Effectiveness of VSL Signs in Reducing Crash Rates on Roadway Construction Work Zones in Alaska

Osama Abaza, Tanay Datta Chowdhury

***Abstract*—**As a driver's speed increases, so does the probability of an incident and likelihood of injury. The presence of equipment, personnel, and a changing landscape in construction zones create greater potential for incident. This is especially concerning in Alaska, where summer construction activity, coinciding with the peak annual traffic volumes, cannot be avoided. In order to reduce vehicular speeding in work zones, and therefore the probability of crash and incident occurrence, Variable speed limit (VSL) systems can be implemented in the form of radar speed display trailers, since the radar speed display trailers were shown to be effective at reducing vehicular speed in construction zones. Allocation of VSL not only help reduce the 85th percentile speed but also it will predominantly reduce mean speed as well. Total of 2147 incidents along with 385 crashes occurred only in one month around the construction zone in the Alaska which seriously require proper attention. This research provided a thorough crash analysis to better understand the cause and provide proper countermeasures. Crashes were predominantly recoded as vehicle-object collision and sideswipe type and thus significant amount of crashes fall in the group of no injury to minor injury type in the severity class. But still 35 major crashes with 7 fatal ones in a one month period require immediate action like the implementation of the VSL system as it proved to be a speed reducer in the construction zone on Alaskan roadways. In addition, other measures need to be taken into consideration as well.

***Keywords*—**Speed, Construction zone, Crash, Severity

I. Introduction

Variable speed limit message sign (VSL) is an effective measure not only in maintaining traffic speed and limit delays but also to ensure safety as well particularly at construction work zone sites of roadway. Diverse studies indicated that 10-17% of all traffic congestion was responsible due to work zones activation on the roadway [1], [2]. Moreover, comparison of crashes from pre-work zone period to work zone continual period demonstrated inclination of crashes from 7 to 119% suggesting requirement of a measure such as VSL [3]. VSL, a prominent part of Active Traffic Management System (ATMS), considered as a widely used system in European nations as well as in U.S [4].

Due to Alaska's severe winter weather, most construction within the state is restricted to summer months. Summer also comes with the state's peak annual traffic volumes due to tourism and more people taking part in outdoor activities at that time. The larger traffic volume and road construction coinciding creates potential for conflict, worsened by drivers speeding through construction zones. To combat this, the Alaska Department of Transportation and Public Facilities (DOT&PF) has implemented portable variable speed limit (VSL) feedback systems, consisting of a radar speed detector and an electronic LED display that provides real time feedback to the drivers. The programmed speed limit may be adjusted to suit the construction site's needs, and flashes to indicate to when a driver is speeding in order to alert the driver.

II. Research Significance

Because a VSL system may lessen the issue of speeding through construction zones and therefore lessen the crashes associated, determining its effectiveness in cold region like Alaska is necessary. The purpose of this study is to determine the effectiveness of the VSL systems for use in construction zones in Alaska. This research helps the DOT&PF on decisions to invest more resources in using this system. In addition, this will give DOT&PF a basis for future crash frequency and severity reduction measures, and speed limit compliance in work zones. This is accomplished by doing a spot speed study on free-flowing traffic to see if traffic is following the current posted speed limit along with the double traffic fines signs. In addition to reading the speed of drivers on the road and relaying it back to them, the VSL also records the speed of individual vehicles pass the work zone.

III. Literature Review

The VSL system has been used in past applications addressing the effectiveness of the VSL device within a construction zone environment similar to this project. Based upon past research studies, the VSL system has proven to be effective compared to using static speed limits; which are sometimes not credible for the motorists because they cannot reflect up-to-date roadway conditions, traffic flow conditions, and construction activities [5-8]. Average speed limit declined by about 8.5 mph in a work zone in Massachusetts after installation of portable variable massage sign where insignificant changes in mean speed was observed while comparing before and after period study of static signage [9]. Various factors such as number of lanes, lane widths, curvature, lateral clearance, variable speed limit signs (VSL), speed monitoring and displays, flaggers and law enforcement are usually affect the speeds of the vehicles passing the construction zone[10].

