Integration of AASHTO Element Inspections Data into NYSDOT Structures Management System and Processes

SPR PROJECT # C-15-04

FINAL REPORT

New York State of Opportunity. Department of Transportation

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DISCLAIMER

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The goals of this research project were to develop, evaluate, and recommend changes necessary to integrate the AASHTO element-based inspection system into NYSDOT bridge management decision-making processes, guidelines, and bridge performance measures.
The research developed a logic for identifying the work needs for each bridge based chiefly on AASHTO element inspection data. It also developed the logic for predicting the change in element condition states as a result of performing the needed work.
The research developed and evaluated two alternative types of performance measurement concepts:
(1) a bridge condition index, rated on a 0-100 scale, which is built upon a weighted average of condition state percentages of each element (2) a condition category assignment based on the estimated level of work needed on the bridge, where the work needed is determined by the selection logic developed as part of the research project.
Finally, the research produced programming logic to implement the performance measurement and selection logic within the NYSDOT bridge database system.</td></tr>
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Table of Contents

Appendices

List of Exhibits

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STATEMENT ON IMPLEMENTATION

This research project produced several alternative bridge performance measurement methods using AASHTO element inspection data and resulting measures for the 2019 NBIS bridge dataset submission. The alternative measures were evaluated and recommendations were offered regarding their suitability for use. The research project also produced a logic for using AASHTO elements in identifying maintenance, rehabilitation, and replacement needs of the state's highway bridges and for predicting the effects of such projects on the bridge's element ratings. The research project also produced the logic for software programmers to implement the performance measures and project selection and effects models into the NYDOT bridge management database.

EXECUTIVE SUMMARY

Motivation for the Research

For the past several decades, the New York State Department of Transportation has been well-served by a sophisticated bridge management system that uses detailed inspection data to monitor and report on bridge and network performance and to guide planning for bridge maintenance, rehabilitation, and replacement. The recent (2016) transition from a state-specific inspection and recording system to one based on AASHTO elements requires substantial reconfiguration of the NYSDOT bridge management system. While the bridge members that are rated are not substantially different under the two systems, the rating schemes are so conceptually different that it is not possible to simply map one rating scheme into the other and fit the new rating data into the existing management system. This research project was undertaken to develop and evaluate potential changes to the NYSDOT bridge management system that would enable the system to use AASHTO element inspection data directly in bridge and network performance measurement and in identifying bridge treatment needs.

AASHTO Element Inspection Data

The rating system for AASHTO element inspections combines a measure of the severity and extent of defects on the inspected element. Inspectors measure and record the quantity that is in each of four condition states: CS1-good, CS2-fair, CS3-poor, CS4-severe. This system replaces the legacy NYSDOT inspection system, in which inspectors assigned a rating between 1 and 7 to the element based on its condition overall and in consideration of its ability to perform its intended function. Unlike the AASHTO element inspections, the legacy rating system does not include quantity measurements.

Condition and Performance Measurement

Several alternatives methods for measuring bridge condition and network performance were developed and evaluated. The original direction of the research was to apply an index concept to the AASHTO element data to create a Bridge Condition Index (BCI) number on a 0-100 scale, where 100 would reflect a structure in which all portions of all elements were in the highest condition state (CS1). The basic approach behind a bridge condition index is to apply successive steps of weighted averages. First, an element condition index is created for each element from a weighted average of the quantities in the four levels of element condition states. Then a component condition index is created for each component on each span as a weighted average of the element condition indices. Then a span condition index is created for each span as a weighted average of the span's component condition indices. Finally, a bridge condition index is created from a weighted average of span indices.

BCIs for all of the NYSDOT highway bridges were calculated and various descriptive statistics and graphical interpretations of the BCIs were prepared by the principal investigators and examined by the NYSDOT project team. NYSDOT found that the bridge index concept did not meet its needs for use in measuring network performance. The averaging that is integral to the index concept had differing effects on the resulting condition measures for small versus large bridges. The difference created anomalies in performance comparisons between different populations of bridges, particularly when the populations were of substantially different compositions in terms of bridge type and/or size. NYSDOT determined that it would need to develop an alternative to the index concept for use in measuring and reporting bridge network performance.

The project team evaluated an alternative performance measurement concept that is based on the identified treatment needs of a bridge. Development of the logic for identifying bridge treatment needs was a separate track of the research project and is described in the following section. The treatment needs map readily into the existing four performance levels that NYSDOT has been using to characterize its bridge population (Good, Fair-Protective, Fair-Corrective, and Poor). This element-based measurement concept continues to be viewed as a viable option for NYSDOT to use AASHTO element data for measuring network performance.

Treatment Needs Identification

The research project developed a logic to select the type of project needed for each bridge, based on AASHTO element inspection data and certain bridge inventory and evaluation data. The new logic was developed with an objective of being more transparent and providing more information, compared to the logic in the existing (legacy) bridge management system.

The logic begins with the identification of element treatment needs. A panel of subject matter experts met in a two-day workshop and defined treatment levels and treatment triggers for the elements. The triggers are threshold values for the percentage of an element in the lower condition states (CS3 and CS4) at which the treatment is deemed necessary. The research project developed a logic for rolling up the element treatment needs to identify bridge treatment levels ("Project Types") for each bridge.

Project Outcomes and Future Direction

Following the conclusion of this research project, NSYDOT will continue to investigate performance measurement options: both those that use AASHTO element data directly and those that use other available inspection data, such as NBI component condition ratings and the NYSDOT General Recommendation.

In summary, the research project has made considerable progress on integrating AASHTO element inspection data into the NYSDOT bridge management system. Several performance measurement concepts were created and subjected to initial evaluation, and viable candidates are being advanced for further consideration. Condition measures for individual bridges and for components of bridges were developed and appear useful to bridge managers. Models for element treatment and bridge project selection and for modeling the effects of treatments were developed. The research project also created logic and instructions for programmers to apply these models in the existing NYSDOT bridge database system.

CHAPTER 1 - PROJECT PURPOSE AND REPORT OVERVIEW

1.1 PROJECT PURPOSE AND OBJECTIVES

Bridge inspections in New York State have for decades been reporting bridge conditions in a state-specific condition rating system.[1] NYSDOT has developed a bridge management system using this inspection and evaluation data that has served the public well. Hereafter in this report, the term "Legacy System" will be used to refer to this legacy inspection and rating system and associated bridge management system.

Starting in March 2016, and prompted by federal mandates, the New York State Department of Transportation (NYSDOT) transitioned its inspection rating system to one based on AASHTO elements.[2] The purpose of this research project is to explore the integration of AASHTO element-based inspection data into NYSDOT's bridge management system. Specifically, this research project has the following objectives:

1) Create a new condition measure using AASHTO element inspection data that reflects the condition of an entire structure and that can be aggregated to measure bridge network performance at the regional and statewide system levels.
2) Develop rules that identify the most appropriate treatment types for each element by condition state and develop decision rules for work recommendations (i.e., preservation, rehabilitation, and replacement activities) for each structure.
3) Provide computer logic for the implementation of items (1) and (2) into the NYSDOT Bridge Management System.

The remaining chapters of the report will summarize the activities completed and present the results. The components of a typical bridge management system, and the order in which they flow, form the organizing principle for the chapters that follow. The following section presents an overview of a typical bridge management system. The overview is intended to help place the research project methods and results in context.

1.2 BRIDGE MANAGEMENT SYSTEM OVERVIEW

BRIDGE MANAGEMENT SYSTEM FUNCTIONS

A bridge management system uses inventory and condition data, performance objectives, deterioration models, funding levels, cost information, and treatment selection rules to determine the strategies for preserving or improving bridge network conditions over the long term. Relatively recent advances in software tools to support data modeling have resulted in increased sophistication in bridge management systems. New software capabilities include analytical modules that are applied at the network level to develop a program of bridge projects

[1] New York State Department of Transportation Bridge Inspection Manual. 2014. https://www.dot.ny.gov/divisions/engineering/structures/manuals
[2] AASHTO Manual for Bridge Element Inspection, Second Edition. 2019.

that optimizes the agency's policy objectives subject to funding constraints. Conversely, an agency can apply an optimization module to develop the lowest cost program of projects to meet one or more network performance targets (e.g., no more than 10% deck area on bridges classed as "poor").

At an individual bridge level, the analytics within a bridge management system (BMS) can be used to identify the projects and sequencing that minimize the life cycle cost of maintaining the bridge in an agency-defined state of good repair. Agencies also can use a bridge management system for project prioritization. For example, a bridge management system can compute the benefit—cost ratio of a project by estimating its cost and the resulting change in condition (benefit). The calculated benefit-cost ratios can then be used as a factor in prioritizing the various bridge work candidates.

THE NYSDOT BRIDGE MANAGEMENT SYSTEM SOFTWARE PLATFORM

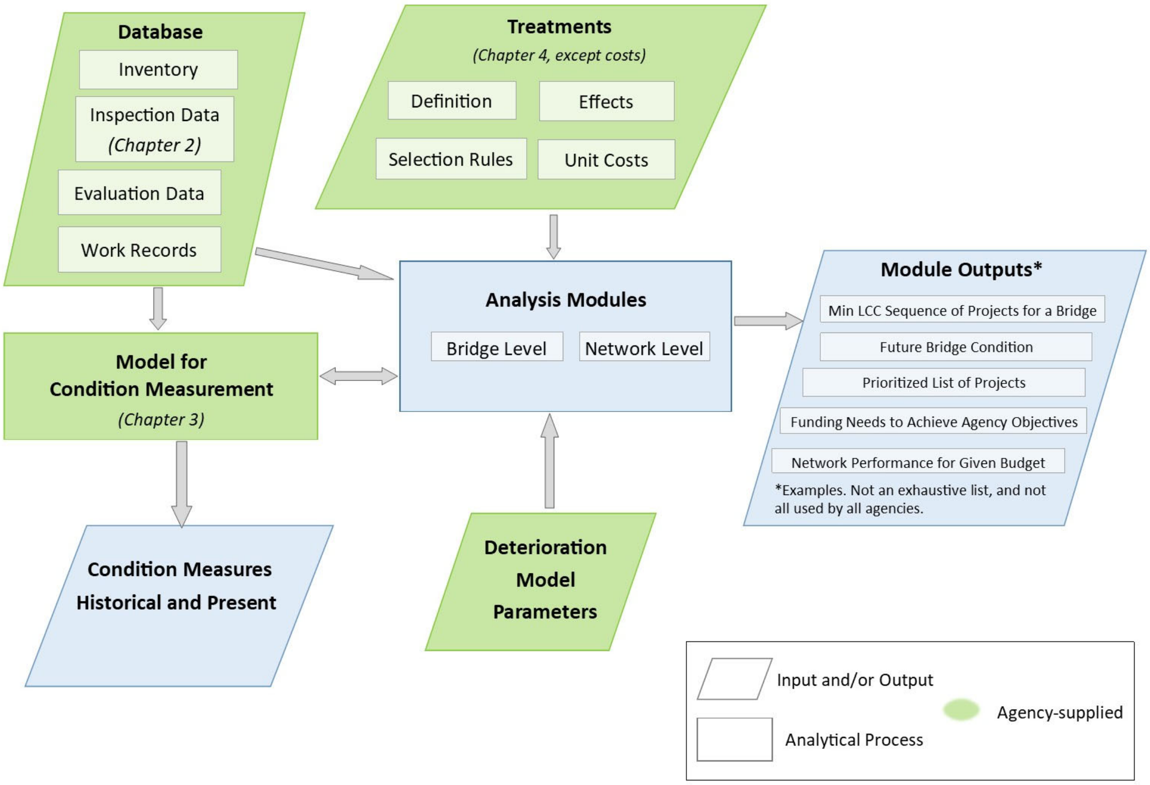
The software for the NYSDOT BMS is currently provided by Agile Assets. The AgileAssets Bridge Inspector module as applied by NYSDOT is known as the BDIS (Bridge Data Information System). NYSDOT uses the AgileAssets Structure Analyst module with logic configured internally by NYSDOT. The NYSDOT logic implements decision trees applied to inventory and inspection data to select work candidates. NYSDOT applies a prioritization scheme to select which work candidates advance to project development.

NYSDOT is also in the process of configuring AASHTOWare BrM for use as an alternate platform to evaluate its development of investment strategies and work programs.

BRIDGE MANAGEMENT SYSTEM COMPONENTS

Exhibit 1-1 depicts a simplified schematic of a bridge management system. A description of select components and their relationship to the research project follows.

Exhibit 1-1. Bridge Management System Schematic



DATABASE

The data items in a bridge management system database include the following:

1) *Structure Inventory Data* – For example, structure type, material type, number of spans, route carried, lanes, width, under clearance, AADT, and many other data items, as required by the National Bridge Inspection Standards[3] and other data items specific to the NYSDOT inventory standards.
2) *Inspection Condition Data* – Inspection results reporting the condition of the structure's elements.
3) *Evaluation Data* – Load ratings and vulnerability assessments.
4) *Work Records* – Records of bridge maintenance, repair, and rehabilitation ("MR&R") activities.

Chapter 2 describes the inspection condition data for the legacy and new systems. Structure inventory data, evaluation data, and work records are not discussed in the report because they were not a subject of this research project.

[3] FHWA Report No. PD-96-001. https://www.fhwa.dot.gov/BRIDGE/mtguide.pdf

MODEL FOR CONDITION MEASUREMENT

Agency models compile condition data for each bridge element into an index that represents a structure's overall condition. Besides condition indices, there are other measures of bridge condition, most notably the NBI general condition ratings (GCR), described in Chapter 2.[4] Bridge condition measures are both an *output* for reporting and tracking and an *input* into analytical tools within the bridge management system.

Chapter 3 describes how bridge condition and performance are measured in the Legacy System and presents the alternative condition measures that were developed as part of this research project.

TREATMENTS

The term "treatments" in a BMS context commonly refers both to the particular actions performed on individual elements (e.g., patching spalls on a reinforced concrete deck) and the collections of actions that constitute various work categories (e.g., rehab of a superstructure, which may include concrete patching of primary and secondary members, replacing bearings, and other superstructure actions). The existing NYSDOT system uses the terms "work types" and "work strategy", which are broad categories of work (i.e., replace, rehabilitate) applied to the bridge or its components or individual elements. AgileAssets uses the term "treatments", while BrM uses the term "actions".

There are several subcomponents of a BMS relating to treatments.

1) *Definition of Treatments* – A list of the treatments in the BMS and their definition.
2) *Selection Rules* – Element and/or component conditions under which a treatment is selected.[5] In the NYSDOT Legacy System, the collection of these rules is referred to as the "decision logic" or "decision tree". BrM uses the term "triggers". AgileAssets uses the terms "decision tree" and "decision matrix" with the two terms referring to slightly different ways to structure the treatment selection rules.
3) *Treatment Effects* – For each treatment, the change in element and/or component condition ratings resulting from the treatment. BrM refers to these effects as "benefits".
4) *Unit Costs of Treatments* – Unit costs are applied to the treatments to create project cost estimates. The cost estimates are used in life cycle cost estimation and in optimization analysis.

