * Monitoring of weather conditions along fog prone corridors	* Careful consideration of upgrading existing ITS technologies to help alert drivers of fog advisories *Establishing new partnerships to encourage active sharing of weather information	* Installation of new active fog detection systems along known fog prone corridors *Installation of Roadway Weather Information Systems in fog prone areas
Existing Fog Detection System/Technologies	* Explore the use of advanced weather forecast maps to provide current driving conditions * Seek assistance from NCSU to determine if it is possible to predict heavy fog conditions	* Better coordination of existing ITS technologies * Using Traffic Management Centers to alert drivers of fog advisories * Integration of existing fog detection data/alerts in TIMS with the 511 system	* Reluctance to discuss the known issues with existing fog detection systems in our state * Declining public opinion of NCDOT as safety champions
Predominate Time of Day When Fog Related Crashes Occur	* Management awareness that 49% of all fog related crashes occurred between the hours of 5am to 7am * Management awareness that 45% of all fatal fog related crashes occurred between the same hours	* Public information campaign to educate drivers on the dangers of not heeding to fog advisories * Pilot test countermeasures (ex. restricting travel to one lane, increased enforcement) aimed at changing driver behaviors	* Bad press for not attempting to implement safety countermeasures to help reduce the number of fog related crashes * Possibility of a catastrophic event that causes a not so well thought out plan of action to take place

Actual Variability in Number of Fog Related Crashes

Risk Assessment	
High (Red)	Unacceptable. Major disruption likely. Different approach required. Priority management attention required.
Moderate (Yellow)	Some disruption. Different approach may be required. Additional management attention may be needed.
Low (Green)	Minimum impact. Minimum oversight needed to ensure risk remains low.

Risk Management is not a new concept to the North Carolina Department of Transportation

[1] The North Carolina DOT (NCDOT) has implemented risk management that addresses risks to organizational objectives, asset conditions, achieving performance targets and complying with environmental regulations.

[2] The 2010 FHWA Corporate Risk Assessment report notes that the *"A major concern is the austere fiscal environment and resulting loss of personnel by State Highway and Transportation Agencies."* The report stated that not maintaining sufficient organizational capacity (people, knowledge and system) will affect the future delivery of the transportation program. Agencies like NCDOT are developing data warehouses, virtual libraries and document management systems to capture the existing institutional knowledge and mitigate such risks. They are also implementing training and mentoring programs to document the business intelligence and facilitate knowledge transfer to address the risk of such loss of institutional knowledge.

1, 2 **Risk-Based Asset Management: Examining Risk-based Approaches to Transportation Asset Management.** *Report 2: Managing Asset Risks at Multiple Levels in a Transportation Agency* USDOT FHWA, August 2012