Speed is an important character to address for ensuring safety as well as overcoming crashes. The more vehicles following the average speed limit, the less crashes will held in the roadway

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[11]. So, in that case, VSL which usually maintain an updated speed limit may be an effective tool to encounter crashes and congestion in the work zones as well. Mean speed, median speed, 85th and 95th percentile speed and speed variance on free flow speed of the vehicles were considered strategies to manage speed data in the construction zones of the roadway [12]. Construction works in the roadway simply have a statistically positive influence in reducing speeds of about 3.5 to 2.2 mph in Missouri work zones though vehicles speeds were found higher than the posted speed limits [13]. Implementation of VSL in the construction work zones not only decrease the speed and delay but also improve the traffic flow efficiency [14-16]. Reduction of speed limit of 10 mph from the free flowing speed of vehicles (before construction started) at construction zones not only observed with decline mean speed but also with higher speed variance as well [17].

From the Measure of Effectiveness Criteria (MOEs) such as mean speed, travel time, 85th percentile speed, speed variance and percentage of higher speed vehicles, the data collected in Lansing, Michigan of a VSL system placed in a work zone proven to be effective as by increasing the speed limit compliance, increase the credibility of the speed limits, improve safety, and improve traffic flow in the work zones [5]. Similar research studies in Canada, installing VSL device in work zones proved to be effective in reducing the mean speed between 7.8 km/h to 11.6 km/h (7.2 mph) and the 85th percentile speed between 6.0 km/h to 11.2 km/h (7.0 mph) from the original speed limit [18]. Variable message sign is predominantly used in eliminating congestion as well as queue length along the construction work zone arena. Though there was no consistent result of eliminating queue length was found for weekdays evening peak hour but impressive outcome showed regarding lowering congestion in form of terminating queue length at weekend peak hours [19]. In a questionnaire study [20], it was proved that motorist favored simple and reliable information of VSL signage in the construction zones of roadways. Though quantitative speed analysis in work zones at UAE highlighted insignificant reduction in speed after installation of portable variable message sign but qualitative survey analysis from both drivers and workers showed positive attitude towards variable message sign for safety concerns [21]. The presence of a dynamic speed limit VSL system in work zone environment alerts drivers to follow the speed limit and ensure safety more effectively and efficiently than a static speed limit.

Safety as the first and foremost driving criteria for implementing VSL along the construction work zone of the roadway. Analysis of accidents at 79 working zone spots around seven states of U.S. not only highlighted the 69% of those studied spots experienced inclination of crash rates but also 24% of those having increased of crash rates 50% or more [22]. Different studies [23, 24]; indicated that work zone at roadway encounter more accidents than the non-work zone locations. Even Work zone road way recoded with significant amount of fetal crashes than non-work zone [25]. A study [26] confirmed that speeding was the prime reason of making the work zone roadway vulnerable for fatal accidents. Another study [27] revealed that rural work zone with speed limit ranges from 51-70mph along with complex geometric condition were identified as greater risk for fatal accidents. Crash analysis at work zone of some European region such as Germany, United Kingdom, Netherlands and Finland showed declination of crash rate from 8 to 30% after installation of VSL at the respective sites [4, 28]. Crash analysis at three different spot at Texas suggested the decrease of accidents amounts except the site at San Antonio after the VSL was introduced at the construction zone of roadway [29]. In addition, crash severity was also declined to minor injuries from fetal crashes as well [29].

In summary, Drivers as well as construction workers favor VSL signage system for ensuring safety around the construction zones of the roadway. As VSL was proved to be a unique component for reducing speeds in the work zones thus it can be an effective application for a region like Alaska as well. The before and after period (installation of VSL) comparison of speed data at the construction zones may provide a scenario of applicability and effectiveness of VSL in Alaska. Mean speed, 85th percentile speed and variation of speed in the work zone of roadway may be used as implicit criteria's for measuring effectiveness of VSL. Crash frequency, crash types and severity along the work zone arena of roadway at Alaska may provide a greater outlook of safety requirements such as VSL if needed.

IV. METHODOLOGY

In order to evaluate the effectiveness of VSL systems in construction zones in cold region like Alaska, a typical Before-and-After study of speed data at a particular construction zone was conducted by a research team from Civil Engineering Department of University of Alaska Anchorage [30]. The "Before" condition represents a temporary highway construction zone without the use of a speed display system. The "After" condition represents the same temporary construction zone with the placement of a speed display trailer. The statistical difference determines the effectiveness of VSL system. Both the mean speed and 85th percentile speed were used as measurements to determine effectiveness of the system. A statistical analysis was then conducted to verify that the results are significant or not. The purpose of this is to verify that any resulting speed reduction is real and did not occur because two different samples were selected from an underlying distribution that did not change [31].

Speed data for this study was collected from the Parks Highway Milepost 44-52 Church Road to Big Lake Road construction project as a representative of a typical construction zone for the purpose of a VSL system evaluation as shown in Figure 1. During the project, both temporary speed signs and a radar speed display trailer were used intermittently. Figure 1 shows the location of the project site.

