PennDOT BridgeCare Deterioration Modeling 2022

PennDOT BridgeCare Deterioration Modeling

(January 2022)

1. Introduction

PennDOT has developed bridge deterioration models to be used in conjunction with BridgeCare, its bridge asset management forecasting software. This document serves as a reference of how the bridge deterioration curves are calculated. In this document, the deterioration modeling approach used by PennDOT is summarized, followed by a brief explanation of the bridge inspection data used and the effect of work treatment types on the deterioration analysis. The "Condition Rating Duration Prediction" section of this document outlines the steps used to develop the deterioration curves, and the "Core Assumptions" section provides additional detailed explanations that supplement the steps in the "Condition Rating Duration Prediction" section.

2. Modeling Mechanics

After lengthy investigation, PennDOT ultimately decided to pursue deterministic modeling rather than probabilistic modeling for its bridge deterioration modeling methodology. A deterministic model is a mathematical model in which outcomes are determined through known relationships among conditions and events, and is fundamentally different that a probabilistic model, where there are ranges of probabilities given for each outcome. Due to the desire to be able to predict discrete values in the future per structure, PennDOT opted for deterministic modeling.

In deterministic models, all data is known beforehand and the user makes predictions based on this data pool. Regarding bridge deterioration, deterministic modeling predicts future condition ratings based on the stepped nature of the 10 condition ratings and the rates at which bridges moves through previous condition ratings.

PennDOT created general sets of deterioration curves per bridge family to represent these rates of deterioration through previous condition ratings. The deterministic modeling approach was considered to make best use of PennDOT's bridge condition data and was the only methodology that could support individualized treatment recommendations and also be understandable by key stakeholders, including PennDOT's district engineers and bridge engineers.

3. Bridge Data

PennDOT's Bridge Management System 2 database (BMS2) is the Department's system of record for all bridge inspection data and history. Inventory and inspection history data extracted from BMS2 provide attribute information for deck, superstructure, substructure, and culvert components and characteristics of each structure. This data was the starting point for PennDOT's deterioration analysis, and due to a substantial lack of breadth of recorded inspection findings prior to 1995, only condition ratings from inspection records from 1995 to the present are used to create the deterioration models.

Initially, an effort was made to develop deterioration curves that would represent true native deterioration of the bridge components by accounting for the impacts of work performed on the structures. Various information sources were used to link rehabilitation and preservation history to corresponding bridges.

However, the information stored in various systems did not align and was not reliable. The history of preservation, rehabilitation, and maintenance efforts recorded in PennDOT's systems (ECMS, MPMS, BMS2, Morris, SAP PM) is not sufficiently complete and is difficult to account for with each individual bridge. For example, it was difficult to correlate overlay projects and other maintenance history contained within Morris to specific bridges. The locations shown in Morris provide route and section information, but does not contain the segment and offset information needed for identifying specific structures. The incomplete and inconsistent details regarding work efforts make it too difficult to accurately filter out all work types when determining true native deterioration rates of the structures. Ultimately, the Department determined that the level of accuracy in legacy systems was insufficient to directly correlate deterioration curves.

Instead, the Department chose to view the data in a different manner and base its analysis upon changes that have occurred to the condition ratings. Jumps in condition ratings are typically indicative of impacts due to rehabilitations, replacements, and some larger preservation projects and are more easily accounted for in creating deterioration curves. However, impacts due to most preservations and other maintenance work are more difficult to eliminate from the analysis because preservation efforts often only extend the duration of bridge components in a certain condition rating, instead of increasing the rating. Because not all treatments and work types can be accounted for with changes to condition ratings, particularly at the service ends of the rating spectrum of 8-7 and 5-4, the deterioration curves that were modeled do not represent true native deterioration. However, the results obtained have provided the Department with reasonable deterioration curves for implementation in BridgeCare.

4. Condition Rating Duration Prediction (CRDP)

The deterioration analysis was conducted using a method known as "Condition Rating Duration Prediction" (CRDP). The CRDP method determines the statistical duration in years that bridges spend at each condition rating, using the 0 to 9 rating scale of the National Bridge Inspection Standards. This procedure is followed to create deterioration curves for each of the following bridge components: deck, superstructure, substructure, culvert. The method includes the following general steps:

1. **Determine Condition Rating Durations:**

   The first step is to use inspection data to find the duration (time in years) that each bridge has stayed in each condition rating. Inspection data is obtained annually from the 4th Quarter (calendar year) internet reports, which provide a snapshot of the BMS2 inspection data at the time the reports are created. The condition rating durations are determined for each of the following bridge components: deck, superstructure, and substructure. An overall culvert condition rating duration is determined for each culvert structure.

   Example: Based on historical inspection data, the superstructure of bridge #123 has stayed in condition rating 6 for 11 years and in condition rating 5 for 14 years. These duration values (11 years and 14 years) will then be used, along with other values collected, to calculate the statistical superstructure duration (based on percentile) in each condition rating.

2. **Specify Desired Category:**

   The next step is to select the desired category or breakdown of bridges for analysis by different factors (e.g., material, traffic level, BPN). During analysis of various factors, PennDOT found that there were mainly three factors that significantly affect condition rating durations and how the bridges and culverts should be categorized. The first factor is district location, the second is bridge/culvert family, which is determined by main structure type and material, and the third factor is span configuration (single versus multi-span). The BMS2 bridge and culvert inventory was divided into 6 bridge families (General Concrete, General Steel, P/S Concrete, P/S Composite, P/S Non-Composite Adjacent Box Beam, and Other Bridge) and 5 culvert families (Box Culvert, Frame Culvert, Arch Culvert, Pipe Culvert, and Other Culvert). See a more detailed list of the bridge and culvert families in the Appendix (Section 6).

   Example: The desired category is single span general concrete bridges in District 7, and the goal is to compute the statistical duration of each condition rating for superstructures of single span general concrete bridges in District 7.

3. **Identify Qualified Bridges:**

   Once the desired bridge category is specified, the next step is to process the data and select the qualified bridges, i.e., the bridges that fall into the desired category.

   Example: Single span general concrete bridges located in District 7 are bridges #124, #52, #12658, #3687, #431, #3650, #98, and #4650. These are the qualified bridges on which to base this specific analysis.

4. **Select Qualified Durations:**

   After identifying qualified bridges (step 3) in a specified bridge category, the method selects qualified durations for each condition rating based on rules and assumptions that are explained in Section 5.3 (see "Qualifying Durations" under "Core Assumptions"). Only qualified durations are considered for each condition rating. Each of these qualified durations is called a "sample" or an "instance". The method needs several samples (qualified duration values) for each condition rating to compute the statistical duration of that condition rating.

