# Concrete Bridge Deck Service-Life Prediction Tools

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Many of our nation's bridges have aging decks, and bridge owners are struggling to keep these decks in satisfactory condition. Bridge decks directly support vehicular and truck traffic and have large surface areas that are exposed to the environment, which makes them among the most difficult bridge components to maintain. Bridge owners are constantly searching for ways to build and maintain long-lasting decks. The research project described in this article used the National Bridge Inventory (NBI) database to study concrete bridge deck performance and develop probabilistic service-life prediction tools which may assist owners in maintaining their concrete bridge decks.

## Nationwide Concrete Bridge Deck Performance Inventory

The NBI database includes data on every highway bridge on public roads in the United States (615,002 bridges in the 2017 edition). After filtering this massive database, researchers found 150,136 suitable concrete bridge deck service-life data strings between the years of 1992 and 2014.

There are 116 data fields for each bridge in the NBI. The researchers identified 21 parameters and computed four others that offer useful service-life data. These 25 parameters were compiled for each of the 150,136 service-life data strings to develop a database that the researchers titled the Nationwide Concrete Highway Bridge Deck Performance Inventory (NCBDPI). **Table 1** lists 18 parameters; 14 that came from the NBI and are included in the NCBDPI, and the four others were computed from NBI data.

## Time-in-Condition Rating

The bridge deck condition rating (CR), NBI item 58, provides a numerical assessment of the bridge deck's condition on a scale from 0 (failed condition) to 9 (excellent condition). This assessment is typically made by visual inspections in which inspectors use indicators such as cracking, spalling, leaching, delamination, and full or partial-depth failures to assign a CR. The researchers identified a string of unchanged condition rating assessments occurring over multiple years as a time-in-condition rating (TICR). Therefore, TICR is defined as the duration of time in years that a CR remains constant before it decreases, indicating further deterioration. Sample CRs for three hypothetical concrete bridge decks for the period from 1992 to 2014 are shown in the figure on the opposite page. A TICR can be visually identified in the figure as any plateau in the data string.

**Table 1. Nationwide Concrete Highway Bridge Deck Performance Inventory (NCBDPI) Parameters and Data Sources**

| NCBDPI Parameter | Data Source or Corresponding National Bridge Inventory Location |
|---|---|
| County (parish) code | Item 3 |
| Structure number | Item 8 |
| Maintenance responsibility | Item 21 |
| Functional classification of inventory route | Item 26 |
| Lanes on structure | Item 28 |
| Structural material/design | Item 43a |
| Type of design and/or construction | Item 43b |
| Deck condition rating (CR) | Item 58 |
| Designated inspection frequency | Item 91 |
| Deck structure type | Item 107 |
| Type of wearing surface | Item 108a |
| Type of membrane | Item 108b |
| Deck protection | Item 108c |
| Average daily truck traffic (ADTT) | Item 109 |
| Deck area | Item 49 × item 51 |
| Climatic region | Assigned using the IECC |
| Distance to seawater | Calculated based on coastline and bridge location items 16 and 17 |
| Bridge age | Based on items 27 and 106 |

Note: IECC, *International Energy Conservation Code*. Table: Federal Highway Administration.

The ideal service-life TICR data string falls completely within the time boundaries of the research period (1992–2014) and shows no anomalies such as gaps or sudden drops and rebounds in the CR value. A significant proportion of TICR data (approximately two-thirds of the CR from the NCBDPI database) is "censored," meaning that the plateau forming the TICR is only partially observable. A key attribute of this research was the proper treatment of censored data. Examples of censored and uncensored TICR strings for the three hypothetical bridge decks are shown in the figure. Discarding censored data or treating them as uncensored data would introduce significant bias. In contrast, the approach used by the researchers resulted in a more robust and accurate analysis.

## Bridge Deck Survival Analysis

Survival analysis is routinely used in other industries to analyze data in which the time until an "event of interest," such as death, divorce, or failure of a mechanical part, occurs. In this research, the "event of interest" is a drop in the CR. In this study, a Bayesian survival analysis was used to compute the probability that the CR of a bridge deck with specific characteristics remains unchanged. The analysis results were used to generate survival curves for varying parameters. These survival curves provide practical data in an illustrative graph. The research found that varying the parameters of climatic region, average daily truck traffic (ADTT), maintenance responsibility, and structure type generated the most noticeable changes in TICR survival. An example of hypothetical concrete bridge deck survival curves is shown in a figure on this page. This curve was generated