Chapter 4 presents the legacy treatment decision logic and describes the process and results of the research project to define the treatments, selection rules, and effects. The development of unit costs is not a part of this research project.

[4] NBI GCR is input by the inspector; it is not calculated with a NYSDOT model.
[5] Some agencies also include other NBI inventory items such as scour critical status (NBI Item 113) in selection rules.

DETERIORATION MODEL PARAMETERS

The deterioration model is the set of equations and parameters that is used in projecting the change in elements' ratings that occurs over time in the absence of treatment. The deterioration modeling occurs within the analysis modules depicted within the blue rectangle in the center of Exhibit 1-1. The deterioration modeling *parameters* are agency-supplied inputs, as shown in the green box below the analysis modules. The NYSDOT Legacy System had an established deterioration model developed with the support of an empirically based, analytically rigorous research project completed by faculty at the City College of New York Department of Civil Engineering.[6] With the transition to AASHTO elements, this model is no longer applicable. Efforts to develop a new deterioration model based on the AASHTO element data are underway. Deterioration modeling is not presented in this report because it is not a part of this research project and is on a different timeline for completion.

ANALYSIS MODULES

Bridge management system software such as AgileAssets Structure Analyst and AASHTOWare BrM can run a variety of analysis and optimization modules, as previously described. An agency can use the software to run analyses at the bridge level, at the network level, or on subdivisions of the network based on functional class, region, and bridge type, among others. The software is useful for comparing network performance outcomes for different funding levels or different funding allocations among work categories (i.e., preservation v rehabilitation v replacement). The software can also be used to generate alternative work candidates and their resulting bridge condition and network performance outcomes. Project selection from among the work candidates could be made outside the software, for example by being input into an agency's prioritization formula.

[6] Agrawal, A.K. and A. Kawaguchi. 2009. *Bridge Element Deterioration Rates*. New York State Department of Transportation. Report No. C-01-51.
https://www.dot.ny.gov/divisions/engineering/technical-services/trans-r-and-d-repository/C-01-51_Final%20Report_March%202009.pdf

CHAPTER 2 – INSPECTION DATA

2.1 INTRODUCTION – STATE AND FEDERAL INSPECTION REQUIREMENTS

NYSDOT is responsible for ensuring that all highway bridges in the state are inspected following state and federal requirements. NYSDOT inspects about 94 percent of all highway bridges in the state, including municipally owned bridges. Tolled structures are inspected by their respective authority/commission with NYSDOT oversight.

The National Bridge Inspection Standards (NBIS) established the regulations for the inspection and evaluation of the Nation's bridges (23 CFR 650 Subpart C). A "bridge" under the National Bridge Inspection Standards (a "NBIS bridge") is a highway-carrying structure that is at least 20 feet in length. In this report the term "bridge" refers to an NBIS bridge. New York State established a program of comprehensive bridge management and inspection, codified in the Uniform Code of Bridge Inspection (UCBI) (17 CRR-NY IV C 165).[7] All NBIS bridges in New York State are subject to the UCBI. Bridges are inspected at least once every two years. States are required to prepare and maintain an inventory that adheres to the Federal Highway Administration (FHWA) "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (FHWA Report No. PD-96-001, as amended by errata sheets).[8] NYSDOT submits the inventory and inspection data for all NBIS highway bridges in the state to FHWA every year in March.

With the passage of MAP-21 in 2012, Congress committed to the development of a data-driven, risk-based approach to asset management in the United States. Among other important provisions, MAP-21 requires the collection and submission of AASHTO element level bridge inspection data for all National Highway System bridges, starting in October 2014.

While the federal requirement for element level inspection applies only to bridges carrying the National Highway System, NYSDOT has implemented the AASHTO element level inspection for all NBIS public highway bridges. NYSDOT chose to do so for uniformity and consistency across the entire state, given that NYSDOT inspects 94 percent of all these bridges. As noted in Chapter 1, New York State had been conducting inspections using its own, state-specific rating system. Starting in March 2016, it has replaced this state-specific inspection system with an AASHTO element-based inspection system.

Bridge inspection in New York State is guided by four key reference documents:

1) *AASHTO Manual for Bridge Element Inspection, Second Edition*. 2019.
2) *New York State Department of Transportation Bridge Inspection Manual*. 2017.
3) *Bridge Inspector's Reference Manual.* FHWA NHI 12-049. December 2012. https://www.fhwa.dot.gov/bridge/nbis/pubs/nhi12049.pdf

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[7] The Uniform Code of Bridge Inspection is reprinted in Appendix A of the New York State Bridge Inspection Manual, 2017. https://www.dot.ny.gov/divisions/engineering/structures/manuals

[8] https://www.fhwa.dot.gov/BRIDGE/mtguide.pdf

4) *NYSDOT Bridge and Large Culvert Inventory Manual.* July 2020. *https://www.dot.ny.gov/divisions/engineering/structures/manuals/bridge-inventory-manual*

The remaining sections of this chapter describe the condition data that is recorded and reported during the biennial inspection. Besides the condition data, the New York State BMS bridge database also contains a large amount of inventory data items on each structure. The inventory items, documented in the New York State Bridge Inventory Manual, include and exceed the inventory items required by FHWA pursuant to the National Bridge Inspection Standards. The data include functional descriptions and assessments that also can factor into bridge management decisions.

The following sections describe New York State's legacy and current inspection systems. The data collected and rating guidance under each inspection system are presented. Appendix B contains excerpts from past inspection reports for the same bridge under the legacy and current systems, demonstrating a comparison of the data collected in each of the inspection systems.

2.2 NYSDOT LEGACY INSPECTION RECORDING SYSTEM

OVERVIEW

New York State's Legacy System was a hybrid element/component recording and reporting system.[9] The system recorded a rating for each component by span. Some components were rated based on the worst instance (e.g., the worst bearing) while others were rated based on the overall condition of the component.

COMPONENTS IN THE NEW YORK STATE LEGACY RECORDING SYSTEM

Exhibit 2-1 identifies the components and component categorization in the Legacy System.

[9] Prior to the implementation of AASHTO element inspections, the NYSDOT system referred to the items being inspected as "elements". However, not all of the items were elements in the specific sense of the AASHTO system. To highlight this difference between the legacy and AASHTO element systems, this report will use the more generic term "component" when referring to the items inspected in the Legacy System. Where necessary for clarity, the term "major component" will be used in reference to decks, superstructures, and substructures.

Exhibit 2-1. Components in the NYSDOT Legacy System

Rated by Span			
DECK	SUPERSTRUCTURE	PIERS	UTILITIES
Wearing Surface **Curbs**** **Sidewalks & Fascias**** Railings & Parapets** Scuppers Gratings Median	**Structural Deck** **Primary members** **Secondary members** **Joints** Paint Overall Superstructure Rating	**Bearings, Bolts, Pads*** **Pedestals*** Solid Pier Stem Pier Columns* Top of Cap or Beam Cap Beam Footings Erosion or Scour Piles **Overall Pier Rating**	Lighting* Sign structures Utilities & Supports*
Rated by Bridge			
ABUTMENTS (2 per bridge)***	WINGWALLS (2 per bridge)***	STREAM CHANNEL	APPROACH**
Joint with Deck **Bearings, Bolts, Pads*** **Seats and Pedestals*** Backwall Stem Erosion or Scour Footings Piles **Overall Abutment Rating**	**Walls*** Footings* Erosion or Scour* Piles*	Stream Alignment Erosion and Scour Waterway Opening Bank Protection*	Drainage Embankment Settlement Erosion Pavement Guide railing

Source: *NYSDOT Bridge Inspection Manual*, 2014.
Note: The NY State system used a combination of component and element ratings. To highlight the contrast with AASHTO elements, this report will refer to all NY State system ratings as "component" ratings.
Components in **boldface** type are used in the formula to calculate the bridge condition rating (described in Chapter 3).
*Component is rated for the worst instance of the component or, in the case of lighting and utilities, the worst system of lighting or utilities.
** Inspector rates both sides/approaches but records the lower of the two ratings on the report.
***In limited instances (ramp structures), there is only one abutment or wingwall to rate.

THE NEW YORK STATE LEGACY COMPONENT RATING SYSTEM

Components were rated on a 1-7 scale according to the extent of deterioration and the component's ability to function structurally, relative to how it was originally designed (see Exhibit 2-2). Ratings 8 and 9 were assigned, respectively, to cases "not applicable" and "condition and/or existence unknown". Components marked with an asterisk in Exhibit 2-1 are rated based on the worst instance of the component (e.g., the worst bearing in the line of bearings). For the other components the rating is representative of multiple components. For example, the rating of a primary member is not based on the worst girder in a multi-girder span, but rather evaluates all girders to derive a representative rating. However, even those components that are not designated to be rated by the "worst of" instance of the component could still have their rating be controlled by a defect in a small area. For example, a severe localized condition that compromises the structural capacity of a primary member would lower the rating of the entire primary member of the affected span. An important characteristic of the legacy inspection rating scale is that the guidance specifically instructs the inspector to consider the *functioning* of the component.

More detailed rating guidelines specific to each component are contained in the New York State 2014 Bridge Inspection Manual.[10] The coding guide for reinforced concrete structural deck is presented in Appendix C as an example of the type of specific coding guidance that the manual provides to inspectors.

Exhibit 2-2. NYSDOT Legacy Component Condition Rating Scale

Condition Rating*	Description
7	Element is in new condition. No deterioration
6	Used to shade between 5 and 7
5	Minor deterioration, but functioning as originally designed
4	Used to shade between 3 and 5
3	Serious deterioration, or not functioning as originally designed.
2	Used to shade between 1 and 3
1	Totally deteriorated, or in failed condition

Source: *NYSDOT Bridge Inspection Manual*, 2014.
*1 to 7 is the rating scale for components that can be rated. A rating of 8 is assigned if a rating is not applicable for the component. A rating of 9 is assigned if the condition is unknown.

Section 3.2 of Chapter 3 will present the formula for converting the legacy component inspection ratings into bridge condition ratings and will describe how the resulting bridge condition ratings are interpreted.

2.3 CURRENT SYSTEM – AASHTO ELEMENT INSPECTION

2.3.1 AASHTO ELEMENTS

AASHTO elements differ slightly from New York State legacy components in what elements are included, differ moderately from legacy components in how they are categorized, and differ significantly from legacy components in how they are quantified and rated. The legacy system combines considerations of condition and serviceability, while the AASHTO elements focus strictly on condition and contain no serviceability information. The AASHTO element inspection

[10] https://www.dot.ny.gov/divisions/engineering/structures/manuals/bridge-inspection

and rating system was designed with the philosophy that other existing measures, such as load rating and posting levels, provide the necessary serviceability information and are more objective in their derivation.

There are three categorizations of elements in AASHTO element inspections: National Bridge Elements, Bridge Management Elements, and Agency-Defined Elements. The categories are described below and illustrated in the tables of elements presented as Exhibits 2-3 and 2-4.

(1) *National Bridge Elements (NBEs)* – NBEs are the primary, load-carrying members of a bridge. The National Bridge Inspection Standards (NBIS) require that all NBEs be inspected and ratings submitted to FHWA.

(2) *Bridge Management Elements (BMEs)* – BMEs include non-structural members of bridges that are typically managed by agencies utilizing a bridge management system, such as joints, wearing surfaces, protective coating systems, concrete reinforcing, steel protection systems, and approach slabs. BMEs equip agencies to make more detailed management decisions, especially relating to bridge preservation activities. Some, but not all, BMEs are required to be inspected and collected as part of the federal National Bridge Inspection program.

(3) *Agency-Defined Elements (ADEs)* – ADEs are elements that are not included as NBEs or BMEs, but which the agency adds to its inspection because it finds them useful to monitor. The definition of the element and how it is measured and assessed is specified by the agency.

Exhibit 2-3 identifies the NBEs and BMEs that are required to be inspected under the National Bridge Inspection program. Exhibit 2-4 identifies the elements that New York State has elected to add to its inspection program. The exhibits also identify the corresponding Legacy System component (if one exists). As shown in the table, a unique element identifier is associated with each material for a given element type. For example, there are a variety of elements that are superstructure primary members; six of these elements are arches, one for each of six different material types (Elements 141-146). In contrast, the legacy components were defined by function/general type; the system did not assign different identifiers to different types of element or material composition. The specificity of the AASHTO elements makes it simpler for the bridge management system to assign distinct treatment selection rules, treatment effects, cost parameters, and deterioration parameters that are specific to the element's type and material composition.

Exhibit 2-3. Elements Required by the National Bridge Inspection Program

AASHTO Element	Legacy System	Units	Element Number					
			Steel	Prestressed Concrete	Reinforced Concrete	Timber	Masonry	Other
Deck/Slab (NBE)								
Deck	Structural Deck	SF		13	12	31		60
Open Grid Deck		SF	28					
Concrete Filled Grid Deck		SF	29					
Corrugated or Ortho. Deck		SF	30					
Slab		SF			38	54		65
Top Flange		SF		15	16			
Superstructure (NBE)								
Closed Web/Box Girder	Primary Member	LF	102	104	105			106
Girder/Beam		LF	107	109	110	111		112
Stringer		LF	113	115	116	117		118
Truss		LF	120			135		136
Arch		LF	141	143	144	146	145	142
Main Cable		LF	147					
Secondary Cable		EA	148					149
Floor Beam		LF	152	154	155	156		157
Pin, Pin and Hanger		EA	161					
Gusset Plate		EA	162					
Substructure (NBE)								
Column	Column	EA	202	204	205	206		203
Column Tower (Trestle)	Column	LF	207			208		
Pier Wall	Stem	LF			210	212	213	211
Abutment	Stem	LF	219		215	216	217	218
Pile Cap/Footing	Footing	LF			220			
Pile	Pile	EA	225	226	227	228		229
Pier Cap	Cap Beam	LF	231	233	234	235		236
Culvert (NBE)								
Culvert	Primary Member	LF	240	245	241	242	244	243
Bridge Rail (BME)								
Bridge Rail	Railings & Parapets	LF	330		331	332	334	333
Joint (BME)								
Strip Seal	Joints	LF	300					
Pourable		LF	301					
Compression		LF	302					
Assembly with Seal		LF	303					
Open		LF	304					
Assembly without Seal		LF	305					
Other		LF	306					

(continued on following page)

Exhibit 2-3. Elements Required by the NBI Program *(continued from previous page)*

Bearing (BME)			
Elastomeric	Bearings	EA	310
Movable (roller, sliding, etc.)		EA	311
Enclosed/Concealed		EA	312
Fixed		EA	313
Pot		EA	314
Disk		EA	315
Other		EA	316
Wearing Surfaces and Protective Coatings (BME)			
Wearing Surfaces	Wearing Surface	SF	510
Steel Protective Coating	Paint	SF	515
Concrete Protective Coating		SF	521

Exhibit 2-4. Additional Elements Included in the NYSDOT System

AASHTO Element	Legacy System	Units	Element Number		
			Undefined	Prestressed Concrete	Reinforced Concrete
Other Bridge Management Elements (BME)					
Approach Slab	Approach Pavement	EA		320	321
Concrete Protective Systems		SF	520		
Agency-Defined Elements (ADE)					
Erosion or Scour	Erosion or Scour	LF	800		
Stream Hydraulics	Stream Alignment Waterway Opening Bank Protection	EA	801		
Sidewalk	Sidewalks and Fascias	SF	810		
Curb	Curb	LF	811		
Secondary Members	Secondary Member	EA	830		
Steel Beam End		EA	831		
Backwall	Backwall	LF	850		
Abutment Pedestal	Pedestal/Seat	EA	850		
Pier Pedestal		EA	851		
Wingwall	Wingwall	LF	853		
Headwall		LF	860		

There are a few notable differences in the components/elements included in the legacy and new systems. The new inspection system includes less detailed breakdowns of ancillary deck items, no longer separating scuppers, gratings, and median. The new system does not include any of the items in the utilities category (lighting, signs, utilities and supports). The detail on stream channels has been reduced. The three legacy items for rating stream channel characteristics have been integrated as defects to consider in rating stream hydraulics (Element 801). Erosion or scour (Element 800) replaces the ratings of erosion and scour as separate items for each of the substructure footings. Many of the ADEs are items that were inspected in the Legacy System. Steel beam end is added as an Agency-Defined Element (Element 831).