   Example: From single span general concrete bridges located in District 7 and for superstructure condition rating 5, the following durations were selected based on rules and assumptions and are the qualified durations:

   - *Bridge #124 superstructure stayed in condition rating 5 for 12 years.*
   - *Bridge #52 superstructure stayed in condition rating 5 for 8 years.*
   - *Bridge #12658 superstructure stayed in condition rating 5 for 5 years.*
   - *Bridge #3687 superstructure did not have any qualified duration in condition rating 5. Its superstructure was in condition rating 5 for 6 years before the condition rating jumped to condition rating 9 after the superstructure was replaced.*
   - *Bridge #431 superstructure stayed in condition rating 5 for 22 years.*

- *Bridge #3650 superstructure stayed in condition rating 5 for 19 years.*
- *Bridges #98 and #4560 superstructures stayed in condition rating 5 for 14 years.*

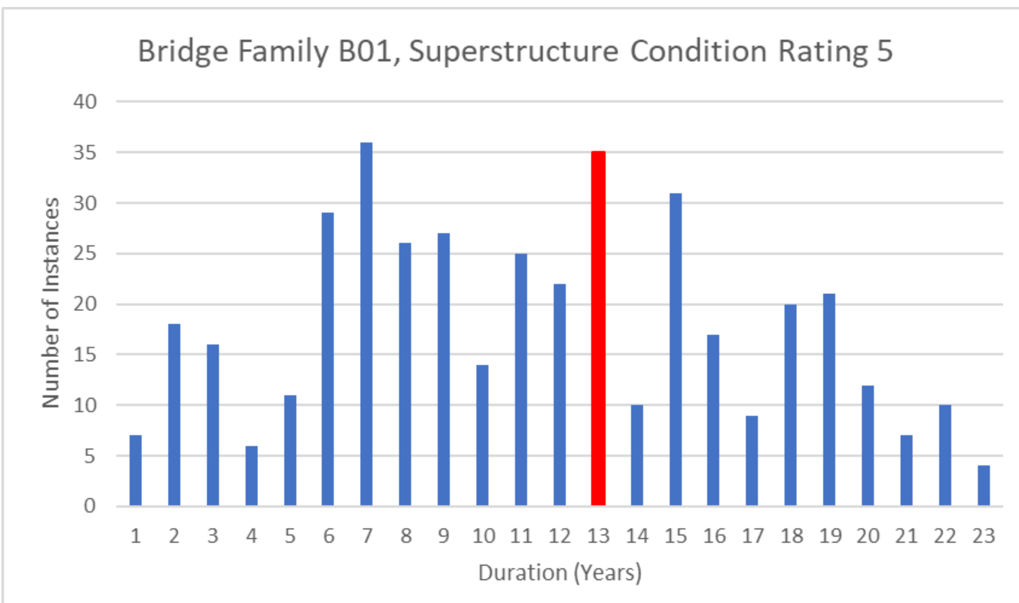
The samples from which to calculate the statistical duration that single span general concrete bridge superstructures in District 7 spend in condition rating 5 are 12, 8, 5, 22, 19, 14, and 14 years.

5. <u>Compute the Statistical Duration</u>:

The qualified durations (identified in step 4) are compiled and analyzed to determine an overall statistical duration (65th percentile) of each condition rating for each category of bridge and culvert components. Further explanation for the basis of the 65th percentile duration is explained in Section 5.4.

In order to perform an analysis to determine the 65th percentile duration of a particular condition rating, a minimum of 7 instances (or samples) of qualified durations is required. Typically, each bridge in the analysis only has 1 instance of a qualified duration for a particular condition rating; however, some structures have multiple instances. If there are less than 7 instances of qualified durations in the analysis, a default statistical duration is selected, as opposed to a calculated 65th percentile statistical duration, to be used in the deterioration model. The following default statistical durations are used per condition rating being analyzed when there are less than 7 instances:

- Condition Ratings 3 and 9: 5 years
- Condition Ratings 4 through 8: 10 years



Example: For a certain set of bridges that are part of the single span general concrete bridge family, the chart above shows the number of instances per duration (in years) that the superstructures were in a condition rating 5. The 65th percentile duration is 13 years, as highlighted in red.

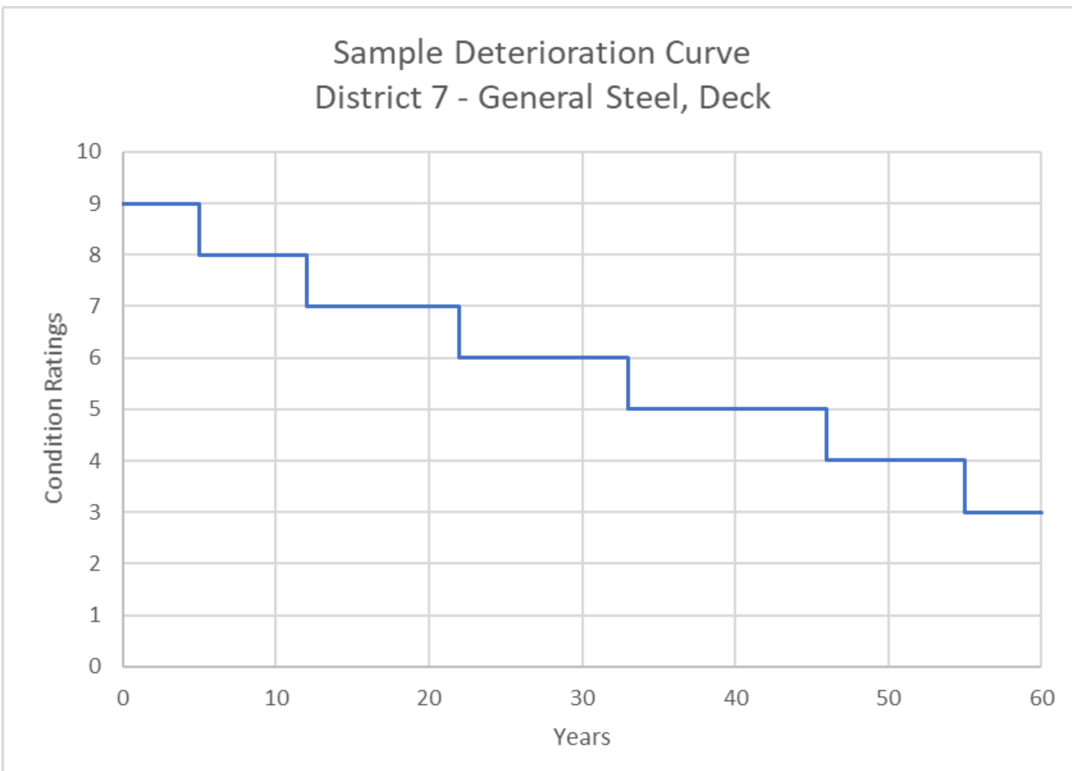
6. **<u>Compute Expected Life / Deterioration Curve</u>:**

When statistical durations of the condition ratings (9 through 3) are summed, the entire functional life of a bridge component can be estimated. The expected life until a bridge component deteriorates to Poor condition (condition rating 4) and then to Serious condition (condition rating 3) is computed by summing the statistical durations in preceding condition ratings, as shown below:

