Developing Implementation Strategies for Risk Based Inspection
Progress Report – 10/16/2023

Project Number: TR201910

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Co-PI(s): Henry Brown

Award date:	11/1/2018		
Scheduled completion date:	**3/31/2024**	**% of project completed to date:**	**85%**
Total budget:	$850,000	**% of budget expended to date:**	**80%**
Draft report due:	8/31/2023	**Final report due:**	10/31/2023

Dates should match those listed in the contract. If unsure, contact your MoDOT project manager.

Noteworthy items achieved this quarter. *Provide a 4-5 sentence summary of work completed this quarter. Include meetings, work plan status, significant progress, etc. Additional details can be included in "Additional project information" below.*

Back-casting and updating of risk model spreadsheets were completed for participating states in the previous quarter. Analysis of these data did not provide the expected insight regarding weighting the models to be effective given the FHWA guidelines for RBI. The sensitivity studies that were completed provided some insight regarding if the RBI models would be effective, but the population of bridges used for backcasting, which were randomly selected, did not provide consistent results. To address this issue,the research team (RT) developed a different approach to weighting the models using a Monte Carlo (MC) simulation process. As part of that process, NBI element-level data and component-level data from state-owned and NHS bridges was analyzed to assess the criteria for attributes in the risk models and provide appropriate weights. Using those data, a MC simulaton process was developed that allows for weights of different attributes to be effectively modeled. This provides the needed tool to complete the risk models and efforts are ongoing to complete this modeling for each of the participating states' bridges and RBI models. This process is still on-going, but results to date of the MC process is more effective for providing weighting for the RBI models. See additional information.

Anticipated work for next quarter. *Provide a 4-5 sentence summary of work planned for next quarter.*

In the next quarter, the MC analysis will be completed and a back-casting report will be developed and distributed to participating states. The report being developed includes

that original back-casting results utilizing the original set of bridges, which generally did not provide suitable results due to relatively low condition ratings for many of the bridges. The RT plans to select additional bridges that meet the guidance provided by the FHWA and will be more effective for verifying the RBI models. The RT will be contacting participating states to pursue getting additional inspection data for a set of five bridges that have components with condition ratings (CR) for primary components of 7 such that the bridges would represent the population of bridges that would meet the FHWA guidance. These new bridges can be analyzed quickly to verify the models developed through the study.

Identify any circumstances or issues that may need to be addressed. *Provide a summary of issues that are important for the TAC to know. For example, staffing difficulties or supply chain delays.*

The research progress met a challenge with the back-casting because the condition of bridges selected randomly did not produce results that could be applied to the emerging guidance for applying RBI to only bridges with CR 7 (for a 72 month interval). A significant effort to develop a methodology using the original set of bridges was not successful. That outcome required a different approach to be developed which has taken some time to develop and implement. To address this issue, the RT is developing a back-casting report with the original results and the newly developed MC process, and seeking some additional bridges that are in good condition (i.e., CR 7) to test the RBI models once the weighting process is complete.

Deadline for next deliverable. *For example, quarterly report, draft report, presentation, etc.*

Back-casting report **10/31/2023**

Additional project information that MoDOT and technical committee should know.

The original back-casting process examined the inspection histories of 10 randomly selected bridges from each state that had developed RBI models. Inspection records over 10-20 yrs were studied to score the risk models and determine if these models would be effective for estimating suitable inspection intervals. However, the bridges included many bridges with CRs 5 or 4, and sometimes limited and/or inconsistent data on the conditions (e.g., cracking, spalling) that caused the low condition rating. As a result, the analysis did not provide insight if the risk models would be effective despite a number of different approaches attempted. Ultimately, a different approach was needed and this was developed beginning in the previous quarter and through this quarter.

In summary, this approach uses the actual element-level data provided for NHS bridges to develop probability matrices the relate the CRs of a bridge component (i.e., deck, superstructure, substructure) with the CS that represents deterioration/damage in that component. For example, and CR 7 deck is unlikely to have >5% CS 3 damage, whereas a CR 5 bridge is much more likely to have CS 3 damage of > 5%. Developing such a probability matrix for each attribute allows for a MC simulation that provides a quantitative estimate of the outcome of the model when applied to CR 7, CR 6, and CR 5 bridges. In this way the model is applicable for a given bridge inventory as required, even though the extended interval of 72 months can only be applied to CR 7 bridges.

An example result is shown below for a bridge deck using one of the risk models developed through the study. Figure A shows the results from the original risk model, which indicates that approximately 68% of CR 7 bridges would have a "remote" likelihood that would enable a extended interval of 72 months, while only 41% of CR 6 bridges and 14% of CR 5 bridges would have a "remote" likelihood according to the model. Figure B shows the results of the weighted model showing the effect of increasing the weight of condition-related attributes of CR and condition state (CS). The weighting results in about 80% of CR 7 bridges being rated as remote while only about 4% of CR 5 bridges are rated as "remote." In this way, the process can quantitatively assess the effect of weighting different attributes and illustrate the expected outcome, and demonstrates how the model applies across a given inventory. It should be noted that the models are based on actual data from an individual state's inventory for attributes such as CS, ADT, ADTT, etc. based on data for NHS bridges, with some engineering judgement used where data was unavailable. Most of these data are available from existing databases containing element-level data and NBI/SNBI data, and consequently can be implemented from existing data. It should be noted that the risk model would apply to non-NHS bridges in practice, once the weighting of the model is completed.

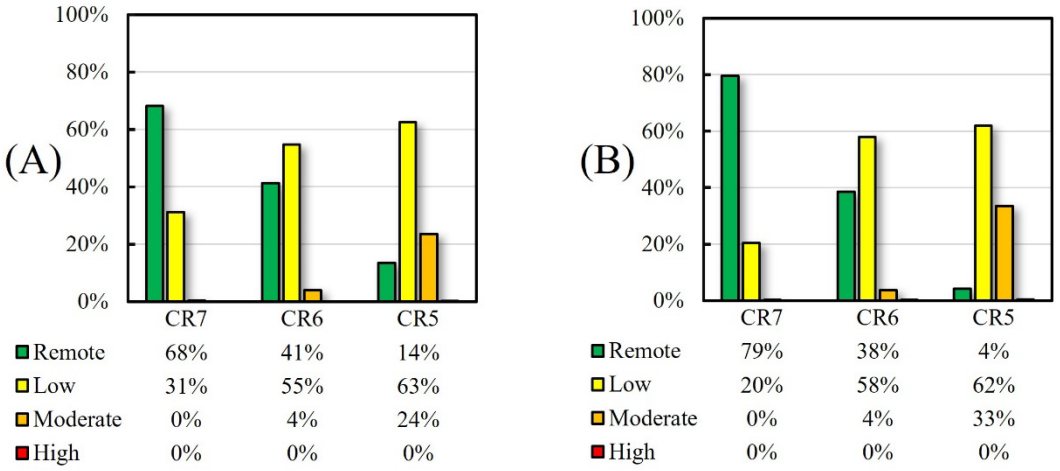

Figure 1. Results from a MC simulation of risk model results for a deck component, showing the original risk model (A) and a weighted risk model (B). .

The process is relatively simple to implement in a spreadsheet program such as Excel, and does not require extensive expertise or special knowledge. These models are data-driven and effectively illustrate how the risk models will behave when implemented. The models are taking some time for the RT to complete given the number of different risk models being considered in the study, but is not time consuming to implement in practice since most the data is already available in databases of owners.