Vehicle speeds for the "Before" condition were collected using a Doppler radar speed gun, and 112 samples were recorded for this condition. The "After" condition data was collected using a portable radar speed display trailer. A day and time with similar road conditions and the same posted speed was chosen for comparison. 378 samples were recorded for this condition. It was determined that the “before” condition needed a minimum sample size of 39, while the “after” condition warranted a minimum sample size of 96. Since both of these minimums were fulfilled, no additional data collection was required.

Fig. 1 Construction work zone location

In order to justify the need of any measures like VSL at the work zones at Alaska, it was an initiative taken to have the overview of recent violation and crash condition. Alaska Department of Transportation and Public Facilities (DOT&PF) provided the necessary data of violation and crashes over the work zone arena along the roadway of Alaska. In a region like Alaska, summer is the suitable time for construction and maintenance work around the roadway. Based on this perspective, Comparative analysis of diverse type of violation, crash type and crash severity was analyzed by considering the month of June, 2017. For a proper outlook of crash condition around work zone in Alaska, crash type frequency and crash severity can be an effective choice. Most frequent violation type which were cited should be taken into account to identify whether any measures should be taken regarding speed related activities. Consequently, the more violation, the more crash or severe severity will occurred. In addition, crash type will provide information regarding identifying the most vulnerable or frequent types among all in the work zones of Alaska. Moreover, Severity types will enable reader to have an idea about the extent of severity types around the work zone. In an essence, violations and crashes will provide a greater ground for the need of preventive measures such as VSL or not.

V. Data Analysis and results

The speed data of before and after implementation of VSL sign at the respective construction zone was represented in figure 2 and 3 respectively. The 'before' data represented the variation of speed ranges from around 40-60 mph in that study area. The frequency distribution of speed ranges as shown in figure 2 follows a traditional bell shape distribution representing normal distribution of the speed data's. After the application of VSL, the speed of the vehicles were much more in the form of fluctuation rather than previously (before study) as presented in figure 3. In addition, the 'after' study frequency distribution shown in figure 3 of speed ranges are representing right skewed distribution instead of normal distribution.

Due to the need for only free-flowing vehicle speeds, the lower-end vehicle speeds from the 'after' study were removed from the data set, as these speeds representing vehicles that were unable to drive freely and were inhibited in traffic stream under forced speed. In order to justify the removal of data and to determine the extent of data that is to be removed, the normal distribution was considered since nearly all statistical analysis of traffic data operates under the assumption that vehicle speeds naturally fall within a normal distribution and the free flow speed is best representing driver's choice of speed in work zones. The chi-square test was used to determine whether the difference between an observed distribution and its assumed mathematical form was significant or not. The observed data for before and after study was first tested using a 95% confidence bound. As expected, the results laid well outside for 'after' study whereas 'before' study perfectly fitted with the normal distribution. The lower-end speed data for the after study was then removed through an iterative process until the remaining data was within a normal distribution with 95% confidence. Through this process, it was determined that vehicle speeds of 39 mph or higher lie within the normal distribution and were thus usable, free-flowing speeds. The corrected data through this method is presented in figure 4.

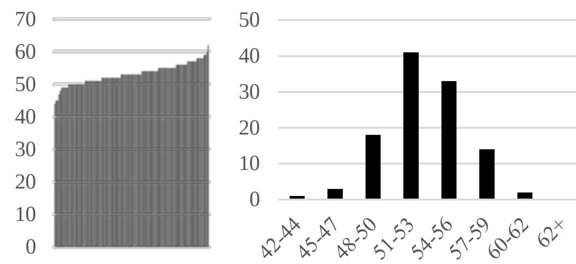

Fig. 2 a) Speed data b) frequency distribution interns of speed range before VSL application

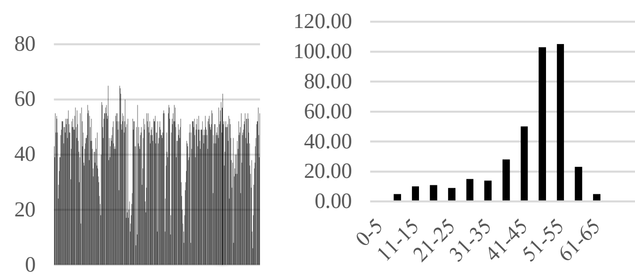

Fig. 3 a) Speed data b) frequency distribution interns of speed range after VSL application