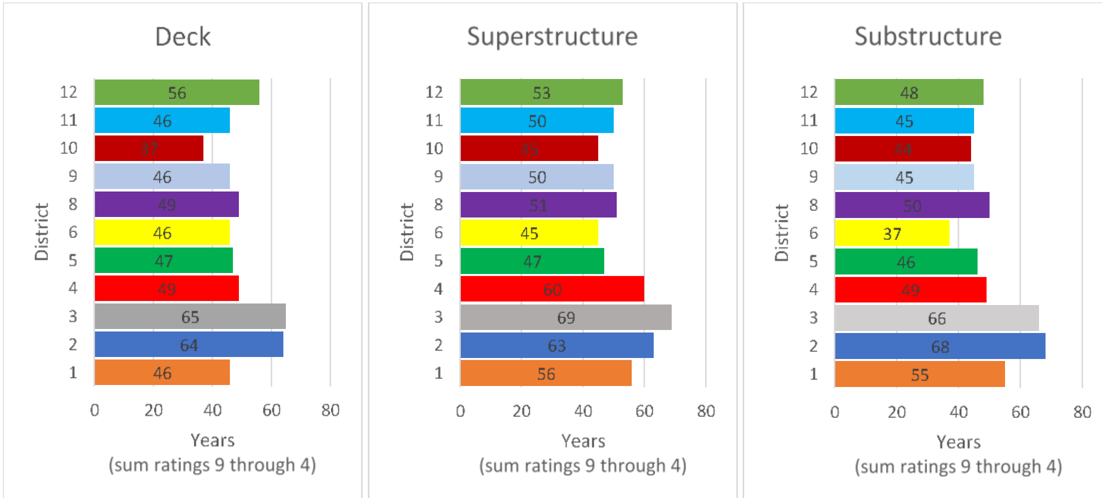
Expected Life until Poor condition = Statistical duration in condition rating 9 + … + Statistical duration in condition rating 5

Expected Life until Serious condition = Statistical duration in condition rating 9 + … + Statistical duration in condition rating 5 + Statistical duration in condition rating 4

The expected life of a bridge component can be expressed in terms of a deterioration curve. Deterioration curves show rates at which bridge components within a certain category are expected to deteriorate during its lifetime, based upon the statistical durations that were previously calculated in steps 1-5. As shown in the example below, deterioration curves and expected life can be displayed both graphically and numerically.



Family 2 General Steel								
Struct	Years in Condition							
Type	9	8	7	6	5	4	3	Sum 9 through 3
Deck	5	7	10	11	13	9	5	60
Super	7	10	11	10	17	8	7	70
Sub	7	12	12	14	15	12	12	84



[1]

7. <u>Refinement of Bridge Deterioration Curves Using 10-Year Rolling Averages</u>:

Initially, the Bridge Asset Management Section created new bridge and culvert deterioration curves for each of the bridge/culvert families in each district on an annual basis. Those updated curves were then used in the BridgeCare simulations. However, in early 2020 it was discovered that the deterioration curves sometimes varied greatly from year to year, which caused some skepticism as to the accuracy and reliability of the curves being produced. This variance from year to year can be attributed to various factors:

- Bridge inspections occur on an ongoing basis, which introduces new drops and jumps in condition ratings due to deterioration and completed work projects. Because of that, the pool of eligible bridges included in the analysis changes.
- Sometimes the pools of bridges for specific structure types and districts are too small and must utilize an assumed default minimum statistical duration value (5 years for condition ratings 3 and 9; 10 years for condition ratings 4 through 8). Updated changes in condition ratings for those smaller sets of bridges can create greater variability in the calculation of the statistical durations.

Although the method used in steps 1-6 to create the annual deterioration curves was not necessarily flawed, the initial implementation of them was. The updated annual deterioration curves represent how the bridges have deteriorated in the past up to that moment. With that moment changing on a yearly basis, the historical data used in the analysis also changes. In order to develop deterioration curves that introduce less variability and could be applied to provide a more reliable forecast of future deterioration, new curves were developed using 10-year rolling averages.

A 10-year rolling average deterioration curve is developed by averaging the statistical durations from the annual deterioration curves compiled over ten years. Updating the 10-year rolling average deterioration curves occurs annually, and as such, the ten years of curves also shifts each year. For example, a 2019 rolling average curve is calculated by

---

[1] *District bridge deterioration curves created in May, 2020*

averaging the annual deterioration curves from 2010 through 2019. At the end of 2020, the 2020 rolling average curve is developed from the annual deterioration curves from 2011 through 2020. While an annual deterioration curve can vary greatly from year to year, the variance from year to year of the 10-year rolling average deterioration curves will be more subtle, which will subsequently produce less variability in results produced in the BridgeCare simulations.

Refer to Appendix 6.3 for an example calculation of a deterioration model.

8. **<u>Deterioration Models of SOS Bridges (Structures of Significance)</u>:**

Initially, the Bridge Asset Management Section applied the deterioration models to all structures, regardless of size. However, it was recognized that larger structures in the Department's inventory generally deteriorate slower than the rest of the structures. The Department created a list of SOS structures (Structures Of Significance). These 703 structures include large State-owned structures (5A21 = "01") with a deck area greater than or equal to 28,500 ft^2. The list also includes structures, regardless of ownership or size, that are associated with the large State-owned structures. The majority of these "associated" structures are ramp bridges that connect to the large State-owned bridges.

The same deterioration models that were applied to the majority of the Department's structures were also applied to the SOS structures. However, the duration of the current condition rating for each SOS structure was evaluated through examination of the inspection records, and a new projected duration was created for the current condition rating of each SOS structure. The typical deterioration model durations were applied to all other non-current condition ratings. The Bridge Asset Management Section was only able to review about 1/3 of the SOS structures and revise their current condition ratings. The remaining 2/3 of the SOS structures utilize the typical deterioration models for all condition ratings.

