The Truck Blowover Algorithm for the Pikalert® System

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SOARS® Summer 2017

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ABSTRACT

Wyoming has various forms of hazardous weather, most of which occur in the winter. However, high winds occur year-round and pose the most danger to the freight traffic along the I-80 corridor with elevations of up to 8000 feet. Freight traffic makes up half of the daily average traffic volume along the corridor, making half of the traffic along I-80 at risk of being blown over during high wind events. In one year, the Wyoming Department of Transportation (WYDOT) recorded over 700 commercial vehicle accidents and over 1,000 hours in road closures. The combination of accidents and road closures can cost trucking companies millions of dollars yearly.

The Pikalert® System, developed by The National Center for Atmospheric Research (NCAR), is being used in the WYDOT Connected Vehicle (CV) Pilot (CV) in an attempt to alleviate the number of blowovers along I-80. Pikalert uses various algorithms to combine vehicle and weather data to generate warnings for users but was lacking a wind algorithm.

A blowover algorithm was developed using a fuzzy logic methodology with the purpose of being integrated into Pikalert. The algorithm was adjusted based on outputs from case studies of increasing size. This resulted in a reliable algorithm that has the ability to identify roadways with high blowover risk for different vehicle types.

The deployment and testing of the algorithm will aid in its performance during the verification period once implemented into Pikalert.

This work was performed under the auspices of the Significant Opportunities in Atmospheric Research and Science Program. SOARS is managed by the University Corporation for Atmospheric Research and is funded by the National Science Foundation, the National Center for Atmospheric Research, the National Oceanic and Atmospheric Administration, the Woods Hole Oceanographic Institute, the Constellation Observing System for Meteorology, Ionosphere, and Climate and the University of Colorado at Boulder.
1. Introduction

Hazardous weather conditions impact the ability to safely operate a motor vehicle, including freight vehicles. Road weather-related delays can cost trucking companies over 2.2 billion dollars annually. Additionally, with over 5000 road weather fatalities occurring yearly, the impact that weather has on drivers is severe (FHWA, 2017). These impacts are strongly felt along the 402-mile long Interstate 80 (I-80) corridor in Wyoming where extreme weather occurs year-round at elevations between 6,000 and 8,600 feet. One of the most dangerous forms of weather, high winds, predominantly affects freight traffic due to their high profiles. Freight traffic makes up half of the daily average traffic volume in this corridor; thus 50 percent of the vehicles traveling along the corridor are at risk of being blown over (WYDOT, 2017). In 2006, 36% of the 146 total road fatalities along I-80 were caused by commercial vehicles being blown over (WYDOT, 2010).

Blowovers often cause road closures and fatalities. With minimal alternative routes available when the corridor closes, economic losses for transportation agencies can increase exponentially. Previous road weather research was conducted in order to find solutions to reducing blowover impacts. The University of Manitoba Transport Institute used a truck simulation model to determined that lightly loaded, fast moving freight vehicles had the highest risk of being blown over during high wind events and dry road conditions (Summerfield and Kosior, 2001). The Wyoming Department of Transportation (WYDOT) issues a strong wind warning when winds exceed 40 mph and closes the corridor to light, high profile vehicles for winds exceeding 60 mph (WYDOT Travel Information Service, 2017). Extensive research was conducted at the University of Wyoming to determine effective operational modes to decrease road closures along I-80. The study developed four levels of operational decision-making; the most common level of operations being level one and two. These operational levels use wind and road conditions to transmit advisory messages and determine road closures (Young and Liesman, 2007). Currently, WYDOT primarily uses operation level 1, using their own judgment rather than fixed wind thresholds to determine closures. The least common operational levels are three and four. These operational levels use a combination of wind...
and road conditions, vehicle profile and weight to restrict road access to light weight, high profile vehicles (Young and Liesman, 2007). These operational levels require maximized usage of connected vehicle technology and since its still in development very few locations make use of it.

There is strong political and economic pressure put on WYDOT to keep the roadway open during strong winds to avoid these economic losses. To combat this issue, WYDOT is participating in the U.S. Department of Transportation’s (USDOT’s) Connected Vehicle (CV) Pilot Deployment program. The WYDOT CV Pilot aims to develop a system that provides information to equipped commercial and fleet vehicles (Gopalakrishna, 2016). The WYDOT CV Pilot needed a processing system that could combine vehicle and weather information, thus the Pikalert® system, developed by the National Center for Atmospheric Research (NCAR), was used.