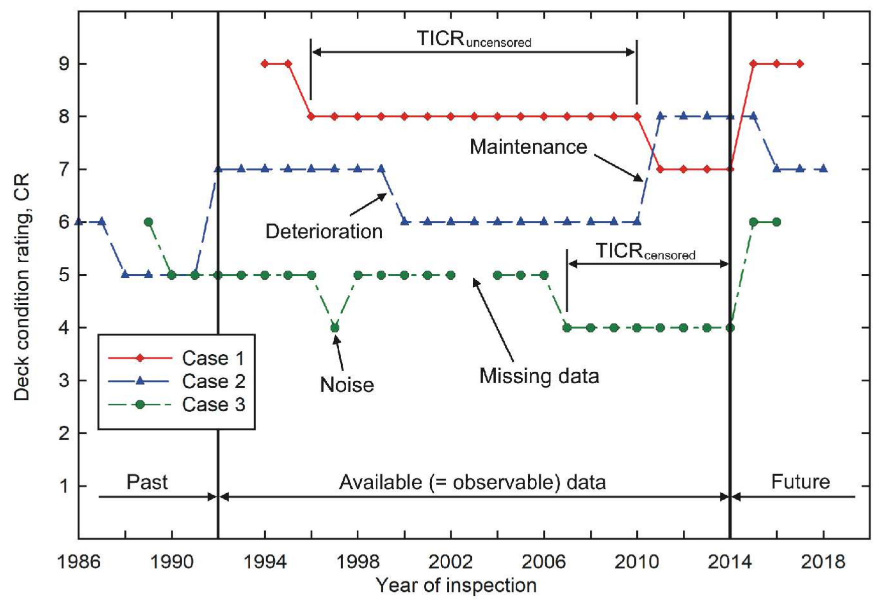
Example of a concrete bridge deck in poor condition. Photo: Dr. Thomas Schumacher.

assuming the following parameters:

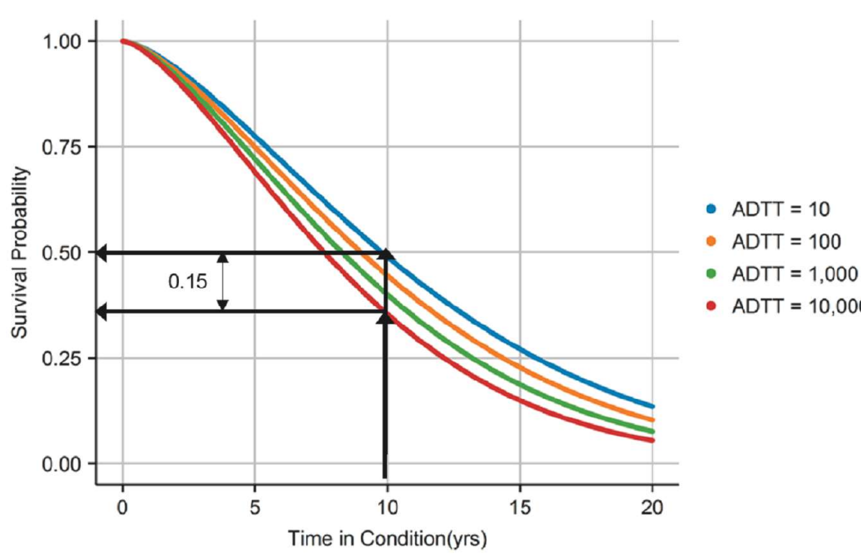
- CR = 7
- Climatic region = cold
- Deck protection = none
- Deck type = concrete: cast-in-place
- Distance from seawater > 3 km
- Functional class = urban
- Maintenance responsibility = state highway agency
- Superstructure type = steel: simple-span

This figure shows the probability that this bridge deck will stay at a CR = 7 (that is, survive) for varying ADTT levels. The curve shows a clear trend: As ADTT increases, the likelihood that the CR for this bridge deck will stay at 7 decreases. Survival curves can be used to answer important questions such as, “What is the change in probability that a bridge deck will stay at CR = 7 with TICR = 10 years if the ADTT increases from 10 to 10,000?” The curve for this bridge deck shows that it has an approximate survival probability of 50% with an ADTT of 10, compared with a survival probability of approximately 35% with an ADTT of 10,000.

The results of this research study are found in a TechBrief titled “Performance of Concrete Highway Bridge Decks using Nationwide Condition Data,” which will be available from the Federal Highway Administration (FHWA).[1] The information included in this article and the posted TechBrief are a result of the FHWA-funded research by Ghonima et al. An internal final report is available online.[2]




Condition ratings (CR) for three hypothetical concrete bridge decks and the determination of time-in-condition rating (TICR). Figure: Federal Highway Administration.




Survival curves for a hypothetical bridge deck for varying average daily truck traffic (ADTT) levels. Figure: Federal Highway Administration.

## References


1. Federal Highway Administration (FHWA). 2018. “Performance of Concrete Highway Bridge Decks using Nationwide Condition Data.” FHWA-HIF-18-082. Washington, DC: FHWA.
2. Ghonima, O., T. Schumacher, A. Unnikrishnan, and A. Fleischhacker. 2018. *Advancing Bridge Technology, Task 10: Statistical Analysis and Modeling of US Concrete Highway Bridge Deck Performance—Internal Final Report.* Portland State University Library. DX Scholar website. https://pdxscholar.library.pdx.edu/cengin_fac/443. Accessed October 25, 2018.