5. Core Assumptions

5.1 Prediction Confidence

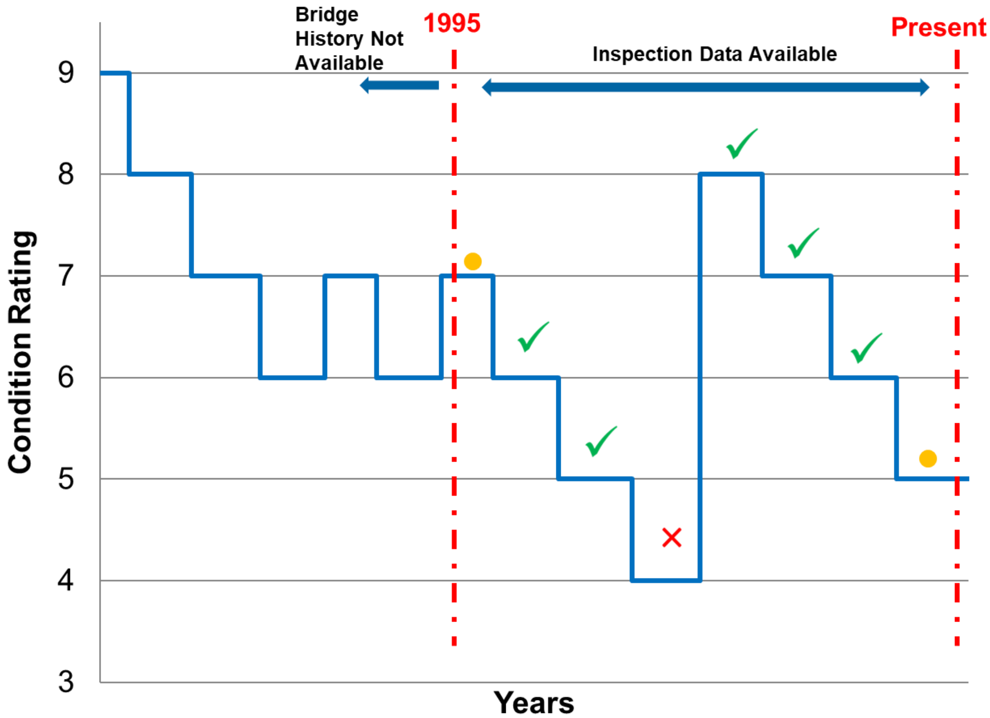
A minimum sample size of 7 instances of qualified durations is used to calculate the statistical duration of specific categories of bridges for each condition rating. If there are fewer than 7 instances of a condition rating, the statistical duration in that condition rating is estimated by using a default minimum duration for that condition rating (5 or 10 years, depending on condition rating). For example, if District 7 only has 5 samples for general concrete bridge superstructures in condition rating 4, a default minimum duration of 10 years is used for condition rating 4.

5.2 Condition Rating Independence

The years that a bridge component remains in different condition ratings are independent of other component ratings on the same structure. For example, if a deck remains in a condition rating 6 for 8 years and the superstructure remains in a condition rating 5 then for 12 years, the values 8 and 12 years are independent and do not affect each other in the analysis.

5.3 Qualifying Durations

Although all condition ratings and their durations for each bridge are initially identified in Section 4, step 1, only qualified durations (Section 4, step 4) for those condition ratings are used in the deterioration analysis. Figure 1 below and the following descriptions provide detailed criteria used to identify qualified durations.



✓	The condition rating durations before drops are considered in the analysis.
✗	Condition rating durations immediately before jumps are not considered in the analysis.
●	For the beginning and end of data inspection, the condition rating durations are considered only if the duration is greater than a certain period.

Figure 1 Assumptions to Identify Qualified Durations

1. The first observed condition rating for each bridge component is not considered in the analysis if the bridge component has been in that condition for less than 6 years. For example, if the first observed condition rating is a 9, it must be a 9 for at least 6 years in order to be counted as a qualified duration. The 6-year threshold was selected based on sensitivity analysis and consultation with bridge engineers.
2. The last observed condition rating for each bridge component is not considered in the analysis if the bridge component has been in that condition for less than 6 years. For

example, a given bridge deck was last observed in condition rating 7 for 4 years. It is not known how long this deck will remain in condition rating 7 after its last inspection in 2019. Therefore, this duration of 4 years is not a qualified duration. Thus, it is not considered in computing the statistical duration of the deck in condition rating 7.

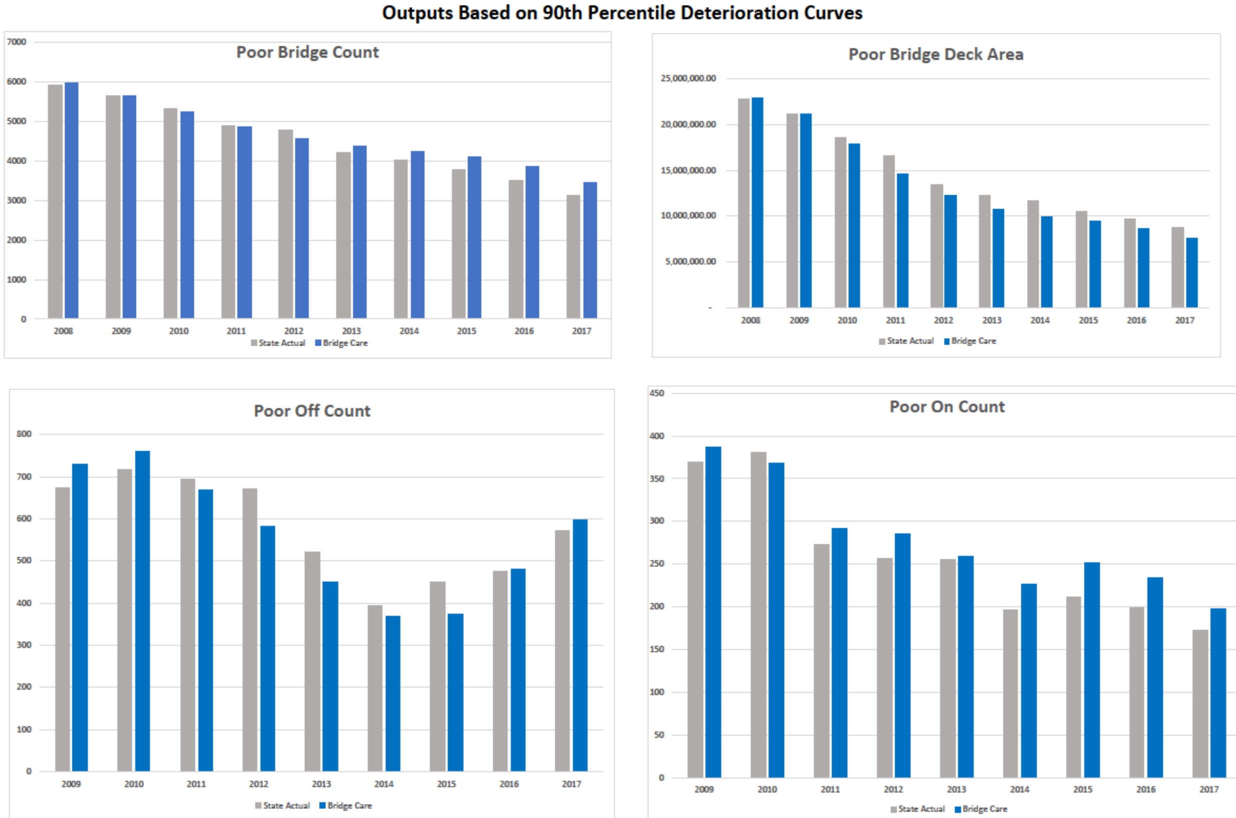
3. Where there is a jump to a higher condition rating (likely resulting from a rehabilitation or replacement), the duration immediately before that jump is not a qualified duration and is therefore not considered in the deterioration analysis. For example, if a bridge component remains in condition rating 5 for 9 years and then jumps to a condition rating 6 as a result of an intervention, that 9-year period is not a qualified duration. The work completed on the component interrupts the bridge's deterioration, and there is no way to know how long the component would have remained in condition rating 5 without intervention.