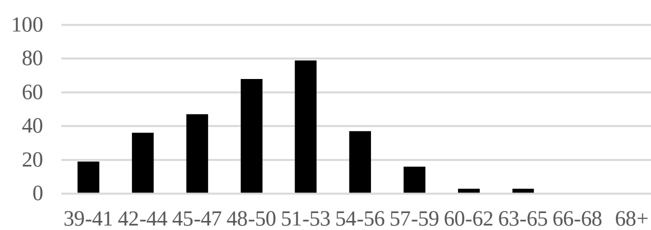

Fig. 4 Frequency distribution of adjusted speed data after VSL application

For measuring the effectiveness of VSL along the construction zone of roadway, the two samples of speed data of 'before' and 'after' were tested to reveal whether there was any statistically significant change exists. The summery of the results were presented in table I.

The results indicated (table I) an overall positive change towards addition of VSL along the roadway. The mean speed observed a reduction of 3.5 mph and the 85th percentile speed received a 1.0 mph reduction. Both reductions were determined to be statistically significant at the 5% significance level. The radar speed display trailer's impact on speed is considered effective; this is because the 85th percentile speed is within the posted speed limit. The overall percentage of vehicles speeding, between the before and after condition, decreased by over half, showing improvement; however, the overall percentage of vehicles within the pace also decreased, indicating a greater variation in speed for the after condition. This is also indicated by the greater differences between the minimum and maximum speeds. Based on the above analysis, it was evident that VSL was an effective measure to reduce the speeding as well as speeds of the vehicles around the construction zone of roadway.

TABLE I
BEFORE AND AFTER SUMMARY RESULTS

Elements to consider	Before	After	Change
Sample Size	112	308	
Posted Speed Limit	55mph	55mph	
Standard Deviation	3.2	5	
Min/Max speed in mph	44/62	39/65	
Pace(mph) / % in pace	48-58/92.7	45-55/ 73.2	
% of speeding vehicles	21.8	9.4	
Mean Speed (mph)	53	49.5	-3.5*
85th percentile speed	56	55	-1*

* Statistically significant at 5% significance level

According to citation data provided by Alaska DOT & PF summer project at different work zone around Alaska, Speeding was most a common violation around the work zone consisting of about 1254 violation (58.41%) from the overall 2147 violation recorded. Proof of insurance and equipment violation was also found significant amount comprising about 22.31 and 10.62 percentage respectively. In addition, small amount violations such as "not wearing seat belt", careless driving and disregarding stop sign was also recorded as 4.94%, 1.44% and 1.304% respectively.

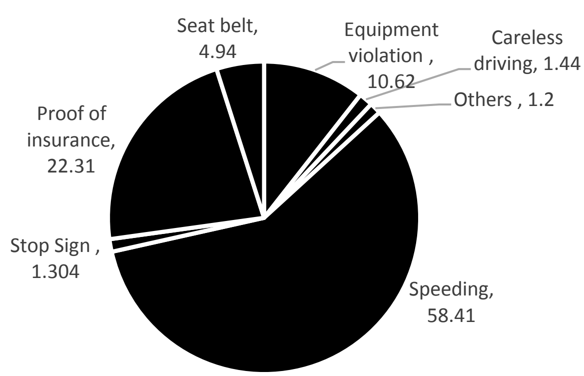

Fig. 4 Percentage of diverse type of violation recorded in the month of June, 2017 in Alaska

Total of 385 crashes of different types were documented at the work zone around Alaska at the month of June, 2017 (fig. 5) based on the Alaska DOT&PF crash data. Among the total amount of crashes, 117 (30.4%) were recoded as the collision of vehicles with other objects rather than vehicle-vehicle collision. Sideswipe also found as predominant amount such as more than 100 over the whole crash type scenario. Moreover, Angel and front to rear wheel crashes were documented at an amount of 63 and 34 respectively.

Based on one month of observation, 7 fatal accidents were recorded around the work zone regions of Alaska whereas around 44% (168) were recoded as no injury in the class of severity type of crashes presented by fig. 6. As the crashes were more or less not in the verge of serious accidents, minor or possible injury were recoded (89) more than the major injury (28) around work zone. Though crashes were more towards minor or no injury type but total of 35 crashes with both the fatal and major type which were happened in a one month period around the work zone of Alaska.