2.3.2 AASHTO ELEMENT RATING SYSTEM

The AASHTO element rating system is an advancement upon the one-dimensional numerical rating scales because it provides the simultaneous recording of both severity and extent of distress. Bridge inspectors rate the elements by recording the total quantity of the element (area, length, or number) and the quantity in each of the five possible condition states defined in Exhibit 2-5.

Exhibit 2-5. AASHTO Element Condition State Definitions

Condition State	Condition Type	General Condition Guideline
CS-1	Good	That portion of the element that has either no deterioration or the deterioration is insignificant to the management of the element, meaning that portion of the element has no condition-based preventive maintenance needs or repairs. Areas of an element that have received long lasting structural repairs that restore the full capacity of the element with an expected life equal to the original element may be coded as good condition.
CS-2	Fair	That portion of the element that has minor deficiencies that signify a progression of the deterioration process. This portion of the element may need condition-based preventive maintenance. Areas of the element that have received repairs that improve the element, but the repair is not considered equal to the original member, may be coded as fair.
CS-3	Poor	That portion of the element that has advanced deterioration but does not warrant structural review. This portion of the element may need condition-based corrective maintenance or other remedial action.
CS-4	Severe	That portion of the element that warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge; OR a condition where that portion of the element is no longer effective for its intended purpose.
CS-5*	Unknown	That portion of the element not assessable due to lack of access.

Source: AASHTO 2019.
*CS5 is particular to the New York state rating system; the AASHTO manual specifies only the first four condition states.

The elements are evaluated based on the defects that are present and their severity. Defects are specific indications of distress on an element. Examples of typical defects include concrete efflorescence, pack rust, settlement, and distortion. Like many other agencies in the early stages of using the AASHTO element inspection, NYSDOT inspectors do not record quantities by defect. Inspectors do note some of the defects present in the narrative commentary on the inspection report. Appendix B contains an excerpt from an inspection report that gives an example of defect reporting in the commentary portion of the report.

The AASHTO Manual guides the assignment of condition state rating by defining the severity level thresholds for each condition state for each possible defect. The guidance is specific to element material. An example coding guide, for reinforced concrete, is presented in Appendix C. The condition state descriptions in Exhibit 2-5, along with the example reinforced concrete guidance in Appendix C, show that the differences between condition states 1 and 2 are not substantive in terms of identifying need for corrective actions. And at the other extreme, the interpretation of a rating of condition state 4 for part of an element can be problematic; an inspector is directed to assign CS4 when a structural review is *warranted*, not just when a review has been *completed* or when the inspector has concluded that the portion of the element no longer serves its intended purpose. That is, after a structural review, the portion of an element rated "severe" might not actually prove to be in severe condition. The AASHTO element rating scheme is explicitly designed with the recognition that serviceability is determined in a separate process from the inspection. If the structural review does not find strength or serviceability to be affected, the rating will be changed at the next inspection, *and not before.*

The AASHTO element rating system contains more data than the Legacy System. However, further interpretation and processing of the data are needed to produce a measure of overall condition and information usable for decision-making. The AASHTO element system takes some of the interpretation off the hands of the inspectors and moves it downstream, to the bridge managers. Chapters 3 and 4 of this report address how to adapt the NYSDOT Bridge Management System to take advantage of this more detailed information.

2.4 OTHER RATINGS ASSIGNED AT INSPECTION

The following ratings are not only important in their own right, but they also are particularly valuable for transitional bridge management decisions, as these ratings are collected in both legacy and AASHTO element recording systems.

2.4.1 NBI GENERAL CONDITION RATING

The National Bridge Inspection Standards (NBIS) requires the assignment of a general condition rating (GCR) on each major component of the bridge. Each major component (deck, superstructure, substructure, culvert) is rated on a 0-9 scale, based on the inspector's assessment of the "overall condition" of the component. The code assignment must consider "both the severity of the deterioration or disrepair and the extent to which it is widespread throughout the component being rated." (FHWA 1996) Inspectors also must rate channels and channel protection on a 0-9 scale. The FHWA Inspection and Coding Guide (FHWA 1996) presents the following guide to the assignment of the general condition ratings.

Exhibit 2-6. FHWA Coding Guide to NBI General Condition Ratings for Major Components

NBI Rating	Description
N	Not Applicable.
9	Excellent Condition.
8	Very Good Condition – No problems noted.
7	Good Condition – Some minor problems.
6	Satisfactory Condition – Structural elements show some minor deterioration.
5	Fair Condition – All primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
4	Poor Condition – Advanced section loss, deterioration, spalling, or scour.
3	Serious Condition – Loss of section, deterioration, spalling, or scour may have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	Critical Condition – Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present, or scour may have removed substructure support. Unless closely monitored, it may be necessary to close the bridge until corrective action is taken.
1	"Imminent" Failure Condition – Major deterioration or section loss present in critical structural components of obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic, but corrective action may put it back in light service.
0	Failed Condition – Out of service; beyond corrective action.

Source: FHWA 1996. https://www.fhwa.dot.gov/BRIDGE/mtguide.pdf

States can elect to use a federally supplied translation formula that converts element ratings to NBI general condition ratings, in lieu of having inspectors assign the NBI ratings. New York State has chosen to continue having its inspectors assign the NBI ratings rather than use the converter. Appendix C contains excerpts from the FHWA Coding Guide containing the detailed guidance for assigning ratings to each major component.

2.4.2 GENERAL RECOMMENDATION

The General Recommendation is the inspector's assessment of the bridge condition overall on a 1 to 7 scale. Stream channel, approaches, and utilities are not considered. Maximum weight is to be given to elements of most importance, such as primary members, abutment stems, piers, scour, etc. The General Recommendation coding guide is presented in Exhibit 2-7.

Exhibit 2-7. NYSDOT Coding Guide for General Recommendation

GR	Description
7	The bridge is in new condition, without deterioration except perhaps minor flaking of the top coat of paint. No work is needed other than routine maintenance.
6	Only minor deterioration is present. Touch-up painting may be required or other minor repairs to secondary elements. Minor bearing readjustments may be needed. There may be minor cracks or spalls in the substructures.
5	Primary members and substructures are in good condition and do not need major repairs. Bridge load capacity is not reduced, but other parts of the bridge (such as deck elements) may need extensive repairs. The bridge may require repainting because of corrosion starting on steel members. Scour may have exposed, but not undermined footings.
4	Moderate deterioration of primaries, secondaries, and substructures has occurred, but bridge load capacity is not substantially reduced. Considerable reconditioning of secondary members, substructures, and other components may be needed. Primary members do not yet need extensive reconditioning. There may be some minor substructure undermining.
3	Considerable deterioration of some or all bridge components. The bridge may no longer be able to support original design loads. Load posting may be needed. There may be considerable section loss on primary and secondary members. Concrete components are spalled with rebar exposure over a large portion of the areas. Extensive footing undermining may have occurred.
2	Most bridge components are in poor condition. Primary and secondary members are extensively deteriorated. The bridge can no longer safely carry original design loads. The bridge may still be open to traffic, but at a reduced load posting. Temporary shoring or bracing may be necessary. Substructures may be so badly deteriorated to require immediate repairs. Scour and undermining may be extensive enough to threaten the stability of the bridge.
1	Deterioration is so extensive that partial or total collapse is imminent. There is little or no live load capacity and the bridge may be closed. For the bridge to remain open to traffic, substantially reduced load posting and temporary shoring are necessary. Substructures may have settled and be in danger of failing due to extensive undermining.

Source: *NYSDOT Bridge Inspection Manual*, 2017.

CHAPTER 3 - BRIDGE CONDITION AND NETWORK PERFORMANCE MEASUREMENT

3.1 INTRODUCTION

3.1.1 CHAPTER OVERVIEW

This chapter describes and evaluates alternative methods to measure bridge condition that were developed as part of this research project. The chapter also describes how inspection data has been used to measure bridge condition and network performance in the NYSDOT Legacy System. The results shown in this report and all the Excel workbooks provided as deliverables use AASHTO element inspection data for calendar years 2017 and 2018 (i.e., NY 2019 April Data). The chapter begins with some background information on condition measurement and performance measurement in general, and as applied in New York State.

3.1.2 CONDITION MEASUREMENT AND NETWORK PERFORMANCE MEASUREMENT

New York State DOT has an established four-level scale for characterizing bridge condition. The scale is composed of four condition categories: good, fair-protective, fair-corrective, and poor.[11] These four bridge condition categories are used in measuring and reporting the performance of the bridge inventory. The four condition categories are defined by the type of work generally needed, as described in Exhibit 3-1. NYSDOT has established a correlation of the four condition categories to the legacy bridge Condition Rating between 1 and 7 calculated using legacy inspection data (described in Section 3.2.1). This correlation between the Condition Rating and condition categories is based on what has been observed to generally be the case in the state bridge network; it will not be true for every bridge in the population.

For purposes of this report, *condition* refers to an individual bridge (or its components) while *network performance* refers to the composition of the bridge network in terms of the percentage of bridges in each condition category. The NYSDOT Annual Report on the Bridge Management and Inspection Programs ("Graber Report") presents network performance data in four-color bar charts that depict the percentage, by deck area, of bridges in good, fair-protective, fair-corrective, and poor condition categories. A sample figure from the 2017 report is shown as Exhibit 3-2.

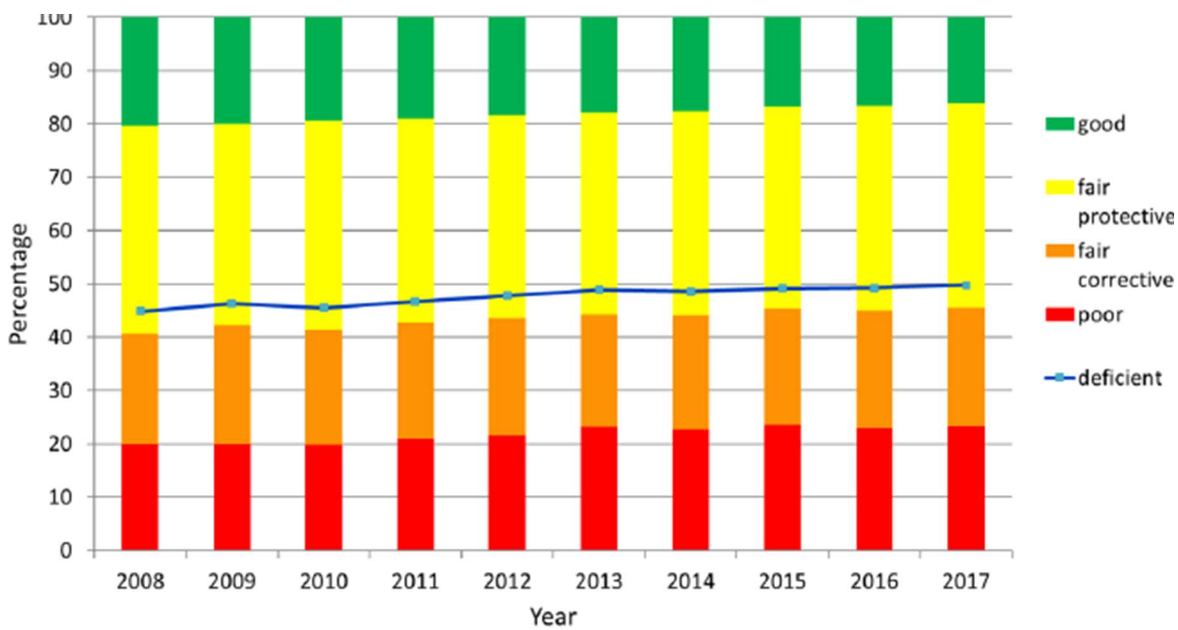
[11] These four condition categories are distinct from the three condition levels (good-fair-poor) required under federal rules for the performance reporting and asset management planning for bridges carrying the National Highway System. Those three levels are related to the ten-level NBI bridge rating scale, which is described in Section 2.4.1.

Exhibit 3-1. NYSDOT Bridge Condition Categories

Condition Category	Description	Legacy Bridge Condition Rating (CR)
Good	Bridges in good condition that generally require preventive and corrective maintenance actions such as: bridge washing, deck sealing, and bearing lubrication.	CR > 5.8
Fair-Protective	Bridges in fair condition that generally require relatively minor preventive and corrective maintenance actions such as: bearing repairs, joint repairs, zone and spot painting and girder end repairs.	4.9 <= CR < = 5.8
Fair-Corrective	Bridges in fair condition that generally require moderate preventive and corrective maintenance actions such as: bearing replacement, deck replacement, and major substructure repairs.	4.4 <= CR < 4.9
Poor	Bridges in poor condition that generally require major rehabilitation or replacement.	CR < 4.4

Source: *State Fiscal Year 2016-17 Annual Report: Bridge Management and Inspection Programs.* NYSDOT. https://www.dot.ny.gov/divisions/engineering/structures/manuals/graber-report
Note: The legacy performance measuring system also identifies a threshold Condition Rating of 5.0, below which a bridge is classified as "deficient".