4. Where there is a drop to a lower condition rating, the duration before that drop is a qualified duration, except at first observed condition ratings (see #1 above).

5.4 65th Percentile Statistical Duration

Several variations of the family deterioration mode were tested, including mean, median, mode, and different percentiles. The run that best emulated past performance was based on the 90th percentile of our deterioration modeling for each family. The charts below show output from a 2018 BridgeCare simulation based on 90th percentile statistical durations.

Outputs Based on 90th Percentile Deterioration Curves



[2]

---

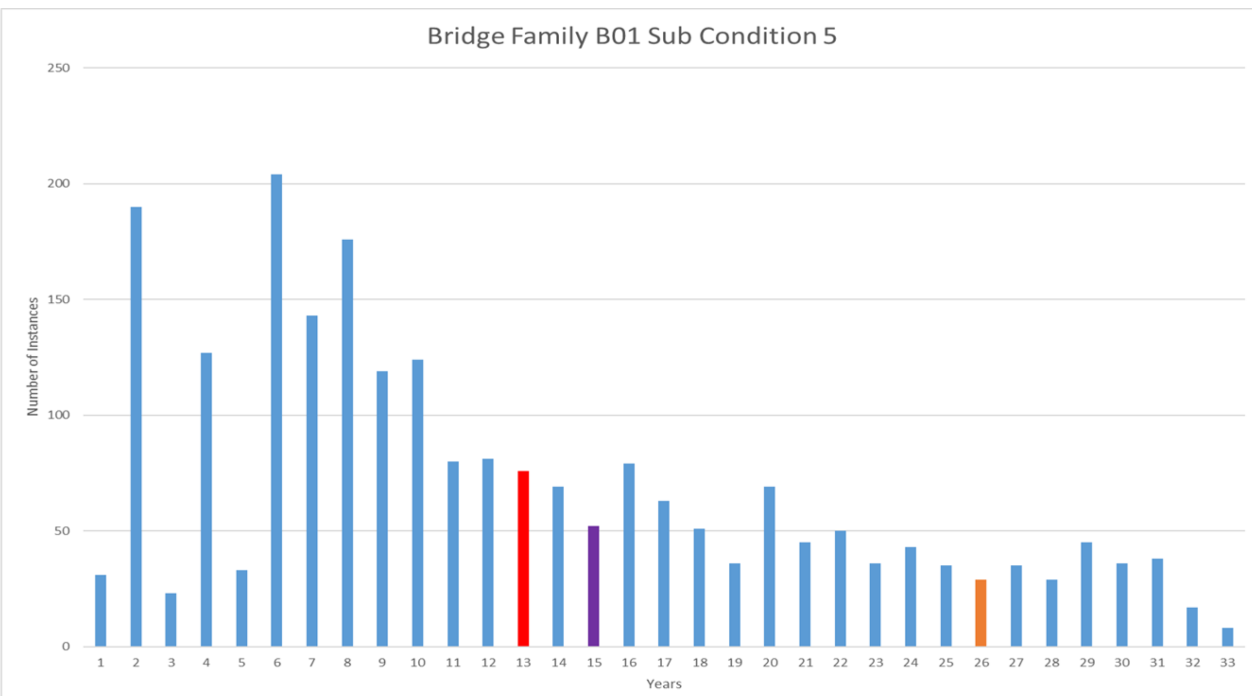
[2] *90th percentile deterioration curves created in October, 2018*

Considering all the potential variables that influence the results of a model not matching exactly the actual historical outcomes, it is reasonable to conclude that the 90th percentile statistical durations best represents historical conditions, as it reasonably reproduces historical poor on rates, count, and deck area to within a small margin of the actual rates. This, however, does not infer that the 90th percentile is the correct expression to use, but simply that the value produced from that formula creates the closest graphs from that time period.

Further analysis on the 90th percentile data shows some concerning information. Specifically, the 90th percentile would utilize a >100-year life for substructure, as well as for deck and superstructure. While the substructure life may be considered reasonable, the superstructure and deck life spans are not reasonable, given available data that shows otherwise.

An in-depth analysis of the durations of the condition ratings was undertaken. Several values were investigated to determine the best representative average value for a condition state. In the graph below, the lack of bell curve indicates that there is likely scatter in the early years, which adversely affects the average duration. This scatter is likely due to resolution issues in the families, i.e. further breakdown of single vs multi-span structures, height above mean water level, etc.

To remove the scatter from the analysis, we solve this graphically by removing the early highs and late tail of the graph. This takes the average from 50th percentile (red) to 65th percentile (purple). Also highlighted in this graph is the 90th percentile (gold), showing the clear error of using the 90th value from the earlier output example.



[3]

[3] *Bridge family graph created in February, 2018*

6. Appendix

6.1 Bridge Families[4]

FamilyID	Family Name	StructureType
1	General Concrete	Concr. encased steel, I beams
		Concr. encased steel, Slab (solid)
		Concrete(in place), Rigid frame
		Concrete(in place), Slab (solid)
		Concrete(in place), T-beams
		P/S, T-beams
2	General Steel	Concr. encased steel, Girder riv/thru
		Concr. encased steel, I-riveted beams
		Steel, Girder riv/deck
		Steel, Girder weld/deck
		Steel, I beams
		Steel, I-riveted beams
		Steel, I-welded beams
3	PS Concrete	Concrete(precast), Channel beams - composite
		P/S, Box beam - (spread)
		P/S, I beams
		P/S, Slab (solid)
4	PS Composite	Concrete(precast), Slab (solid)
		P/S, Box beam - adj- Composite
5	PS NCAB	Concrete(precast), Channel beams - non-composite
		P/S, Box beam - adj - non-composite

