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In-Service Evaluation of Culvert Extensions

tech transfer summary

This study assessed the potential impacts of installing various safety treatments to mitigate the frequency and severity of crashes in which an errant vehicle strikes a culvert and included evaluations of the cost-effectiveness of these safety treatments as compared to the baseline do-nothing scenario.

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RESEARCH PROJECT TITLE
In-Service Evaluation of Culvert Extensions

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Project Objectives

The main objectives of this study were to determine the risk of crashes involving roadside culverts and to assess the potential impacts of installing various culvert safety treatments to mitigate crash frequency and severity. A related objective was to evaluate the cost-effectiveness of these treatments.

Background

Nearly 40,000 fatal crashes occur every year in the US, and about one-third of these fatalities involve a vehicle striking a roadside object, such as a culvert, tree, or utility pole. Culverts, specifically, are placed on the roadside to allow water to flow under a road or railroad from one side to the other. Given that culverts are often placed close to the roadway, they may increase the likelihood for a crash to occur or increase the crash severity.

The American Association of State Highway and Transportation Officials *Roadside Design Guide* (RDG) suggests some safety treatments to reduce hazards from these structures (i.e., redesign using a traversable design, extend the structure outside the clear zone, shield the cross drainage structure).

Problem Statement

Current design manuals direct designers to specific safety treatments; however, a more thorough analysis is needed to also evaluate their cost-effectiveness.

Research Summary

After a thorough review of current state design practices, the researchers extracted culvert-related information from various resources provided by the Iowa Department of Transportation (DOT), such as their crash, geographic information management system (GIMS), and culvert databases, to determine the risk of crashes involving roadside culverts, while also performing benefit-cost analyses to assess the potential impacts of installing the various safety treatments for culverts. The study also involved a survey of state DOTs, highlighting current practices adopted by other agencies throughout the US regarding culverts.

Research Description

An extensive literature review was conducted to first identify potential safety treatments for protecting errant vehicles from striking roadside culverts, as well as studies documenting the efficacy of such treatments. These treatments included shielding culvert openings using safety grates, protecting culverts through the installation of longitudinal guardrails, and extending culverts outside the clear zone.

In addition, a questionnaire survey was sent to other state DOTs to document current design practices as they relate to the use of various types of culvert safety treatments.

The research team conducted an in-depth evaluation of the existing culvert database provided by the Iowa DOT. Subsequently, the culvert database was filtered to isolate only cross drainage culverts. An attempt was made to identify all crashes related to culverts. This was done through a review of standard fields on the Iowa crash report form, as well as through a review of pertinent keywords from the narrative section of the forms. These crashes were then linked to the nearest cross drainage culvert, which was associated with the nearest road segment on the primary (state-maintained) road network.

After removing culverts with unknown lengths or diameters, the final data set included 500 crashes that occurred at 481 culverts between January 2007 and August 2017.

The first stage of the analysis involved the estimation of culvert-involved crash rates for different highway types. But given concerns related to the spatial accuracy of crash data with respect to culvert location, as well as concerns with respect to the underreporting of culvert-involved crashes, the second stage of the analysis involved the use of the Roadside Safety Analysis Program (RSAP), which is an encroachment-based software program developed under the National Cooperative Highway Research Program (NCHRP) Project 22-09. This software can be used to estimate the expected crash costs associated with various highway scenarios.

A series of scenarios were evaluated, culminating in guidance as to the most cost-effective treatments for different combinations of roadway geometric and traffic characteristics. Information regarding installation and maintenance costs were obtained from the Iowa DOT and several online resources. A total of 225 different models were designed in RSAP based on the highway system, culvert sizes, different average annual daily traffic or AADT, and culvert offsets.

Key Findings and Conclusions

Ultimately, the results of this study suggest that the installation of safety grates on culvert openings provides a promising alternative for most of the cases where the culvert is located within the clear zone. Grates are expected to reduce the level of injury sustained by crash-involved occupants, as well as the associated crash costs, resulting in a higher benefit-cost ratio.

The installation of safety grates was found to be the most economical choice for most highway types and for different culvert sizes in the analyses. This is mainly because of the large reductions in crash costs and low installation and maintenance costs as compared to other alternatives.

Specifically, in the case of two-lane 55 mph undivided highways, different types of culverts suggested the use of different treatments. For small pipe crossing culverts, culvert extensions were preferred for offsets less than 20 ft when compared to other alternatives. For medium pipe and box culverts, both displayed similar trends where the majority of the cases suggested that installing safety grates would be more effective as opposed to other treatments or the base case. As for large box culverts, most of the cases preferred the base case (do nothing) when the culvert offset was beyond 14 ft.

Then, for four-lane, 70 mph, divided highways, the majority of cases suggested that safety grates were the most cost-effective treatment compared to other alternatives. The analysis of this facility type showed that safety grates were also preferable for small pipe crossing culverts and small pipe median culverts for all cases. The same was true for medium pipe crossing culverts and medium box crossing culverts.

Implementation Readiness and Benefits

The findings of this research may benefit designers as they choose between varying safety treatments as they relate to overall cost-effectiveness.

In addition, in future research, each culvert from the list compiled as a result of this study can be modeled separately in RSAP. This way, the simulations will give more accurate results, and safety treatments can be chosen thereafter based on individual results.

Limitations and Future Work

There are several limitations that can be addressed through future work or to changes in the manner in which the Iowa DOT maintains its culvert inventory data. One of the main limitations of this project was the degree of missing or incomplete information in the culvert database. This required an extensive quality assurance review and some manual investigation to fill in missing data where possible. Ultimately, about 10 percent of the culvert sizes were missing from the analyzed data, which resulted in a limited sample for specific categories of culverts.

Another limitation of this study was due to the fact that the crash information provided for this study was based upon information in police crash reports. There were likely numerous cases where a crash occurred with a culvert but was not reported. Generally, these unreported crashes tend to be less severe and, as such, the number of crashes predicted under various scenarios using RSAP is higher than what was shown by the in-service evaluation.

The installation costs provided by the Iowa DOT for safety grates was a general figure that was not associated with a specific size of grate. The costs for different sizes of safety grates were found in an online source. The maintenance costs for culverts and safety grates were found through literature review; however, these costs did not have a size associated with them either. Therefore, the same maintenance costs were used for all culverts and all safety grates irrespective of their sizes.

Another limitation is related to the RSAP software and the underlying data upon which the program is based. The run-off-road crash frequencies generated by RSAPv3 are based on the encroachment data collected in the 1970s in Canada, and there are some ranges of volume and geometric conditions in which data are sparse. An ongoing NCHRP study (NCHRP 17-88) is aimed at updating these data, which may provide improved predictive capabilities.

In the analyses performed in this study, it was assumed that the maintenance costs for culverts, safety grates, and guardrails remained the same for varying lengths and sizes. With a better data set having the accurate installation and maintenance costs with varying sizes for culverts and safety grates, it would be interesting to see how these results vary.

Currently, the culverts were combined into groups based on highway classification, speed limit, number of lanes, median type, and culvert sizes. In future research, each culvert from the list of those 547 culverts can be modeled separately in RSAP. This way the simulations will give accurate results and safety treatments can be chosen thereafter based on the individual results.

In the data collection part, the distance to the nearest culvert was chosen as 500 m, keeping in mind the conditions where the vehicle would have struck the culvert and still continued to travel up to some distance before coming to a stop. For such crashes, it would be better to know the exact location of the culvert to trace the right culvert back for safety evaluation.