Exhibit 3-2. Example Bridge Network Performance Trend Chart - NYSDOT Bridges, by Deck Area



Source: *State Fiscal Year 2016-17 Annual Report: Bridge Management and Inspection Programs*. NYSDOT. https://www.dot.ny.gov/divisions/engineering/structures/manuals/graber-report

This research project is tasked with (1) establishing a new *bridge condition* measure to replace the legacy Condition Rating (1-7 scale) and (2) specifying the relationship of the new bridge condition measure to the four condition categories that are used to measure *network performance,* analogous to the performance measures displayed in the four-color bar chart shown previously in Exhibit 3-2.

3.1.3 GENERAL APPROACHES TO BRIDGE CONDITION MEASUREMENT

Two different approaches to using element data in creating a bridge condition measure, as well as network performance measures, were considered in this research project:

(1) Perform weighted-average computations on the AASHTO element condition state data to create element, component, and bridge condition indices that measure the condition of each element, component, and bridge on a scale of 0-100. This approach is described in Section 3.3.

To create network performance measures using the new bridge condition index (BCI), apply statistical methods coupled with engineering expertise to establish a relationship between the bridge condition index and the four condition categories.

(2) Use element inspection data directly to determine the work required to bring the bridge to a state of good repair. The work required is characterized as one of a fixed number of project types. Each project type is correlated to one of the four condition categories, which then serves as the measure of bridge condition and is used in measuring and reporting network performance. This approach is described in Section 3.4.

This research project was concerned with the application of AASHTO element data. FHWA has a required approach to NHS network performance measurement that uses the NBI General Condition Ratings. As described previously in Section 2.4.1, inspectors in New York State assign a general condition rating to major bridge components on a 0-9 scale. FHWA defines the *bridge* condition as the lowest rating of deck, superstructure, substructure, or culvert. A bridge is classified as “good” if its lowest component rating is between 7 and 9, “fair” if its lowest component rating is 5 or 6, and “poor” if it is 4 or lower. FHWA measures network performance as the percentages of bridges, by deck area, in “good” and in “poor” condition. NYSDOT complies with the FHWA target setting and reporting requirements for these performance measures for bridges on the National Highway System.[12]

[12] https://www.federalregister.gov/documents/2017/01/18/2017-00550/national-performance-management-measures-assessing-pavement-condition-for-the-national-highway

3.1.4 CONSIDERATIONS IN DEVELOPING A BRIDGE CONDITION MEASURE

USES OF A BRIDGE CONDITION MEASURE

A bridge condition measure has a variety of potential uses. The characteristics that make a bridge condition measure especially effective for some of the uses may not be as advantageous for other uses. The five potential uses described below are not all entirely distinct; some of the uses overlap with others in the characteristics that make a measure effective.

To track an individual bridge condition over time – To serve this purpose well, a measure should respond to changes in element data in a way that best captures the overall characteristics of interest to the bridge managers. For example, large changes in condition states of elements deemed critical in some sense by bridge managers should be reflected by relatively large changes in the bridge condition measure, while changes in less critical elements should have less impact on the condition measure.

To indicate the expected type/level of work needed on the structure – As described previously in Section 3.1.2, NYSDOT bridge asset managers have established a correlation that generally applies between the legacy Condition Rating on the 1 to 7 scale and the four condition categories, which are roughly characterized by the level of work required to bring the bridge to a state of good repair. Developing a measure that is effective for this use requires identifying the elements and their condition states that are most critical to the determination of work required.

To measure network performance – Network performance is measured by the percent of deck area in each of the four overall condition categories mentioned previously (good, fair-preventive, fair-corrective, and poor). Bridge managers and other stakeholders often have an interest in seeing how different subdivisions of the bridge network (e.g., different NYSDOT regions) perform. To serve this purpose well, a bridge condition measure should accurately differentiate among bridges at the same point in time. That is to say, two bridges should not have a similar condition measure if they are in a substantially different state of repair. Because the four bridge condition categories that factor into network performance measurement are defined by the level of work needed, a bridge condition measure that is effective in capturing the level of work needed also will serve this use well.

As an objective in a BMS optimization module – In a typical optimization, the system will run alternative spending allocations among projects to seek the choice of projects that maximizes the "benefit" of the projects. Benefits can include positive changes in condition (typically measured with an element-based health index and/or NBI general condition ratings), life cycle costs, and risk and mobility measures. If bridge condition is the exclusive measure of benefit in a such an optimization problem, then the benefit that the optimizer seeks to maximize is simply the network-average bridge condition index.[13] Because BMS software (AgileAssets and BrM, for example) uses a condition index on a 0-100 scale, a condition measure for this use should be on the same scale or at least readily scalable to a 0-100 scale.

For this use of a condition measure, bridge managers will want the condition index to change in response to work in a way that they believe best captures the benefit of the work. For example, bridge managers might reason that it is more important to move an element from CS3 to CS2 than to move an element from CS2 to CS1. In such a case the weights that create an element condition index should capture that emphasis so that the optimizer module encounters higher incremental benefit measures on projects that move elements from CS3 to CS2 compared to other projects.

Similar considerations apply to the *weightings* of elements and components in the formulas that compute a bridge condition index. Weights should be higher for elements and components that managers consider more important and/or representative in capturing the benefit of a capital project.

This use is subtly different from the first one described (track a bridge's condition over time), in that it has specific implications for the consideration of weighting schemes.

As a factor in project prioritization – There are variety of ways in which a condition measure might be used in prioritization. For example, if the priority would be to address needs on bridges in the worst conditions, higher priority ranking points would be assigned to bridges with a lower condition measure. Alternatively, the bridge condition measure might be used in an incremental benefits sense, where benefit is measured similar to what was described previously for optimization. In that type of use, projects with a higher benefit-cost ratio would be given higher priority ranking points. The type of use in prioritization may have implications for the characteristics that make a condition measure most suitable for the use.

NYSDOT currently uses *prioritization,* rather than the optimization functionality within BMS software, to develop ranked lists of candidate bridge projects for further consideration by regional bridge managers. NYSDOT calculates a priority index for each candidate bridge project. The priority index is applied within a grouping of candidate projects of the same generalized work category (e.g., replacement, major rehabilitation, preservation). In the current NYSDOT BMS, the Condition Rating is one of the weighted components used in calculating the priority index. A bridge with a lower Condition Rating gets a higher score to enter the priority index calculation. For this specific use, a bridge condition measure does not need to be especially effective for identifying work needed, or even to distinguish condition among all bridges in the population; it

[13] Other objectives can be included in an optimization problem, such as addressing vulnerabilities like scour or seismic resilience or bridge functional deficiencies like inadequate load or traffic capacity. Each objective must be converted to a common scale and weight must be assigned to each objective to compute a weighted average benefit/utility. An important caution to the exclusive reliance on BCI in optimization: unless the analysis period has significant length (at least ten years), the BCI will do poorly at capturing benefits of preservation actions.

should be effective in distinguishing condition among bridges within the similar category of work required.

OTHER CONSIDERATIONS IN DEVELOPING A BRIDGE CONDITION MEASURE

The condition measure should not be so complex that it can't be readily communicated to stakeholders.

The condition measure should be able to be readily programmed into the bridge management system, and to be added without significantly impairing the run-time performance.

The condition measure should have some stability in terms of measurement scale. That is, it should avoid using input factors and intermediate steps that have some likelihood of changing over time. Such changes would make it difficult to compare an individual bridge's condition index and network performance measures over time.

Complexity should be proportional to accuracy/effectiveness. That is, any added complexity should produce a commensurate increment of effectiveness in fulfilling the measure's most important purposes.

3.2 BRIDGE CONDITION MEASUREMENT IN THE LEGACY SYSTEM

3.2.1 CALCULATION OF THE LEGACY BRIDGE CONDITION RATING

Bridge condition in the Legacy System is measured on a one to seven scale, with an interpretation roughly analogous to the Condition Ratings assigned to legacy components at inspection. The bridge Condition Rating is calculated as a weighted average of the ratings of the thirteen components that are considered critical to the structure's unrestricted use. The components and their weights are presented in Exhibit 3-3.

Exhibit 3-3. Legacy Bridge Condition Rating – Legacy Components and Weights

Component	Weight	Component	Weight
Primary Members	10	Backwalls	5
Abutments	8	Secondary Members	5
Piers	8	Joints	4
Structural Deck	8	Wearing Surface	4
Bridge Seats and Pedestals*	6	Sidewalks*	2
Bearings*	6	Curbs*	2
Wingwalls*	5		

*Indicates a legacy component that was rated based on the worst instance of the component (e.g., the worst bearing in the line)

When a bridge has several instances of a component, such as multiple piers, joints, primary members, etc. on a multi-span bridge, the rating of the worst instance of the component is used in the formula. For example, on a typical three-span bridge, the formula will use the lower of the two abutment ratings, the lowest of the two overall pier ratings, and the lowest of the three primary member ratings. For the components that were rated at inspection on a "worst of" basis, (marked with an asterisk) this bridge rating formula amounts to using the "worst of the worst". For example, the bearing rating used in the bridge formula will be that of the *individual bearing* in worst condition. The reasoning for using the "worst of" is because the rating system was oriented more towards safety than reflecting work needs or supporting work prioritization.

3.2.2 INTERPRETATION OF THE LEGACY BRIDGE CONDITION RATING

The interpretation of the legacy element bridge Condition Rating was presented previously in Exhibit 3-1. Bridges with a Condition Rating greater than 5.8 are considered "good". Bridges with a Condition Rating between 4.9 and 5.8 (inclusive) are labeled "fair-protective". Bridges with a Condition Rating greater than or equal to 4.4 and less than 4.9 are labeled "fair-corrective", and bridges with a Condition Rating less than 4.4 are labeled "poor". These four condition categories are correlated to a general type of work need, as noted in the description column in Exhibit 3-1.

3.2.3 USES OF CONDITION RATING IN THE LEGACY SYSTEM

The legacy bridge Condition Rating is used in the following ways:

- To track an individual bridge's condition over time
- To measure network performance - The bridge management system applied a consistent set of thresholds that translate bridge Condition Ratings to bridge conditions, making the rating useful for this purpose. The annual Graber Report displays the use of bridge Condition Ratings in measuring and tracking network performance over time (See Exhibit 3-2).
- As a factor in project prioritization - The bridge Condition Rating is one of several factors entering into a priority index used in ranking projects of a similar work type.

3.3 BRIDGE CONDITION INDEX - BCI

3.3.1 INTRODUCTION

A bridge condition index (BCI) is a number from 0-100 that describes the overall condition of the bridge based on the ratings of the bridge's elements. A method for calculating the index using the AASHTO element ratings was developed by the NYSDOT project team over the period February through June 2019 and was evaluated in June and July of that year.[14]

[14] The discussion of the BCI in this section refers to the BCI following the formula and weighting scheme developed by the NYSDOT project team at the expert elicitation workshop. Variants of the basic index concept have been reviewed and the characteristics described below were not found to be substantially different for the variants than for the original BCI.

3.3.2 BCI CALCULATION METHOD

The basic steps to calculating a BCI using AASHTO element inspection data are outlined below and commentary on the calculation follows. Exhibit 3-4 (following page) presents a stylized illustration of the BCI calculation for a hypothetical bridge that has three components, as well as a "secondary" component, which is a lesser-weighted grouping of various non-structural, protective elements that was created for computing the BCI. Not all of the calculations are depicted in this illustration. Appendix D presents a complete calculation of a BCI with actual inspection data for a two-span bridge. Appendix K contains logic for programming BCI calculations in a database management system.

Step 1: Element ratings (i.e., quantities in each of condition states 1 through 4) are weighted and combined into an element condition index (0-100).

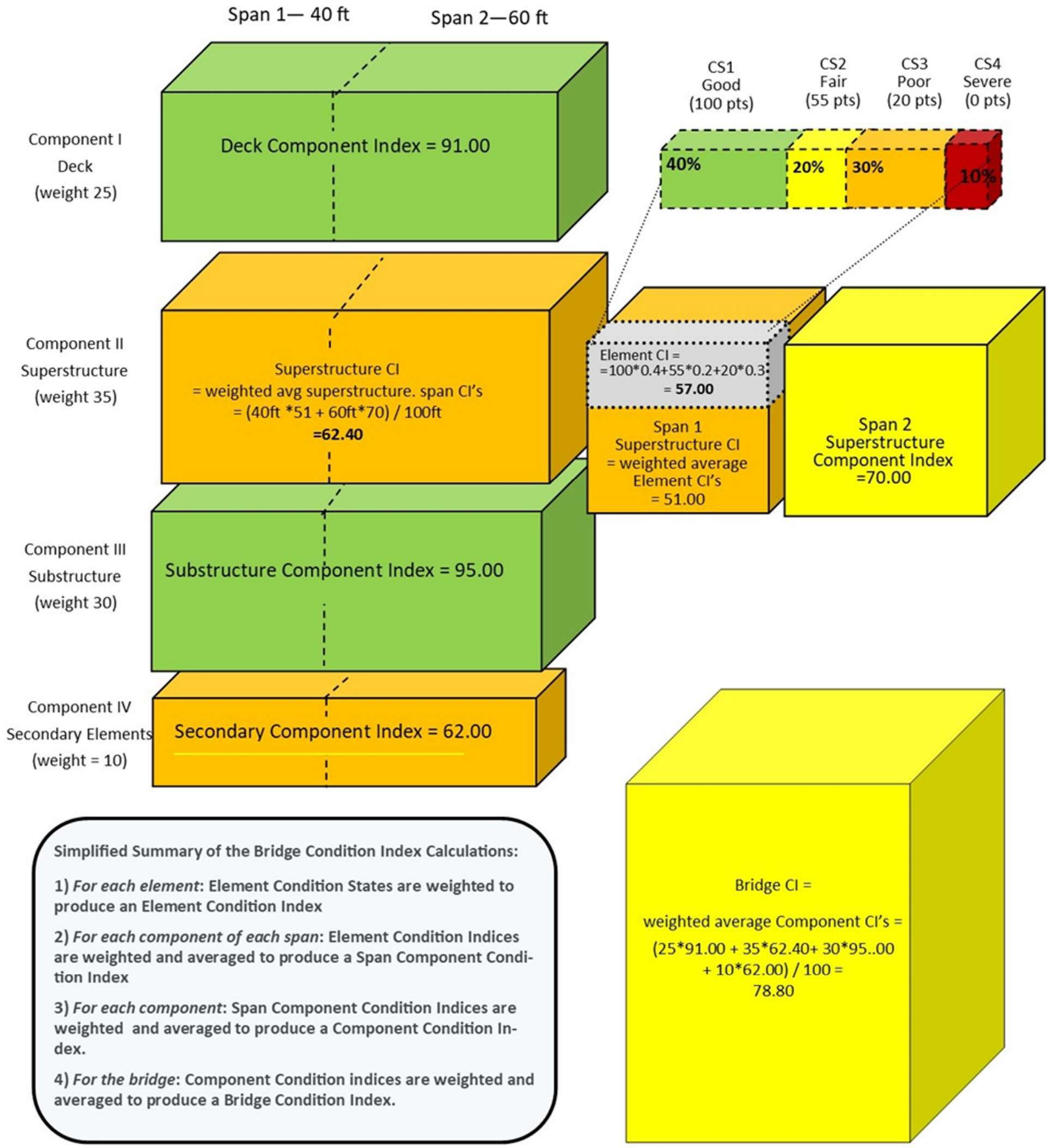
This is a *critical additional step* compared to the Legacy System. It is necessary to convert four numbers—the percentages of the element in each of the four condition states—into a single number that can be used in the remaining steps.