FamilyID	Family Name	StructureType
6	Other Bridges	Alum, Iron, Arch deck - open
		Alum, Iron, Truss - thru
		Concr. encased steel, Arch deck - open
		Concr. encased steel, Channel beams
		Concr. encased steel, Girder riv/deck
		Concr. encased steel, Other
		Concr. encased steel, Rigid frame
		Concr. encased steel, T-beams
		Concr. encased steel, Truss - thru
		Steel, Arch - thru
		Steel, Arch deck - closed
		Steel, Arch deck - open
		Steel, Girder rbr/deck
		Steel, Girder riv/thru
		Steel, Girder weld/thru
		Steel, Rigid frame
		Steel, Truss - deck
		Steel, Truss - thru
		Arch Deck Other
		Concrete(in place), Arch deck - closed
		Concrete(in place), Arch deck - open
		Concrete(precast), Arch deck - closed
		Masonry, Arch deck - closed
		Other, Arch deck - closed
		Steel Other
		Steel, Channel beams
		Steel, Girder wbr/deck
		Steel, Orthotropic
		Steel, Other
		Steel, Slab (solid)
		Steel, Suspension
		Concrete Other
		Concrete(in place), Box beam - (spread)
		Concrete(in place), Other
		Concrete(precast), Box beam - (spread)
		Concrete(precast), Box beam - adj
		Concrete(precast), I beams
		Concrete(precast), Rigid frame
		P/S, Box beam - single
		P/S, Channel beams
		P/S, Other
		P/S, Slab (hollow)
		Other - Tunnels
		Concrete(in place), Tunnel
		Concrete(precast), Tunnel
		Masonry, Tunnel
		Other, Tunnel
		Timber, Tunnel
		Steel Box Beam
		Steel, Box beam - (spread)
		Steel, Box beam - single
		Bascule
		Steel, Movable - bascule
		Other
		Other, I beams
		Other, Other
		Other, Slab (solid)
		Timber, Glue-lam timber
		Timber, Solid timber beams
		Timber, Truss - thru

[4] *Bridge families created in February, 2018*

6.2 Culvert Families[5]

FamilyID	Family Name	StructureType
11	Box Culvert	Concrete(in place), Box culvert
		Concrete(precast), Box culvert - at Grade
12	Frame Culvert	Concrete(precast), Frame culvert
		Concrete(precast), Box culvert - Under Fill
13	Arch Culvert	Concrete(in place), Arch culvert
		Concrete(precast), Arch culvert
		Concrete(in place), Tied arch culvert
		Concrete(in place), Frame culvert
14	Pipe Culvert	Steel, Pipe-arch culvert
		Steel, Pipe culvert
		Other, Pipe culvert
15	Other Culvert	Steel, Arch culvert
		Alum, Iron, Box culvert
		Alum, Iron, Arch culvert
		Alum, Iron, Pipe-arch culvert
		Steel, Box culvert
		Alum, Iron, Pipe culvert
		Other, Box culvert
		Other, Pipe-arch culvert
		Alum, Iron, Frame culvert
		Steel, Frame culvert
		Masonry, Arch culvert
		Masonry, Pipe-arch culvert
		Masonry, Pipe culvert
		Concrete(precast), Pipe culvert
		Concrete(precast), Pipe-arch culvert
		Concrete(in place), Pipe culvert

[5] *Culvert families created in February, 2018*

6.3 Example of Deterioration Model Calculation

The following example shows the steps involved in producing deterioration curves for decks, superstructures, and substructures of single span general steel bridges (Family ID = B02) in District 7.

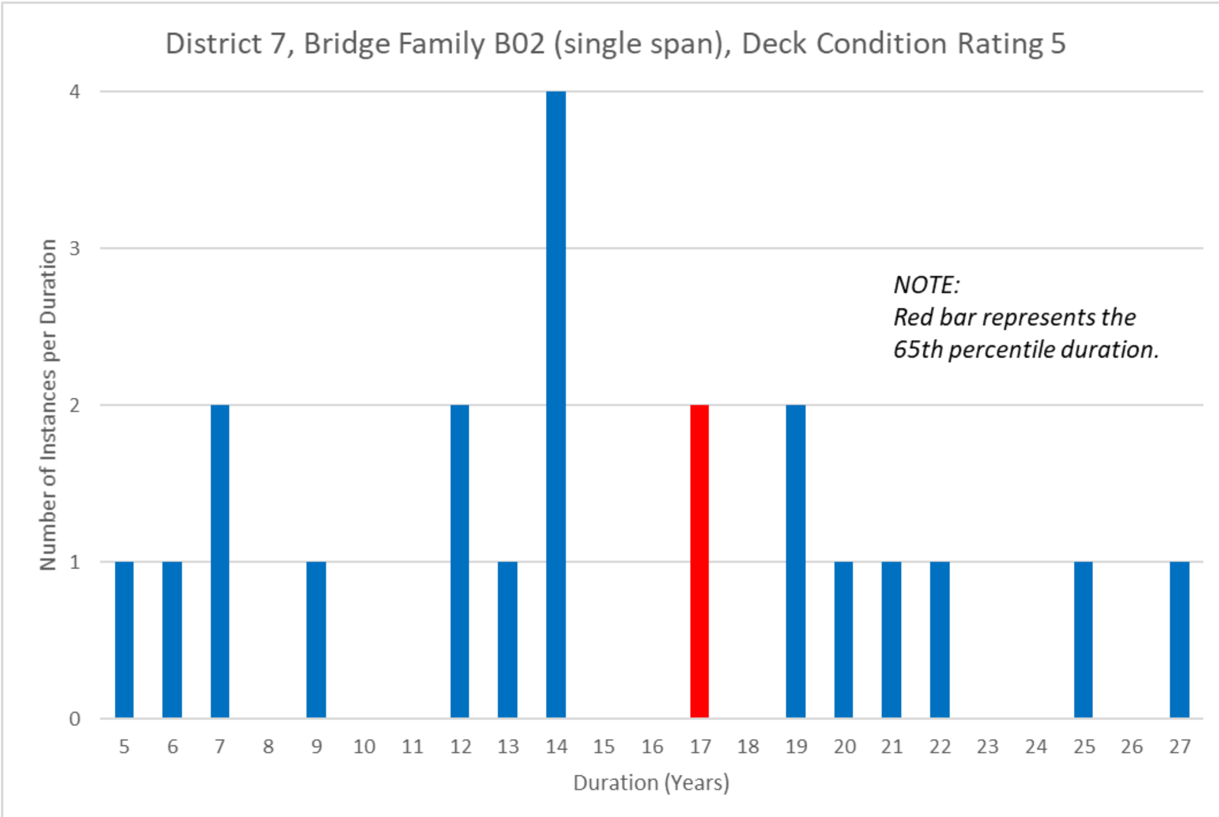
Step 1:

Identify the single span general steel bridges in District 7 and the qualified durations for each condition rating. The table below shows the determination of qualified durations for deck condition rating 5. The same process is repeated for each condition rating (3-9) for each bridge component (deck, superstructure, and substructure).