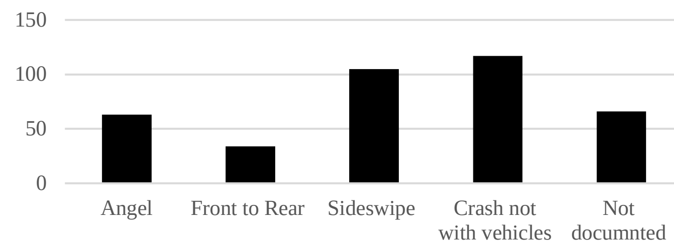

Fig. 5 Number of different type of crashes recorded in month June, 2017 at Alaska

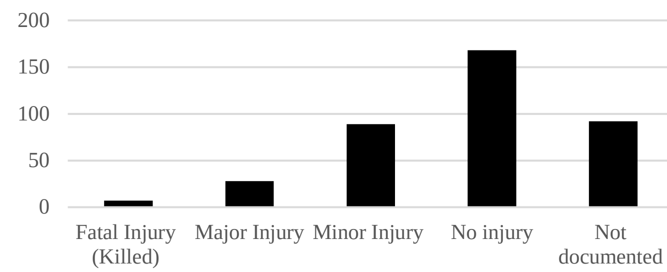

Fig. 6 Number of crashes interns of severity types recorded in month June, 2017 at Alaska

Based on information from Federal Highway Administration (FHWA), in United States total of 49,623 and 87,606 work zone crashes were recorded in the years of 2004 and 2010 respectively [32-33]. According to National Work Zone Safety Information (NWZSIC), annually average work zone fatal crashes were identified as about 778 for ten year period from 2004 to 2013 [34]. Crash analysis of Kansas work zone sites revealed that around 1000 crashes were recorded throughout the year of 2014 where PDO (property damage) and injury crashes were predominant in amount [35]. But overall, for a state Kansas, 411 total fatal crashes with nine fatal work zone crashes occur in each and every year [35]. In addition, many of the researches agreed that rear end, sideswipe and hitting fixed objects are more common collision type around work zone regions of the roadway [36- 41]. In comparison to these data with one month period of crash data of Alaska made the total scenario more complex and intricate and need more attention regarding counter measures. Though, one month period data is not sufficient to conclude with a decisive decision but 2147 citation of violation with 385 crashes (7 fetal) identified the Alaskan's roadway work zone as vulnerable and dangerous for driving. In addition, the significant frequency of crash type such as vehicle-object and sideswipe collision in Alaska roadway work zone also support the previous researches as well. As, speeding was found as the prime contributor in violation data thus effective measures like VSL might be an efficient tool to decrease the speeding of vehicle as well as reduce crashes around work zone regions of Alaska.

VI. Conclusions and Recommendations

In an attempt to reduce crashes and congestion in construction zones, the Alaska Department of Transportation and Public Facilities (DOT&PF) has implemented a Variable Speed Limit system (VSL). The purpose of this study is to determine its effectiveness in reducing speed through these zones. This was accomplished by conducting a before-and-after speed study, in which two separate speed studies were conducted. It was determined that radar speed display trailers are effective at reducing vehicle speeds in construction zones. As statistically shown, not only the mean speed and the 85th percentile speed significantly decreased but also speeding vehicles and pace were also reduced. For investigating the work zone condition around Alaska, recent crashes and incidents were taken into account. Huge amount of incidents (2147) with 385 crashes were observed around the work zone arena in a month. Speeding was found as the prime factor contributing towards occurring incidents around work zones. In addition, Vehicle- object collision and sideswipe type were more prominent in the work zone arena than Angel or front to rear collision type. Though severity of crashes displayed significant amount of no injury and minor injury but 35 major crashes in a one month period flipped the concentration towards it. Therefore, in order to reduce the number of speeding vehicles along with crashes, the VSL systems can be implemented, in the form of radar speed display trailers, as an effective tool.

While this study has indicated that VSL systems can be implemented as an effective tool in reducing speeds in construction zones, certain conditions at the time of data collection should be taken into consideration. During the before-and-after study, the before conditions were conducted when a light shower of snow sprinkled along the surface of the pavement. This caused the roadway to be icy which may have caused drivers to slow down even more within the work zone area. This was not the case with the “after” data, which was taken under acceptable conditions. The original before-and-after speed data is statically effective, but by recollecting the speed data for the before condition in an ideal situation, the study’s accuracy could be improved. The data would be expected to have a wider speed differential under ideal conditions, indicating greater effectiveness of the portable radar speed display trailer. Comparative comparison of before and after implementation of VSL Crash history may be an effective tool to identify the effectiveness of the system in a wider prospect. Furthermore, additional studies should be conducted on a wider range of construction projects to verify the results.

Acknowledgment

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