Step 2: For each span, element condition indices (0-100) are weighted and averaged into span component condition indices (0-100). The table of AASHTO Elements in Appendix E identifies each element's weight and which component condition index calculation it enters into, if any. Not all of the AASHTO elements are used in calculating the BCI.

Step 3: Span component condition indices are weighted and averaged into a component condition index (CCI). The spans are weighted by span length.

Step 4: Component condition indices are weighted and averaged to a bridge condition index (0-100). The component weights are as indicated in Exhibit 3-4.

Exhibit 3-4. BCI Calculation – Stylized Illustration of Calculation*



** Stylized and simplified. Not all values and calculations are shown. Structure is not comparable to structure in illustrative legacy rating example. Some realism may have been sacrificed for the sake of simplicity.*

Selection of Element Condition State Weighting Points

In a workshop held in April 2019, the NYSDOT project team initially selected a weighting scheme that gives 100 points to the share of the element in CS1, 55 points to the share in CS2, 20 points to the share in CS3, and zero points to the share in CS4. The conventional point scheme, used for example as default in the AASHTOWare's Pontis software (predecessor to BrM), assigns 67 points to CS2 and 33 points to CS3. The project team reasoned that it would be useful to have a greater spread between point values for CS1 and CS2, to help spread resulting Bridge Condition Indices.

After reviewing some interim results midway through the research project, the project team reconsidered this approach. The team reasoned that the points assigned for condition states 1 and 2 should be closer to one another because element portions can be assigned to condition state 2 and still be in relatively good condition. Moreover, because it can be difficult or impossible for repairs to restore an element portion to CS1, having a large spread between CS2 and CS1 points will reduce the improvement that a BMS captures from major repair work. Based on these considerations, the project team decided that the conventional point system of 100-67-33 should be used. The analysis in this section (3.3) was conducted earlier in the study, using BCIs calculated with the original 100-55-20-point system. Because the analysis would not be materially different with the other point system, the exhibits in this section were not recreated to reflect the revised point system.

Interpretation of the Element Condition Index

Ideally, the element condition index captures the overall element condition, similar to the legacy ratings for legacy components that were rated on overall condition. In reality, the legacy inspection and rating system was better positioned than the AASHTO element rating system to capture overall condition. In the Legacy System, the inspector is instructed to consider functionality of the component, and therefore the inspector's assignment of a component Condition Rating could be affected by small areas in very poor condition. With AASHTO elements, the element condition states provide just one set of numbers describing a whole element, without regard to the location of defects and therefore without information on the structural effect, if any, caused by those defects. They do not reflect serviceability of the element. Also, because the element condition index averages the shares in the four condition states, it obscures some of this information on severe defects that the legacy rating system was able to capture. Also, for the legacy components that were rated based on the worst instance or portion of the component (e.g., worst bearing in a line of bearings), the new element condition index is especially prone to produce a higher assessment of the element condition than in the Legacy System.

Element Weights in Computing the BCI

The weights assigned to each element condition index and their use in the BCI (i.e., their component assignment) are shown in the elements table in Appendix E. Exhibit 3-5 illustrates how the element and component index weighting points convert to element weights within the BCI calculation formula for an example bridge.

Exhibit 3-5. Illustrative Application of Element and Component Condition Index Weighting Points (Single Span Steel Multi-girder Bridge with Concrete Deck)

Component and Element	Element Weighting Points (a)	Weight of Element within Component (b)*	Weight of Component in BCI (c)**	Weight of Element in BCI (d) = (b) x (c)
Deck Component (*25 weighting points*)				
12 Reinforced Concrete Deck	100	100%	25%	**25%**
Superstructure Component (*35 weighting points*)				
107 Steel Open Girder/Beam	100	77%	35%	27.0%
830 Secondary Members	30	23%		8.0%
	130	100%		**35%**
Substructure Component (*30 weighting points*)				
215 Reinforced Concrete Abutment (BA)	100	23%	30%	6.9%
215 Reinforced Concrete Abutment (EA)	100	23%		6.9%
310 Elastomeric Bearing (BA)	60	14%		4.2%
310 Elastomeric Bearing (EA)	60	14%		4.2%
851 Abutment Pedestal (BA)	60	14%		4.2%
851 Abutment Pedestal (EA)	60	14%		4.2%
	440	100%		**30%**
Secondary Component (*10 weighting points*)				
510 Wearing Surface	10	50%	10%	5.0%
515 Steel Protective Coating	10	50%		5.0%
	20	100%		**10%**
			Total =	**100%**

Note: Exhibit shows only the *weights* within a BCI calculation, not the full BCI calculation using element condition state quantities. See Appendix D for a sample BCI calculation.

*Entries in column (b) are calculated as element weighting points divided by total element weighting points for the component. Yields the percentage weight of the element within the component.

**Entries in column (c) are calculated as component weighting points divided by total component weighting points for the bridge. This particular example bridge has all components, whose weighting points sum to 100.

Unlike the legacy formula for bridge Condition Rating, if there are multiple instances of an element, each instance is weighted and averaged into the span component index. The Legacy System simply selected the worst instance of the element and entered it into the formula for the bridge Condition Rating. There was no averaging of multiple instances of elements or of multiple spans.

Summary

This treatment of elements in the BCI calculation is significantly different from the manner in which bridge condition was measured in the Legacy System. The legacy Condition Rating used the rating of the worst instance of a legacy component, regardless of which span it was on. The new BCI uses all instances of the element ratings (e.g., beginning abutment, end abutment, every pier, every girder element). Also, as described previously, the averaging of the four condition state quantities required to produce the element condition index can obscure the presence of small but severe defects that the Legacy System was able to capture. Combined, these differences contribute to the distribution of bridge condition measures being skewed higher with the BCI than it is with the legacy Condition Rating. That is, more bridges are grouped together at upper levels of the BCI, whereas in the Legacy System the bridges are more distributed along the continuum of legacy Condition Ratings from 1-7. The difference between the BCI averaging approach and the legacy "worst of" approach will tend to be greater, the larger the bridge.

3.3.3 INTERPRETATION OF THE BCI

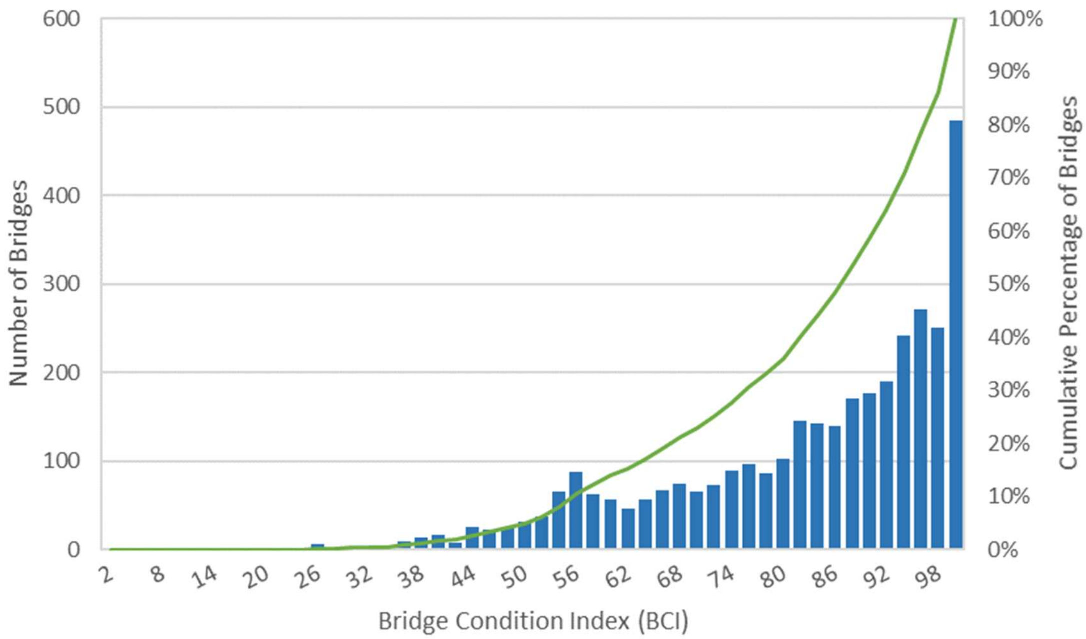
DISTRIBUTION OF BCIs FOR THE BRIDGE POPULATION

Exhibit 3-6 displays a frequency distribution of the BCIs for all single-span state-owned bridges. The bars show the number of bridges in the BCI range and the line tracks the cumulative percentage of bridges from BCI of 0 to 100.

Several features of the pattern in frequency bars stand out. Very few bridges are rated lower than 50, and many of the bridges are rated higher than 90. There is a slight jump in number of bridges with BCIs in the mid 50's (55 points was originally assigned to the percentage of the bridge in CS2), and then number of bridges is almost steadily increasing after that bump in the mid 50's. The reason underlying this distribution pattern was described previously in the Section 3.3.2 summary. The successive layers of averaging in computing the BCI tends to obscure small but severe defects that the Legacy System tended to highlight, resulting in a rightward skew to the distribution of BCIs. In contrast, the legacy bridge Condition Ratings did not have this skew towards the highest ratings; in fact, the legacy Condition Ratings had a slightly bell-shaped distribution.

This concentration of bridges at the upper ends of the scale presents some challenges to defining BCI cutoff values for assigning the four levels of condition category (good—fair-protective—fair-corrective—poor). The bump in the low 50s means that placement of a cut-off for the poor and fair-corrective condition categories can have a significant effect on the resulting performance measure for the network.

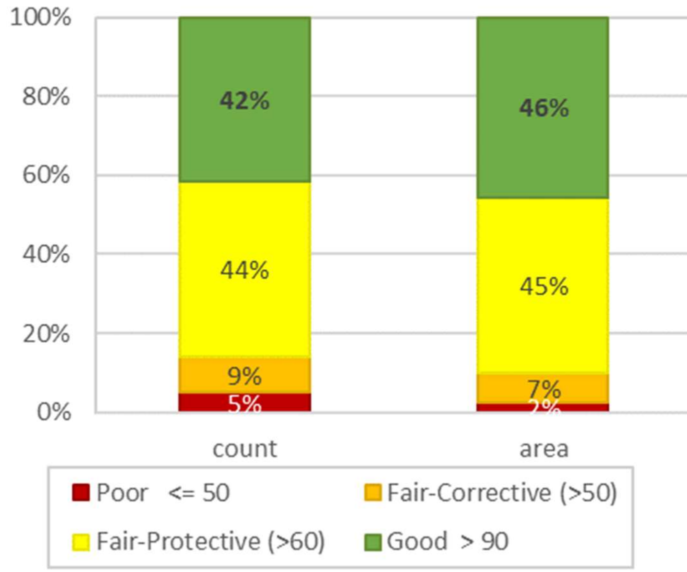
Exhibit 3-6. Frequency Distribution of Bridge Condition Indices for State-Owned Single-Span Bridges



MEASURING NETWORK PERFORMANCE USING THE BCI

The BCI is simply an index number; to interpret what a bridge's condition index means for its condition category requires the establishment of cut-off values, analogous to the legacy Condition Rating thresholds shown in Exhibit 3-1. The NYSDOT project team considered a variety of threshold values for the BCI and examined the resulting network performance charts. Exhibit 3-7 displays the network performance as measured by the shares of the bridges and their deck area in each of the four condition categories using the sample BCI threshold values shown. The example is shown for all single-span state-maintained bridges.

Exhibit 3-7. Example Performance Chart Using BCI – State-Owned Single-Span Bridges



The project team examined the network performance of various DOT Regions[15] using different trial cutoff-values for condition category applied to the BCI. Region performance using the BCI was found to differ considerably from historical performance using the legacy Condition Rating, and to differ in sometimes unexpected ways.

EXAMINATION OF INDIVIDUAL BRIDGE RATINGS

Several Excel workbooks were used to support the evaluation of the performance measures being considered for this research. One example of such a workbook ("Bridge Elements Observer") is shown here as an example. The workbook was developed to facilitate the examination of how the BCI formula applies to any selected structure. Screenshots of the results worksheet tabs in the workbook are presented in Exhibit 3-8. The Excel workbook provided a detailed view of element ratings, span-component condition indices (span CCI), component condition indices (CCI), and bridge condition index (BCI). The workbook was loaded with the inspection data for calendar years 2017 and 2018. It also applied condition state treatment thresholds (described in Chapter 4) and color-coded the element according to treatment triggered (treatments are discussed in Chapter 4). The calculation of span-component condition indices is on a different worksheet tab, not shown.

[15] NYSDOT is geographically divided into eleven operational and administrative regions. Appendix F presents a map of these regions.