BRKEY	Family ID	Single/Multi Span	Component	Condition Rating	Duration (years)	Qualified Duration? (Y/N)
101	B02	Single	Deck	5	13	Y
154	B02	Single	Deck	5	22	Y
178	B02	Single	Deck	5	4	N
208	B02	Single	Deck	5	17	Y
216	B02	Single	Deck	-	-	-
277	B02	Single	Deck	5	2	N
291	B02	Single	Deck	5	27	Y
311	B02	Single	Deck	5	11	N
313	B02	Single	Deck	5	12	Y
345	B02	Single	Deck	5	6	N
356	B02	Single	Deck	5	6	Y
382	B02	Single	Deck	5	14	Y
399	B02	Single	Deck	-	-	-
403	B02	Single	Deck	-	-	-
455	B02	Single	Deck	-	-	-
461	B02	Single	Deck	5	9	Y
468	B02	Single	Deck	5	7	Y
514	B02	Single	Deck	-	-	-
575	B02	Single	Deck	5	20	Y
609	B02	Single	Deck	5	19	Y
611	B02	Single	Deck	5	5	Y
631	B02	Single	Deck	5	6	N
637	B02	Single	Deck	5	14	Y
639	B02	Single	Deck	5	12	Y
668	B02	Single	Deck	5	1	N
672	B02	Single	Deck	5	14	Y
685	B02	Single	Deck	5	14	Y
690	B02	Single	Deck	5	7	Y
695	B02	Single	Deck	5	25	Y
700	B02	Single	Deck	5	3	N
752	B02	Single	Deck	-	-	-
834	B02	Single	Deck	5	2	N
878	B02	Single	Deck	5	21	Y
881	B02	Single	Deck	5	19	Y
904	B02	Single	Deck	-	-	-
923	B02	Single	Deck	5	11	N
962	B02	Single	Deck	5	4	N
977	B02	Single	Deck	5	17	Y

Step 2:

Compute the statistical duration (65th percentile) for each condition rating of each bridge component from the qualified durations identified in the previous step. The example chart below shows determination of the 65th percentile duration for deck condition rating 5.



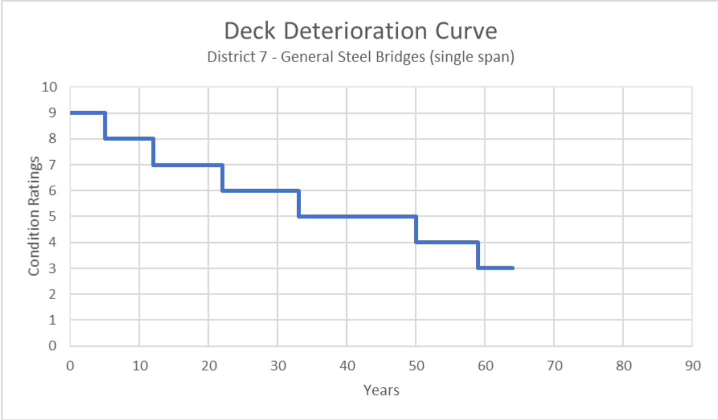
The following table summarizes the statistical durations for each bridge component of the single span general steel bridges in District 7.

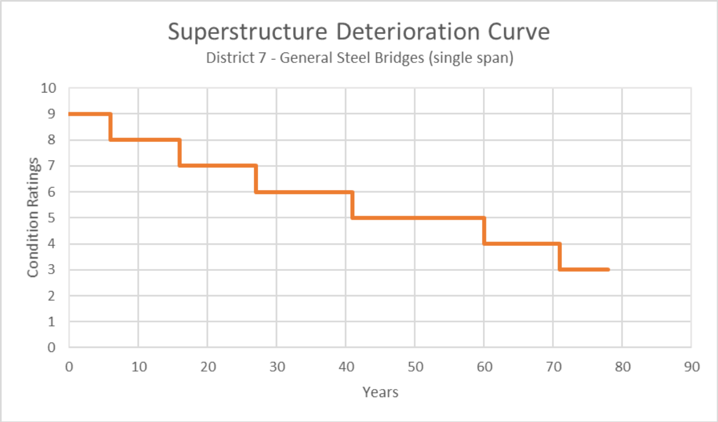
District 7, Bridge Family B02 - General Steel Bridges (single span)							
Bridge	**Statistical Durations (65th percentile) for each Condition Rating**						
Component	**9**	**8**	**7**	**6**	**5**	**4**	**3**
Deck	5	7	10	11	17	9	5
Superstructure	6	10	11	14	19	11	7
Substructure	6	12	12	14	20	12	12

Step 3:

Create the deterioration curve of each bridge component from the statistical durations calculated in previous step. The curves are shown below in both table and chart formats.

District 7, Bridge Family B02 - General Steel Bridges (single span)								
Bridge	**Statistical Durations (65th percentile) for each Condition Rating**							
Component	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**Sum 9 through 3**
Deck	5	7	10	11	17	9	5	64
Superstructure	6	10	11	14	19	11	7	78
Substructure	6	12	12	14	20	12	12	88



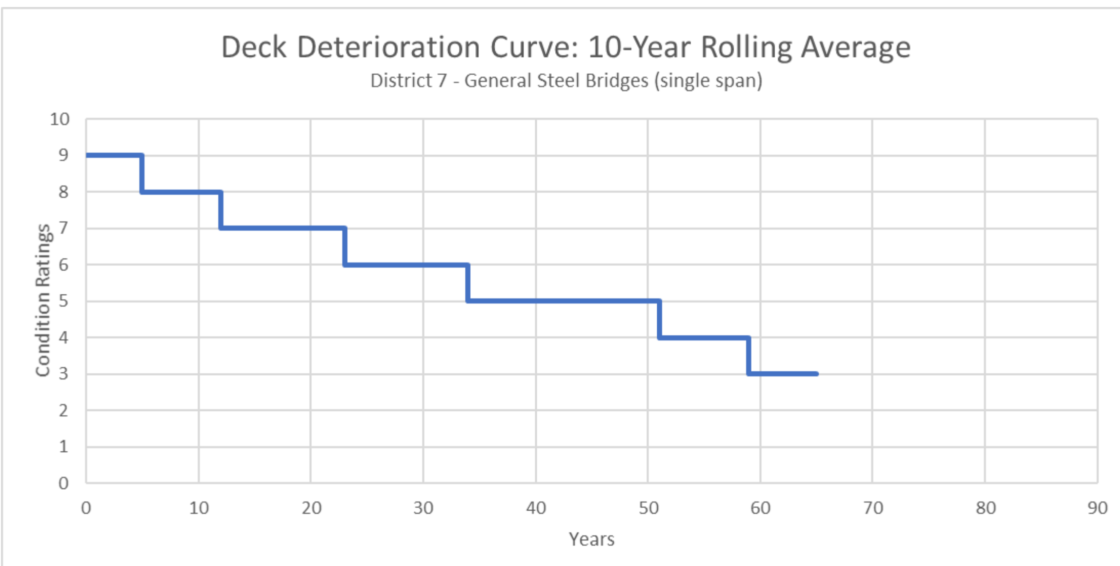


Step 4:

After completing the annual deterioration curves for each of the recent 10 years, create the 10-year rolling average deterioration curves of each bridge component.