Pikalert uses measurements of the roadway and surrounding atmospheric conditions to provide decision makers with a user-friendly map that displays current and forecast road conditions (Anderson, 2016). In the WYDOT CV Pilot, Pikalert is used to interpret weather and vehicle data then output warnings, advisories, and roadway conditions to freight drivers. Although well-suited to this task, Pikalert was lacking a wind hazard algorithm, which was of critical importance to keeping I-80 safe. This research focuses on the creation of a blowover/wind algorithm using sustained wind, wind differential, wind direction, and road slickness. The parameters were used to assess blowover risk for three commercial vehicle classifications (Figure 1). The completed algorithm will be used in Pikalert to aid in route planning and issuing driver advisories or restrictions to reduce the number of blowovers and aid decision-making on advisories and road closures for I-80.

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1 Pikalert® is a registered trademark of the University Corporation for Atmospheric Research (UCAR)
2. Methods

The NCAR Road Weather team completed the initial blowover algorithm development. The algorithm uses fuzzy logic methodology (McNeil and Freiberger 1993), which combines a set of interest functions and weights to determine an overall interest value ranging from negative one to one. The initial values of the weights and functions were primarily based on Young and Liesman (2007) and Baker et al. (2008). The algorithm consists of four different functions: wind gust speed, wind gust differential (difference between sustained wind and wind gust speeds), wind direction relative to the orientation of the road, and road surface slickness. Each of these functions has a different weight depending on its significance to truck blowover risk. The four interest functions used preset bounds, and combined with their weights were used to calculate an interest value for three different vehicle classifications: regular passenger (passenger), loaded high profile (heavy), and unloaded high profile (light) vehicles. This method is used to get an assessment of either a low interest/risk of blowover or a high interest/risk of blowover.

The case studies used to test the algorithm were comprised from two main sources of data. One source was a seven-year data set of crash information along I-80 in Wyoming (Rhonda Young, personal communication). The crash data set included information such as date, time, county, milepost, crash type, lighting, weather, and road conditions from 2010 to 2017. This data set was sorted by cases in which the weather condition was “Severe Wind Only” and the first harmful event was an “Overturn/Rollover”. These conditions were set because without official police reports this was the best way to assume that strong winds caused the blowover. This enabled us to filter out blowovers caused by other factors like cows. The second source of data was from the University of Utah’s MESOWEST Database that contains archived Road Weather Information System (RWIS) station data (University of Utah, 2017).

Three case study groups were used to perform a sensitivity and data denial analysis on the algorithm. The cases were co-located by time, latitude, and longitude of the incident from the database with the closest RWIS station observation. Thus, it was
possible to gather blowover cases and the associated wind variables used by the proposed algorithm. The small case study group consisted of six different wind categories: high speed perpendicular (relative to road orientation) winds, high speed parallel winds, moderate speed perpendicular winds, moderate speed parallel winds, low speed winds, and missing data (i.e., data denial testing), totaling to 18 cases. This case study also used National Weather Service (NWS) records of high wind events in Wyoming and matched those dates with the seven-year crash data set. The medium case study group only used one year (2016) out of the seven-year database for a total of 82 cases. However, the conditions (see previous paragraph) set upon the data set reduced the cases to 32. The large case study used the entire 7-year database for a total of over 7000 cases, however the conditions reduced the cases to 125. The weights and functions were changed based on the outputs of each case study such that they accurately represent the appropriate interest value for each vehicle classification and case. The performance of the algorithm for each case was determined by calculating the probability of detection (POD) (Bullock, 1994) on the first run of each case and after changes was made to algorithm. The POD used a “Hit” to “Total Event Occurrence” ratio to determine the probability that the algorithm would detect a blowover. In this study a hit is when blowover occurred and the overall interest value was above the alert threshold, while a miss is when the interest value is below the alert threshold.

3. Results

The small case study was used to test the initial outputs of the algorithm. Before any changes were made to the algorithm this case study had a POD of 0.67 (Figure 2). From an analysis of the outputs the algorithm was under alerting, particularly for heavy trucks. The alert threshold and the upper bound of the wind gust differential function for heavy trucks seemed too high so each was lowered resulting in a POD of 0.89 (Figure 2).

The changes made to the algorithm in the small study were applied to the medium case study as the initial run. The initial run of the medium study produced a POD of 0.16 (Figure 3). The algorithm continued to have under alerting issues caused by the wind gust differential function for heavy trucks and the weight of the wind direction being too...
large. Thus, again the wind gust differential function for heavy trucks was lowered and the significance of the wind direction was reduced resulting in a POD of 0.41 (Figure 3).