Exhibit 3-8. Example Views from "Bridge Elements Observer" Excel Workbook

Deck	0.25	53.14
Super	0.35	77.50
Sub	0.3	45.87
Culvert	0	0.00
Secondary	0.1	27.50
	BCI	57.00

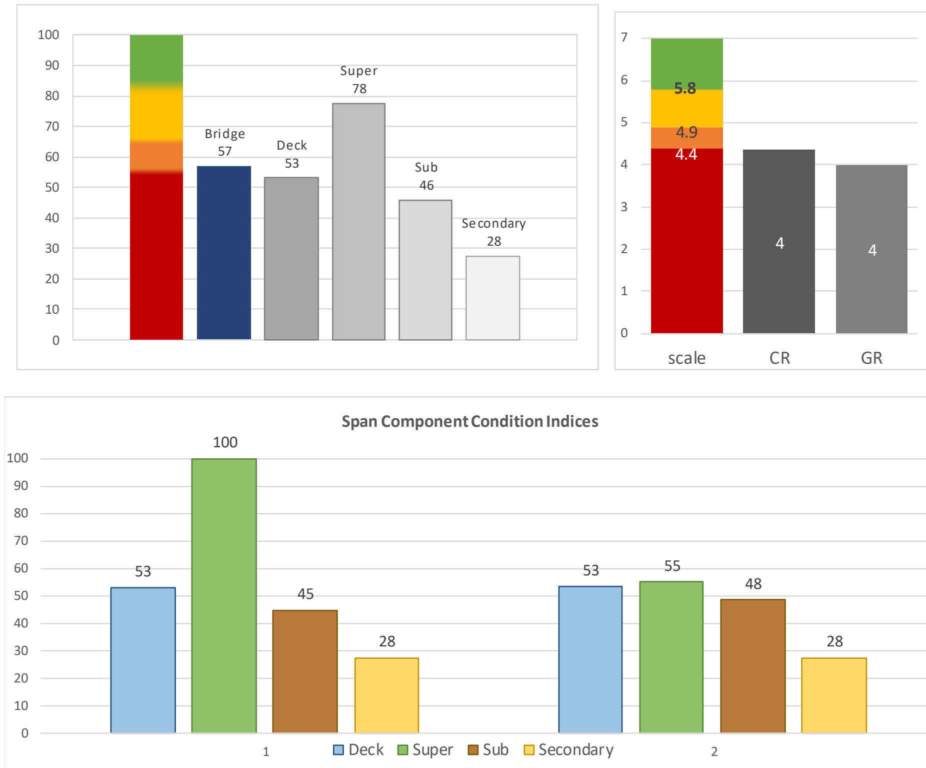
Deck Area	1,300	Type	
Spans	2	Material	

lts Used for

						Calculated from ElemInsps worksheet				Element Results Summary		
						Inspected condition states						
				Component		Fraction by condition state f_{cs}				Element condition Index	Element Weight Shading	Element Treatment Triggered
					Quantity	State 1	State 2	State 3	State 4			
Span	**Element**	**Name**	**Suffix**	**Component**	**Quantity**	**Frac1**	**Frac2**	**Frac3**	**Frac4**	**ECI**	**Weight2**	**Treatment**
1	12	Re Concrete Deck	0	Deck	657	0%	94%	6%	0%	52.87	100	Light
1	107	Steel Opn Girder/Bean	0	Super	231	100%	0%	0%	0%	100.00	100	none
1	210	Re Conc Pier Wall	PR	Sub	20	0%	50%	0%	50%	27.50	125	Replace
1	215	Re Conc Abutment	BA	Sub	44	0%	98%	0%	2%	53.75	100	Heavy
1	331	Re Conc Bridge Railing	0	Unused	66	0%	100%	0%	0%			none
1	510	Wearing Surfaces	0	Second	600	0%	100%	0%	0%	55.00	10	none
1	515	Steel Protective Coatir	0	Second	231	0%	0%	0%	100%	0.00	10	Replace
1	800	Erosion or scour	BA	Unused	44	0%	93%	0%	7%			Light
1	800	Erosion or scour	PR	Unused	40	0%	75%	0%	25%			Heavy
1	801	Stream hydraulics	0	Unused	1	0%	0%	100%	0%			Light
1	850	Backwall	BA	Unused	20	0%	100%	0%	0%			none
1	851	Abutment pedestal	BA	Sub	7	0%	100%	0%	0%	55.00	60	Light
1	852	Pier pedestal	PR	Sub	7	0%	100%	0%	0%	55.00	60	Light
2	12	Re Concrete Deck	0	Deck	657	0%	95%	5%	0%	53.40	100	Light
2	107	Steel Opn Girder/Bean	0	Super	231	0%	100%	0%	0%	55.00	100	none
2	215	Re Conc Abutment	EA	Sub	20	0%	70%	30%	0%	44.50	100	Heavy
2	331	Re Conc Bridge Railing	0	Unused	66	0%	100%	0%	0%			none
2	510	Wearing Surfaces	0	Second	600	0%	100%	0%	0%	55.00	10	none
2	515	Steel Protective Coatir	0	Second	231	0%	0%	0%	100%	0.00	10	Replace
2	800	Erosion or scour	EA	Unused	44	0%	100%	0%	0%			none
2	850	Backwall	EA	Unused	20	0%	100%	0%	0%			none
2	851	Abutment pedestal	EA	Sub	7	0%	100%	0%	0%	55.00	60	Light

(continued on following page)

Exhibit 3-8. Example Views from "Bridge Elements Observer" Excel Workbook *(continued from previous page)*



3.3.4 COMPARISON OF THE BCI TO OTHER BRIDGE CONDITION MEASURES

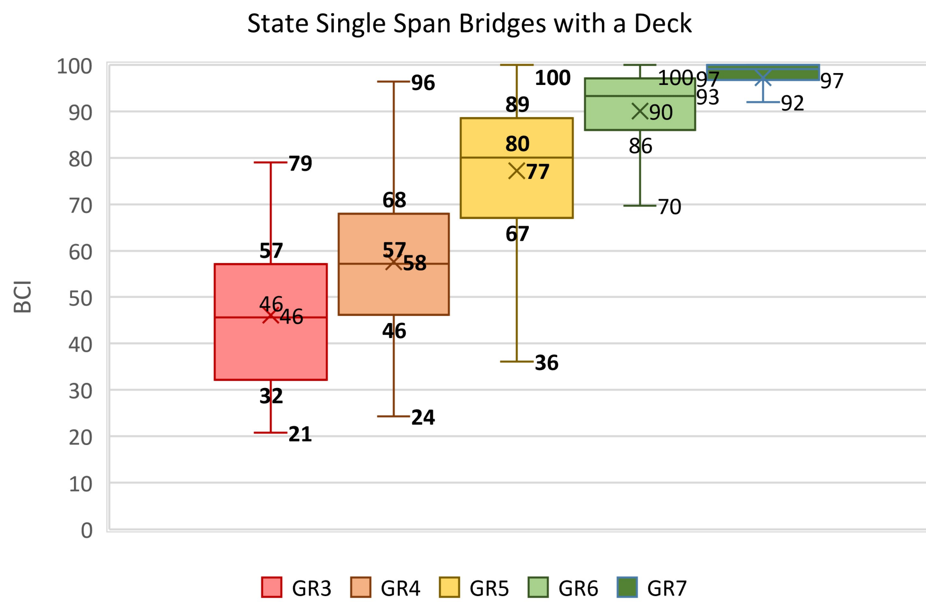
BCI COMPARED TO GENERAL RECOMMENDATION

Exhibit 3-9 uses a box and whisker diagram to depict the relationships between BCI and the NSYDOT General Recommendation. As described in Chapter 2, the General Recommendation is determined at the discretion of the inspector. It follows a seven-point integer scale. Each box in Exhibit 3-9 encloses the middle 50th percentile of datapoints in the grouping of BCIs for bridges that have the indicated GR rating. The line inside the box represents the mean, and the "x" indicates the median. The whiskers extend to all datapoints used in constructing the distribution. Other datapoints are regarded as outliers (based on an algorithm within Excel), are not included in calculating the distribution, and are not shown.

A BCI that closely corresponds with the General Recommendation would show a tight clustering of the BCI distribution for each GR score, represented by a short box and whiskers, with the clustering centered higher for the higher GR scores. There would be minimal overlap in the distributions. This type of distribution would reflect a high level of correspondence between the bridge's BCI and the inspector's assessment of the bridge's condition. This tight clustering is not the case for the BCI.

For example, the bridges rated GR3 ("considerable deterioration of some or all components") had a BCI as high as 79 (top of upper whisker), and 25 percent of these GR3 bridges had a BCI between 57 and 79 (range of upper whisker). Looking at the lower box and whisker for GR 5, one can see that there were many bridges in the range between 57 and 79 that were given a considerably different GR rating. That is, of the bridges with a BCI between 57 to 79, many were rated by inspectors as GR5 ("Primary members and substructures in good condition") while many others were rated as GR3 ("Considerable deterioration of some or all components").

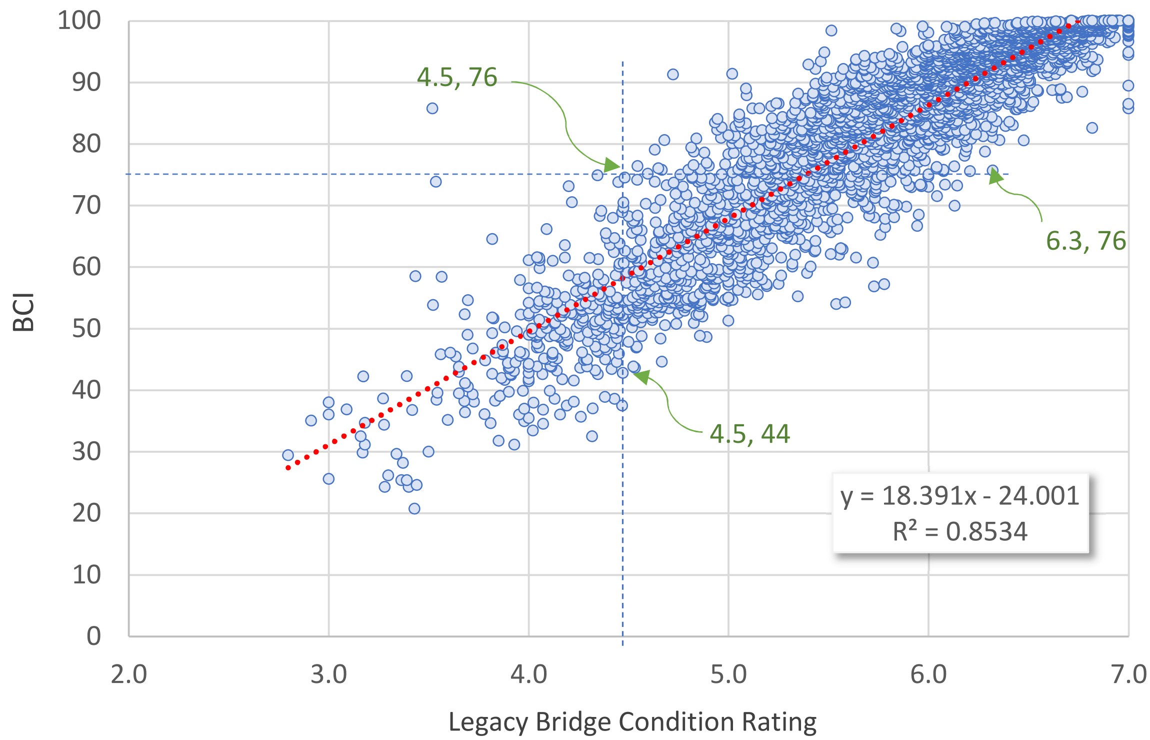
Exhibit 3-9. BCI Distributions Compared to General Recommendation Ratings



BCI COMPARED TO LEGACY BRIDGE CONDITION RATING (CR)

NYSDOT has developed a translation formula to convert AASHTO element ratings to legacy element condition ratings so that the existing bridge management system formulas and decision logic can continue to be used until the department completes the integration of the AASHTO element data into its system. The translated element ratings are applied in the legacy bridge condition rating formula (described in Section 3.2). Exhibit 3-10 displays a scatter diagram that pairs each bridge's legacy method condition rating with the BCI. The population of bridges in this exhibit is limited to state-owned single-span bridges.

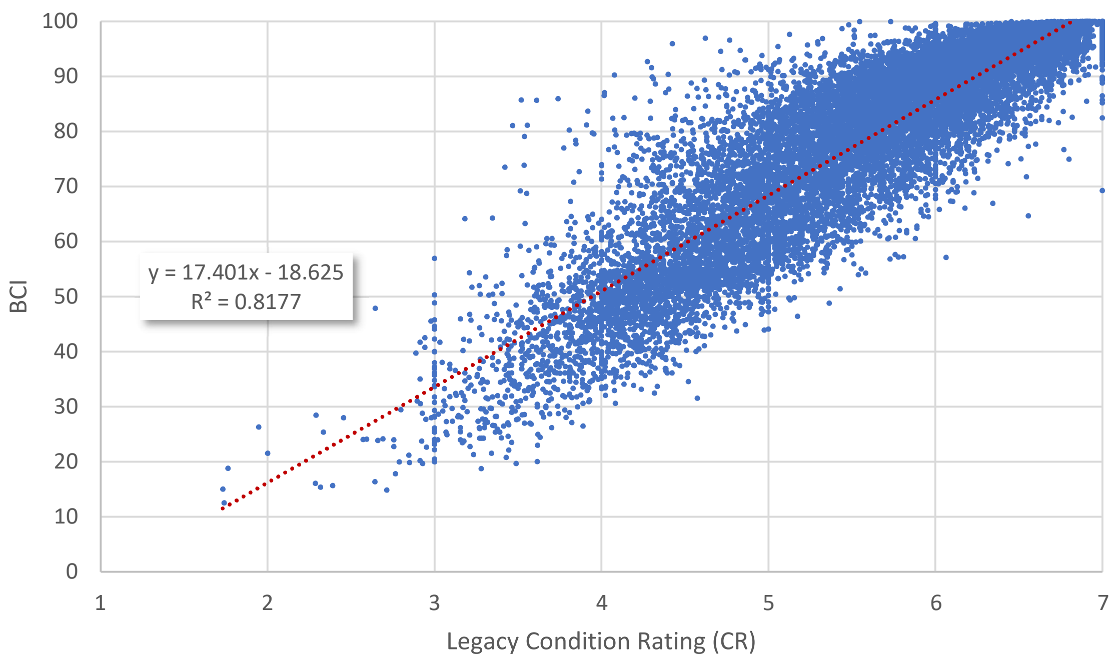
Exhibit 3-10. BCI Compared to Legacy Bridge Condition Ratings – State-Owned Single-Span Bridges with Deck



The scatter diagram in Exhibit 3-10 shows the expected positive relationship between BCI and CR ratings. It also shows that the relationship is strong, with more than 85 percent of the variation in the BCI "explained" by the variation in Condition Rating (i.e., the R^2 is 0.8534) This relationship is not surprising, since they are all single-span bridges and therefore would have a limited number of elements; there is less opportunity for averaging to cause much divergence from the "worst of" approach of the legacy rating formula. On the other hand, there is substantial spread of BCI for any particular Condition Rating. For example, reading along the vertical dotted line, for a Condition Rating of 4.5 (in the low end of the "fair-corrective" range) BCIs range from a low of 44 to a high of 76. Looked at a different way (reading along the horizontal dotted line), bridges with a BCI of 76 can have a Condition Rating of 4.5 (low end of fair-corrective) or as high as 6.33 (middle range of "good"). Detailed element data for three bridges that encompass these three points in Exhibit 3-10 are presented in Appendix G.

Exhibits 3-11 through 3-13 display the BCI and associated Condition Rating for all bridges with decks. These populations include larger bridges with more elements and more spans, which provides for more averaging of element ratings and therefore a greater potential for difference from the legacy Condition Rating. The effect is not noticeable in Exhibit 3-11. The correlation line in this exhibit is very similar to the line for single-span bridges. This result is consistent with the fact that the average number of spans for this population grouping is only 2.2.