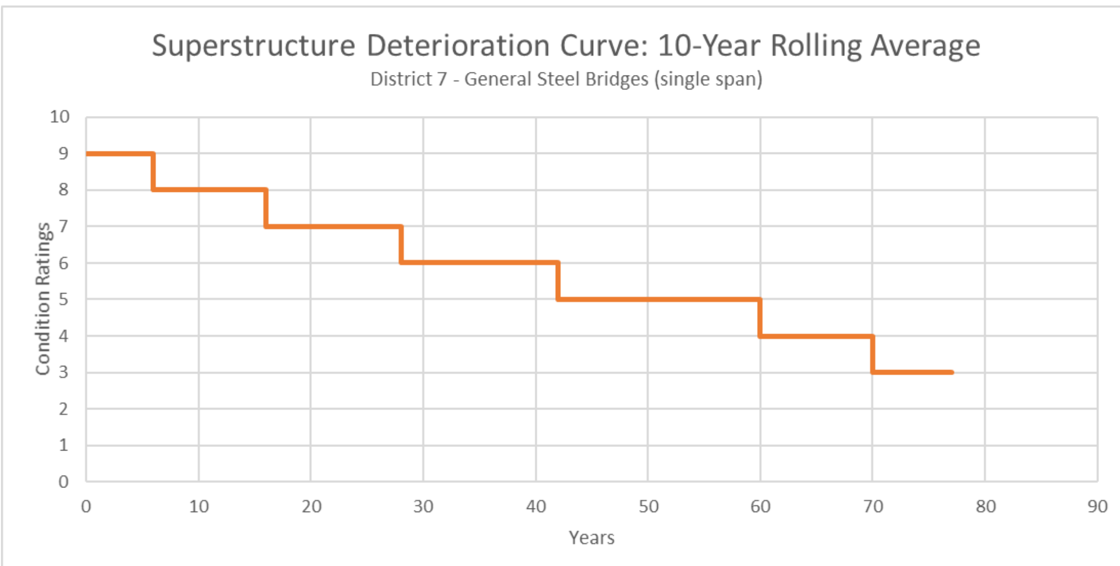
Deck

District 7, Bridge Family B02 - General Steel Bridges (single span), *DECK*								
Bridge	**Statistical Durations (65th percentile) for each Condition Rating**							
Component	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**Sum 9 through 3**
Deck - 2011	5	7	9	10	17	8	5	61
Deck - 2012	5	6	10	11	15	9	7	63
Deck - 2013	5	6	10	13	16	9	5	64
Deck - 2014	6	8	12	12	16	8	6	68
Deck - 2015	5	7	11	12	15	7	5	62
Deck - 2016	5	7	11	11	17	7	5	63
Deck - 2017	5	8	11	9	18	8	7	66
Deck - 2018	6	7	10	11	18	9	5	66
Deck - 2019	5	6	11	14	17	9	5	67
Deck - 2020	5	7	10	11	17	9	5	64
10-Year Average	**5**	**7**	**11**	**11**	**17**	**8**	**6**	**65**



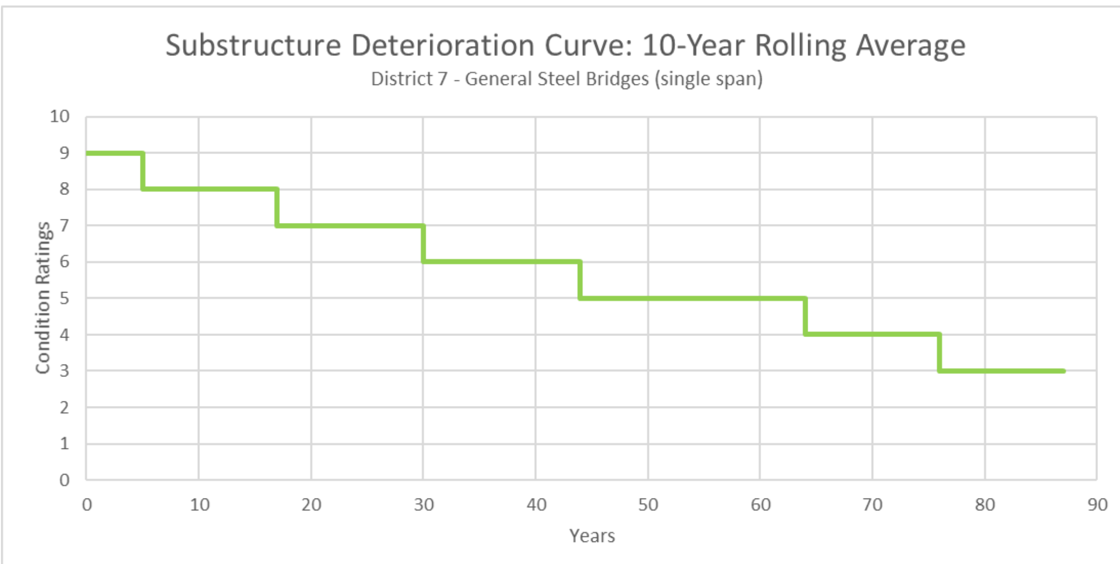
Superstructure

District 7, Bridge Family B02 - General Steel Bridges (single span), *SUPERSTRUCTURE*								
Bridge	**Statistical Durations (65th percentile) for each Condition Rating**							
Component	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**Sum 9 through 3**
Super - 2011	6	9	11	14	18	11	7	76
Super - 2012	7	9	10	14	18	11	7	76
Super - 2013	7	10	11	12	18	10	7	75
Super - 2014	6	10	14	13	17	9	6	75
Super - 2015	6	9	14	14	18	8	7	76
Super - 2016	5	10	13	15	17	9	7	76
Super - 2017	6	11	12	14	18	8	7	76
Super - 2018	7	11	11	16	19	10	7	81
Super - 2019	7	11	11	14	19	10	6	78
Super - 2020	6	10	11	14	19	11	7	78
10-Year Average	**6**	**10**	**12**	**14**	**18**	**10**	**7**	**77**



Substructure

District 7, Bridge Family B02 - General Steel Bridges (single span), *SUBSTRUCTURE*								
Bridge	**Statistical Durations (65th percentile) for each Condition Rating**							
Component	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**Sum 9 through 3**
Sub - 2011	6	12	11	15	20	11	12	87
Sub - 2012	5	10	12	14	20	12	11	84
Sub - 2013	5	12	13	14	21	12	11	88
Sub - 2014	5	12	13	14	22	12	10	88
Sub - 2015	6	13	13	13	21	13	10	89
Sub - 2016	6	14	13	14	22	14	11	94
Sub - 2017	5	14	13	13	20	13	10	88
Sub - 2018	5	13	13	14	19	13	11	88
Sub - 2019	5	12	13	14	19	12	12	87
Sub - 2020	6	12	12	14	20	12	12	88
10-Year Average	**5**	**12**	**13**	**14**	**20**	**12**	**11**	**87**



For more information regarding this product, please contact:

Justin Bruner, PE

Asset Management Engineer
400 North Street
Harrisburg, PA 17110
jbruner@pa.gov