As before, the changes made to the medium case study were applied to the large one in order to test how well the changes work for a larger study. By doing this, the POD for the large case study was 0.50 (Figure 4). There was under alerting occurring in the algorithm caused by the wind speed function for passenger vehicles, the wind gust differential function for light trucks, and the weight of the wind direction. To reduce the amount of under alerting the upper bound of the wind speed function for passenger vehicles was reduced, the upper bound of the wind gust differential function for light trucks was increased, and the weight of the wind direction was lowered further, increasing the POD to 0.62 (Figure 4).

4. Discussion

The POD for the small case study was drastically higher than that of the other case studies. The cases for the small study tended to have extreme wind speeds that were above the function’s bounds. That, coupled with the small size of the study produced a higher POD than the other cases. It was also easier to adjust the algorithm to this case due to its small size. It was easier to go through each case and see what was wrong, whereas with the larger studies that is not possible or efficient. When the changes to the small case study were applied to the medium study it produced the lowest POD out of all of the initial runs. This could be due to the algorithm being tuned to the more extreme values of the small case study and when applied to the more realistic medium case study the algorithm had lower performance than in the small case study. When the changes made to the medium case study were applied to the large case study it performed better than the initial run of the medium case study. This shows how tuning the algorithm through previous cases slowly improved its performance over time.

The algorithm’s functions and weights did have to be reduced from the initial bounds. The weight of the wind direction, how perpendicular the wind is to
the road, did not have much significance in the algorithm and caused under alerting issues. Logically, perpendicular winds on a large surface area (e.g., a truck’s trailer) increase the risks of that object being blown over. The odd result may have been caused by terrain limitations when matching the RWIS data with the latitude and longitude of the crash location. The RWIS stations were not always co-located with the crash; some were a few miles off which means that the exact wind gust speed and direction that caused the crash were not necessarily accurately represented. Wind gusts can vary in direction over time and distance. Terrain variations can also have an impact on wind direction and speed, such that wind characteristics vary over small distances. The lack of official police reports was a major limitation because it was never truly known if the severe wind caused the crash or if an event occurred before hand. WYDOT closes the road way to light trucks when winds reached over 50 mph, potentially reducing the number of cases. When matching the correct interest value to its appropriate vehicle classification, it was uncertain as whether to classify passenger vehicles with trailers attached as light trucks instead. It was decided that since the trailer added not only a pivot point to the vehicle but also increased its surface area that it should be classified as a light truck. The best classification may depend on the type of trailer but regardless the passengers vehicles now have a point at which they can pivot about and become unstable much like trucks.

5. Implementation

The blowover algorithm has been implemented into the Pikalert system. The algorithm’s presence in Pikalert will not only impact drivers along I-80 but also provide further advancement in the WYDOT CV Pilot project such that it can be used by other DOTs. The algorithm will aid in advanced decision support for freight drivers with the goal of increasing safety and awareness and also reducing road closure frequency. This could save trucking companies millions of dollars and lower the number of fatalities caused by blowovers. The blowover algorithm will undergo verification within Pikalert this upcoming winter and undergo further changes if necessary. The algorithm, along with the rest of Pikalert and other code developed under the CV Pilot grant, will be
available on the Open Source Application Development Portal (OSADP; www.itsforget.net) for use by the community.

FIGURES

![Algorithm Diagram](image)

**Figure 1:** The algorithm ingests weather and vehicle information as inputs and outputs a risk level for three vehicle types. This risk level determines if a driver is alerted or not.

![POD Chart](image)

**Figure 2:** The POD that was produced in the initial run (before) of the updated algorithm compared with POD after adjustments were made to the algorithm.
Figure 3: The POD that was produced in the initial run (before) of the updated algorithm compared with POD after adjustments were made to the algorithm.

Figure 4: The POD that was produced in the initial run (before) of the updated algorithm compared with POD after adjustments were made to the algorithm.
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ACHKNOWLEGMENTS

I would like to thank Rhonda Young for providing the crash data set used in this project. The Connected Vehicle Project is funded by a grant from US Department of Transportation. This work was performed under the auspices of the Significant Opportunities in Atmospheric Research and Science Program. SOARS is managed by the University Corporation for Atmospheric Research and is funded by the National Science Foundation, the National Center for Atmospheric Research, the National Oceanic and Atmospheric Administration, the Woods Hole Oceanographic Institute, the Constellation Observing System for Meteorology, Ionosphere, and Climate and the University of Colorado at Boulder.

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