Exhibit 3-11. BCI Compared to Legacy Bridge Condition Ratings - All Bridges with Decks



Exhibits 3-12 and 3-13, respectively, display data for Region 1 (Capital District) and Region 11 (New York City). The average number of spans in the Region 11 network is 7, in contrast to fewer than two spans in Region 1. The line measuring the correlation between the measures for Region 11 lies above that of Region 1 and is flatter. The higher line means that, for a given Condition Rating using the legacy formula, a bridge in Region 11 will tend to have a higher BCI than a bridge in Region 1. The flatter slope means that Region 11's bridge network tends to be higher rated than Region 1, even more strongly for the poorer condition bridges (to the lower left of the chart area). These results likely reflect the greater role of averaging the large numbers of elements for the average bridge in Region 11.

Also notable is that the R-squared measure for Region 11 is considerably lower than that of the entire state population and that of Region 1. This lower R-squared measure means, roughly, that the New York City bridges (larger and more complex bridges, on average) exhibit less correlation between BCI and CR than Capital District bridges (simpler bridges, on average). It suggests that the BCI might not be serving well at measuring the condition of NYC region bridges (or larger bridges in general). In fact, when BCI was used to measure Region 11 network performance (e.g., percent of bridges in good/fair-protective/fair-corrective/poor conditions), it showed the performance appearing significantly better than bridge managers considered to be the case for the Region's bridges, particularly in relationship to the network performance of the other regions.

Exhibit 3-12. BCI Compared to Condition Rating - Region 1 (Capital District)

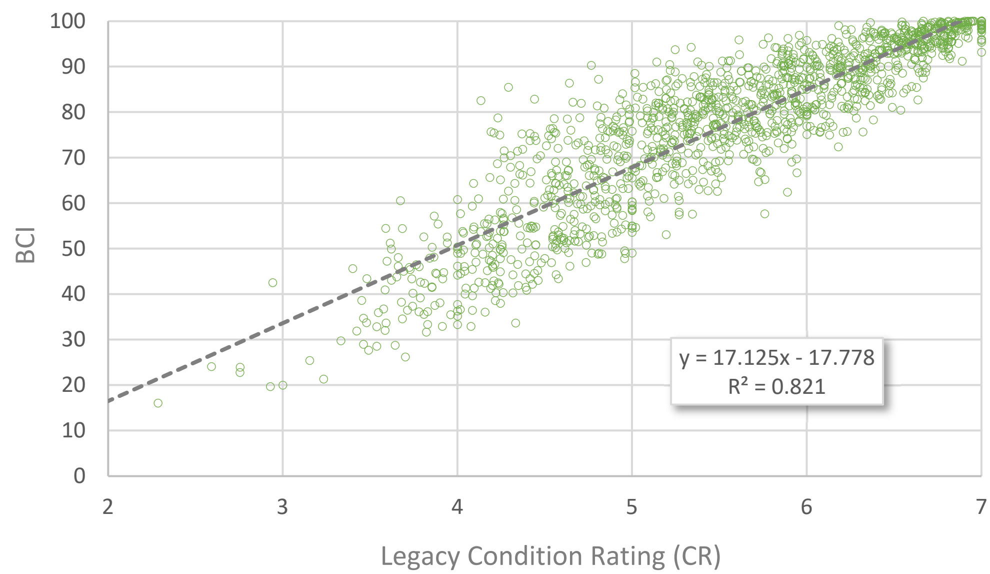
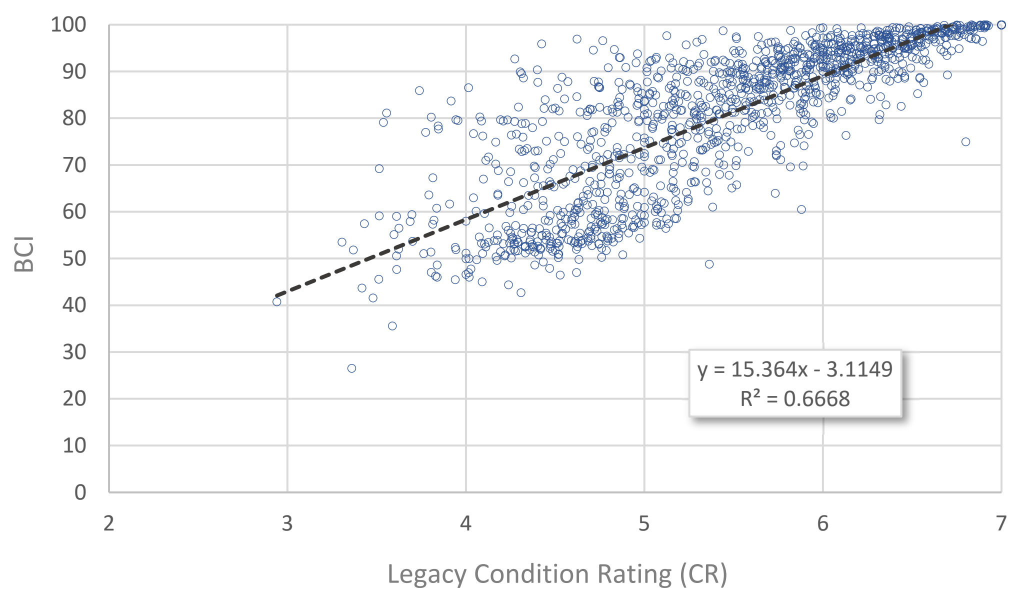


Exhibit 3-13. BCI Compared to Condition Rating – Region 11 (New York City)



The spread in BCIs for General Recommendation and Condition Ratings suggests that the BCI is restricted in usefulness for comparing bridges to one another, in performance measurement or project prioritization. The spread shown in these charts also is suggestive that the BCI has limited usefulness to NYSDOT as an indicator of the type of work needed. The spread does not imply that the measure is inappropriate for tracking the condition of a bridge over time or in management software optimization modules.

3.3.5 SUITABILITY OF THE BCI FOR POTENTIAL USES

Suitability of the BCI to track an individual bridge condition over time

This result was not tested empirically, but the nature of the formula for calculating the BCI indicates that it should function at least reasonably well for this use. Any change to higher percentages of an element in a worse condition state will lower the BCI. Conversely, performing major repair work on a bridge will increase the BCI by moving element ratings to higher percentages in the better condition states.

Suitability of the BCI to indicate the expected level and/or type of work needed

On an individual bridge level, the BCI does not provide the granularity of information needed to determine the work needed. For example, the weighted averaging of condition state percentages to calculate an element condition index can obscure the fact that the percentage of the element in condition states 3 and 4 is so high that repairs are likely needed.

Suitability of the BCI to measure network performance

As noted in the introductory section 3.1.4, to be effective in measuring network performance, a bridge condition measure should accurately differentiate among bridges at the same point in time. The spread in BCIs for Condition Rating (Exhibit 3-10) and for General Recommendation (Exhibit 3-9) suggests that this criterion is often not met. Again, this is a phenomenon that averaging tends to create. Averages of extreme highs and lows are not distinguishable from averages of all mid-range values.

Another challenge of using the BCI to measure network performance is determining where to set the cut-offs aligning BCI value ranges to the four condition categories. The distribution pattern of BCI values shown in Exhibit 3-6, with roughly half of all BCIs above 90, contributes to the challenge of setting cut-off values.

Suitability of the BCI as a factor in software (BrM) optimization module

By general design and scale, the BCI is potentially useful for use in BMS optimization. The BCI formula structure is in close alignment with the “health index” formula used in both AgileAssets and BrM software optimization. The health index is just one of several factor that these systems can use for optimization. The choice of weights for condition states, elements, and components matters for this use, because the weights determine how the condition (health) index changes in response to deterioration and in response to treatment actions. Section 3.1.4 in the introductory section further explains this consideration and Section 3.3.2 describes how this consideration influenced the adjustment of element condition state weighting points.

Suitability of the BCI as a factor in project prioritization

The BCI can be used in NYSDOT project prioritization, with caution and/or perhaps with a modification described in the following section. Some of the comparisons described previously noted that bridges can have very different BCIs but the same General Recommendation and/or nearly the same Condition Rating. This phenomenon suggests that the BCI may not be ideal for distinguishing condition among bridges. Because the NYSDOT prioritization only uses the condition measure to distinguish among bridges within the *same* work type, some of the divergences noted previously may not figure as prominently in such a use. In fact, the BCIs usefulness in prioritization could be enhanced by tailoring the BCI to the work type. For example, a BCI used for prioritization among preservation projects could be weighted to focus on elements and conditions that merit more emphasis in preservation decisions, such as coatings, wearing surfaces, and expansion joints.

3.3.6 VARIATIONS IN BCI CALCULATION FORMULAS

The preceding discussion noted some of the limitations imposed by a formula that relies so extensively on averaging. Each instance of averaging sacrifices some granularity of information that can be useful in distinguishing among bridges. Many variations in the method to compute the BCI could be applied to help preserve some of this information. All of the variations represent a movement part of the way back towards the legacy “worst of” approach.

None of the approaches which follow would help with identifying opportunities for low-cost preservation work to prevent further deterioration on bridges that are in relatively sound condition. Within preservation work types, more emphasis would need to be placed on protective elements such as wearing surfaces and coatings.

ELEMENT FUSE FEATURE

A review of some element condition indices found that it was fairly common that elements with a concerning percentage in CS3 or CS4 had the same condition index value as elements in reasonably good condition. An element fuse is designed to avoid such occurrences. The fuse is a set of pre-selected threshold values, one for percentage in condition state 4 (severe) and one for percentage in condition states 4 and 3 (poor) combined. If the actual condition state percentages exceed either of these thresholds, the fuse is “tripped”, and up to 100 percent (depending on setting) of the percentages in CS1 and CS2 are assigned to CS3. The purpose of the fuse is to help move the element condition index to a lower value than it otherwise would be, to reflect that a critical portion of the element is in poor or severe condition.

This fuse feature was tested on a population of bridges, setting the trigger fairly low and the response high. Even with the extreme settings, the fuse feature did little to affect the distribution of BCIs. Some changes at the margins were shown. Likewise, various fuse settings were examined for effects on element condition indices; there were fewer instances of anomalous combinations of CS distributions and element condition indices, but the anomalies were not entirely eliminated. The small benefit of the feature was deemed to be outweighed by its complexity. The complexity makes the measure difficult to communicate and challenging to incorporate into BMS software.

USING TREATMENT THRESHOLDS IN COMPUTING THE ELEMENT CONDITION INDEX

As will be explained in Chapter 4, the project team selected values for the percentages of an element in condition states 4 and 3 that would trigger the selection of three levels of treatment: light repair, heavy repair, and replacement. These treatment thresholds are applied to the element inspection data for each element, and the selected treatment is identified. This BCI variant substitutes the calculation of an index to the assignment of an index value as follows: (1) no treatment triggered--index is 100, (2) light treatment is triggered—index is 55 (55 was the weight given to CS2 in original BCI formula), (3) heavy treatment is triggered—index is 20 (20 was the weight given to CS3 in the original BCI formula) (4) replacement is triggered—index is zero.

This variant to the BCI formula has the advantage of using the information embedded in the granularity of the AASHTO element rating system. The variant was tested on a population of bridges. Like the fuse feature, the difference it made to the BCI was only found at the margins. The benefit is deemed to be outweighed by the additional complexity and expected challenge at calculating the element condition index this way in BMS software programs. Another disadvantage of this variant is that the element condition index, and ultimately the resulting BCI, are dependent on the treatment thresholds being applied. NYSDOT could well elect to adjust these thresholds, which would change the BCI formula and the resulting BCIs

A "WORST OF" SPAN OR COMPONENT CONDITION INDEX

A hybrid of BCI and a "worst of" approach was considered, in three variations:

(1) Set the BCI equal to the lowest Span BCI. Each Span's BCI is the weighted combination of its Component Condition Indices. This approach aims to measure the bridge condition as the condition of its worst span.
(2) Set the BCI equal to the lowest Component Condition Index for the whole bridge. For each component, the Bridge Component Condition Index is the weighted combination of each span's condition index for the component. This approach aims to measure the bridge condition as the condition of its worst component.
(3) Set the BCI equal to the lowest Component Condition Index *on any span* of the bridge. This is the extreme case of "worst-of" for the component method.

The implications of these alternative BCIs for network performance measurement were studied. Various cut-off levels for good/fair-protective/fair-corrective/poor were set for each of these measures and resulting network performance charts were examined. The performance also was compared to see how it aligned with bridge condition when measured according to calculated work type. Although several of these alternatives seemed a better match to expected network performance, after consideration of the resultant logic, researchers concluded this was a very complex way simply to recreate what is already available in the form of NBI component and bridge condition ratings. Therefore, these alternative BCI formulations are not currently seen as a solution to concerns with the original BCI formula results.

FUSE APPLIED TO COMPONENT CONDITION INDEX

A modified version of the approach described previously is the application of a "fuse" to the bridge component condition index. A component condition index fuse sets the maximum percentage by which the BCI could exceed the lowest component condition index. For example, for a fuse of 20 percent, if the substructure index is 60, but the BCI is 80 because the superstructure and deck have high component condition indices, the fuse would be activated and the fuse-adjusted BCI would be 72 (120% x 60). This fuse feature avoids the situations where the averaging of component condition indices obscures the existence of a component being in a considerably lower condition than the other component(s).

The feature was tested with a setting at 20 percent and was found to have a modest effect, at most, on the distribution of BCIs. There may be limitations to its use in BMS software for optimization, in the sense that the software might not allow for the extra calculation step. Also, as with any fuse, the formula sets up a situation where the BCI can jump somewhat discontinuously as the fuse is activated or deactivated in response to changes in component condition indices. Overall, this type of fuse does not sufficiently address the issues with the BCI to merit its added complexity and challenges in implementation.

VARIABLE ELEMENT WEIGHTS: THE DENVER BRIDGE HEALTH INDEX[16]

This condition index variant is described here for background information only; it was not examined in detail for this research project.

Researchers for the City and County of Denver (CCD) public works department were dissatisfied with the conventional Pontis Bridge Health Index, which bears many similarities to the BCI being examined in this project (Jiang and Rens, 2010). They had encountered various instances in which a bridge had a fairly high index yet was known to have one or two important elements in an advanced state of deterioration. One of the ways they addressed this phenomenon was to provide for the weight assigned to the element to vary according to the effect of the element damage on the bridge health and function. The weight is varied according to an adjustment formula that increase the weight for elements with a lower condition index. The researchers found that the modified health index more accurately categorizes what they know to be the health of their relatively small population of bridges. The modification to the index reduced the concentration of bridge numbers in the 90-100 index value range. It also was found to have a stronger and more responsive negative correlation with bridge age compared to the un-modified Bridge Health Index.

A BCI variant of this sort was not investigated for this research project. Its benefits are not believed to outweigh the added complexity and the added uncertainty entailed in developing the appropriate element weighting adjustment factors.

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[16] Jiang, S. and K. Rens. 2010, "Bridge Health Index for the City and County of Denver, Colorado II: Denver Bridge Health Index". *J. Perform. Constr. Facil.*, 2010, 24(6): 588-596.

3.4 CONDITION RATING BASED ON PROJECT TYPE SELECTION

3.4.1 INTRODUCTION

In addition to the development of a bridge condition index, the second objective of the research project is to develop an algorithm for treatment selection that can be automated in a bridge management system. Chapter 4 covers this product. The selection logic is based primarily on element condition states, and produces a categorical result rather than the scalar result produced by the BCI. For applications where conditions are to be described or categorized based on level of treatment, a method based on this treatment selection logic may be more directly relevant than the BCI. The following sections discuss how the selection logic might be adapted for this purpose.

3.4.2 METHOD FOR CALCULATING THE CONDITION MEASURE BASED ON PROJECT TYPE

For each bridge, the treatment selection logic (presented in Section 4.2) is applied to the AASHTO element rating data. Next, the project type selection logic (presented in Section 4.3) is applied to the selected treatments to identify which of eleven groupings of project types apply to the structure. These eleven project type groupings are mapped into the four condition categories as shown in Exhibit 3-14.

Unlike the legacy bridge Condition Rating and the new BCI, the result of the project type method is not a numerical rating that needs to be correlated to the four condition categories, but rather a direct identification of which of the four condition categories applies to the bridge. These are the same four condition categories enumerated previously for the Legacy System, with the same definitions. Note that the definition of the condition categories has always explicitly referred to the type or level of work required.

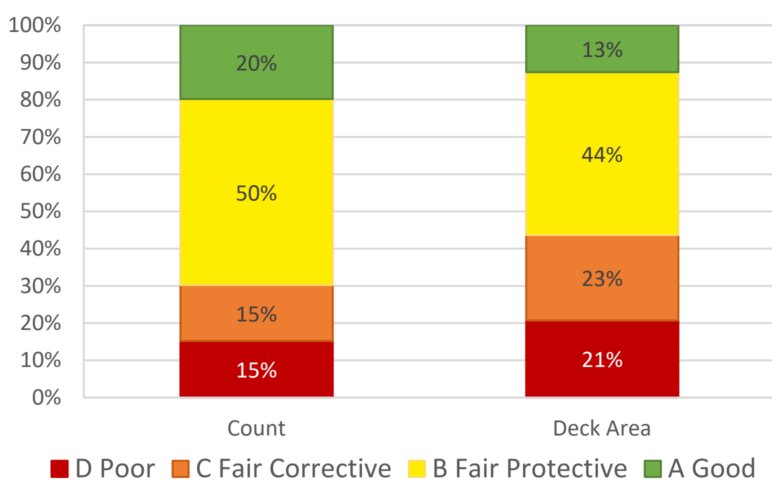
Exhibit 3-14. Bridge Project Types and Corresponding Condition Categories

Condition Category	Project Type	Project Type ID
Poor	Bridge Replacement	1
	Superstructure Replacement Combinations	2
Fair-Corrective	Superstructure Rehabilitation Combinations	3
	Substructure Rehabilitation Combinations	4
	Deck Replacement Combinations	5
Fair-Protective	Paint Replacement	6
	Deck Rehabilitation (deck repairs with joint replacement)	7
	Vertical Down (joint replacement with substructure repairs)	8
	General Repairs (except to paint or wearing surface)	9
	Preservation Treatments	10
Good	Cyclical Maintenance – No repairs	11

3.4.3 INTERPRETATION OF THE CONDITION MEASURE BASED ON PROJECT TYPE

Unlike an index, the result of this method is, in effect, the interpretation. This method produces a designation of what type of work is required and which of the four condition categories the bridge is in. Exhibit 3-15 presents performance bar charts that illustrate how the project types line up into the four condition categories for all NBIS highway bridges in the state.

Exhibit 3-15. Network Performance Using Condition Measures Based on Project Type, All Highway Bridges



It is interesting to note that the performance is worse when deck area is the measure, indicating that using project type as a measure finds that poor and fair-corrective conditions are more prevalent among the larger bridges than among smaller bridges. The opposite is the case for BCI; larger, multi-span bridges tend to “benefit” from the averaging over the multiple elements and spans, and the performance is better when measured by deck area rather than by number of bridges.

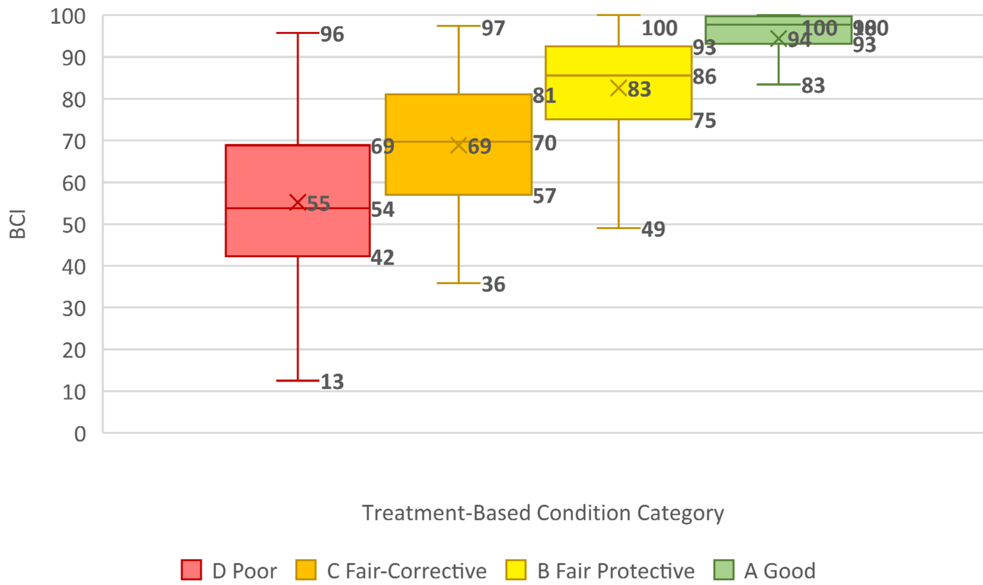
3.4.4 COMPARISON OF THE CONDITION MEASURE BASED ON PROJECT TYPE TO OTHER MEASURES

BCI DISTRIBUTIONS BY PROJECT TYPE CONDITION CATEGORY

Exhibit 3-16 presents a box and whisker chart that shows the distributions of BCIs for bridges that were assigned to each of the four condition categories on the basis of selected project type. The network of bridges analyzed was narrowed to simpler bridges with similarities in material and type. This limited network provides a sort of “best case scenario” for expecting correspondence between BCI and selected project type. The exhibit displays considerable overlap in the boxes for adjacent condition categories. This overlap is most prominent between the poor and fair-corrective condition categories.

The exhibit indicates that, for bridges categorized as Poor based on selected project type, the median BCI is 55; this means that half of the bridges categorized as poor have a BCI higher than 55. Consequently, if a BCI cutoff for poor is set at 55, half of the bridges that the project type method categorizes as poor will not be categorized as poor based on their BCI. Any BCI in the upper box and whisker for *poor* bridges could reflect a BCI that is not well-suited for measuring bridge condition in terms of its level of treatment needs or a project type selection that is overly conservative (or both). The distribution information shown in the exhibit is not capable of giving evidence favoring one measure over the other; it only shows that they can be quite different.

Exhibit 3-16. Condition Measure Based on Project Type versus BCI, Painted Steel Girder 1-3 Span Bridges

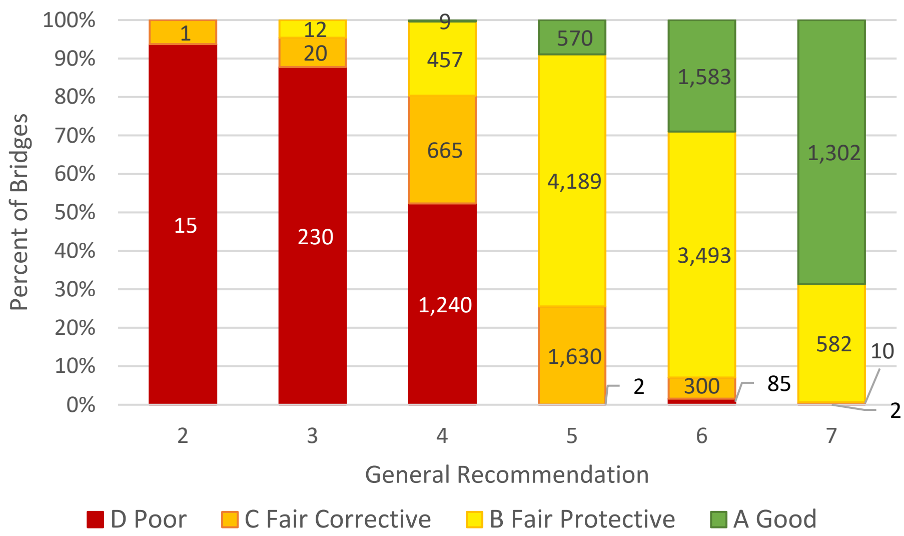


COMPARISON OF PROJECT TYPE BASED CONDITION MEASURE TO GENERAL RECOMMENDATION

As with the BCI, it is instructive to compare this condition measure with the inspector's General Recommendation (GR). In this case a bar chart is used to make the comparison, as there are only four different condition measures, rather than a continuum of values between 0 and 100. The full diversity of bridge sizes and types is included, to give the most extreme test of the correspondence of the two condition measures. Exhibit 3-17 shows the mix of bridge condition categories for each General Recommendation. Fifteen of the sixteen bridges with a GR of 2 (poor, with extensive deterioration of primary members) also were categorized as poor based on project type selected. The great majority of bridges with a GR of 3 (also poor, but less severe) were assigned a condition category of poor. These two findings speak well to the ability of the project type approach to convert element inspection data into a useful measure of bridge condition.

On the other end of the chart, many (582) of the bridges with a General Recommendation of 7 (new condition, only routine maintenance required) were found to need some protective maintenance based on selected project type (i.e., condition category was measured as fair-protective) and only twelve were found to need corrective maintenance or replacement. The distribution of condition categories for GR 6 (only minor deterioration) shows a considerable number of bridges (385) calling for a project type categorized as corrective maintenance or poor, but the great majority (more than 90 percent) have a project type in the good or fair-protective condition category. In general, the condition measure based on project type appears to align reasonably well with the General Recommendation, especially considering the prominent role of judgement required in assigning a General Recommendation.

Exhibit 3-17. Condition Based on Project Type vs General Recommendation, All Highway Bridges



Note: Values within bars are bridge counts.

3.4.5 SUITABILITY OF THE PROJECT TYPE CONDITION MEASURE FOR POTENTIAL USES

Suitability of the Project Type measure to indicate the expected type/level of work needed on the structure

This measure is the best suited of all measures for this use, because it is explicitly designed for this purpose. That said, it should be noted that a logic used to select project types for condition measurement is only a simple screening tool; it is not necessarily the complete set of decision rules for the software to use in identifying and recommending work candidates. For example, the BMS may have rules such as "do not recommend deck replacement if bridge is functionally obsolete". This type of rule would not affect the condition assessment of the bridge, but it would affect project type selection. Moreover, the ultimate selection and design of projects will occur outside the bridge management system software. This research project did develop a more complete set of decision rules for the NYSDOT BMS. These rules are described in Chapter 4.

Suitability of the Project Type measure to measure network performance

Because it is designed as a direct measure of the NYSDOT bridge condition category, which in turn is defined in terms of treatment need, this measure is ideally suited for measuring network performance. The percentage of bridges in any given network (e.g., region, state-maintained) in each condition category should represent fairly well the true percentage of bridges in those condition categories.

3.5 FINDINGS ON BRIDGE CONDITION MEASURES

BCI Performance Measurement Concept

The concept of bridge and network performance measurement using a BCI with averaging of conditions across elements, components, and spans—similar in general concept to a Health Index—has been thoroughly analyzed in this research project. As an individual structure condition measure, the BCI is unable to fully capture the effect of localized conditions on overall structure condition. When used in network performance measurement, the BCI tends to break down in regions with large and unusual structures. As a factor in project prioritization or optimization, the BCI appears reasonably well-suited. However, before implementation of the BCI in prioritization or optimization, the selection of weighting schemes for elements and components merit particular attention and possibly further examination.

Project Type Performance Measurement Concept

The intriguing concept of using BMS-selected project type shows promise in measuring system performance. However, this type of measurement concept lacks the granularity expected in structure performance measurement and clearly does not provide any distinctions among bridge condition useful to serve in project prioritization.

Components of BCI and Project Type Measurement Concepts

NYSDOT is fortunate to have more options for using element data than typical DOTs because it collects the data by span. In the course of creating the bridge condition index (BCI), a number of other condition indices are created and calculated: element condition indices, span-component condition indices and component condition indices. Similarly, work types by span are created in the course of applying the bridge project type selection logic. The additional, more specific measures have the potential to be useful in project prioritization and project selection.

Interim Performance Measure Selection

While the condition and performance measurement concepts evaluated show promise, they also displayed some characteristics that raise concern for their usage. Concurrent with the latter stages of this research project into the use of element level data, bridge managers at NYSDOT investigated the potential for using other condition ratings in measuring bridge condition and network performance. Use of the NBI general condition ratings (GCRs) for the major bridge components was found to have some promise, at least as an interim measure until the agency accumulates more experience with the inspection and use of element level inspection data. Among the alternatives examined by NYSDOT staff was a weighted average of NBI component GCRs that results in a measure of overall bridge condition on the NBI scale of 0 (failed condition) to 9 (excellent condition). The component weights determined through the expert elicitation process for the BCI were adapted for use in weighting the NBI GCR's. The calculation of a weighted average produces a continuum of ratings along the rating scale. Converting the integer NBI rating scale to a continuous one facilitates establishment of cutoff rating values for mapping the calculated ratings into the four NYSDOT condition categories.

The NBI general condition ratings (GCRs) have several features that are advantageous for use in performance measurement:

- NBI GCRs are simple; a performance measure using NBI GCRs should be easy to communicate to all levels of stakeholders.
- NBI GCRs are publicly readily available and are quoted and used by various groups interested in infrastructure condition.
- NYSDOT has a lengthy and stable record of NBI GCRs for its NBIS bridges.
- The FHWA is already requiring state DOT's to report on NHS bridge network performance using NBI GCRs and to set performance targets using the ratings as part of Transportation Asset Management Planning for the National Highway System.
- NBI GCRs are likely to be the transitional basis for decision rules and benefits measures as NYSDOT configures the more advanced, optimization analyses with its bridge management system. This, again, would be an interim measure until the agency gains more experience with and understanding of element level data, as well as more expertise with the detailed workings of optimization functionalities within advanced bridge management system software packages.

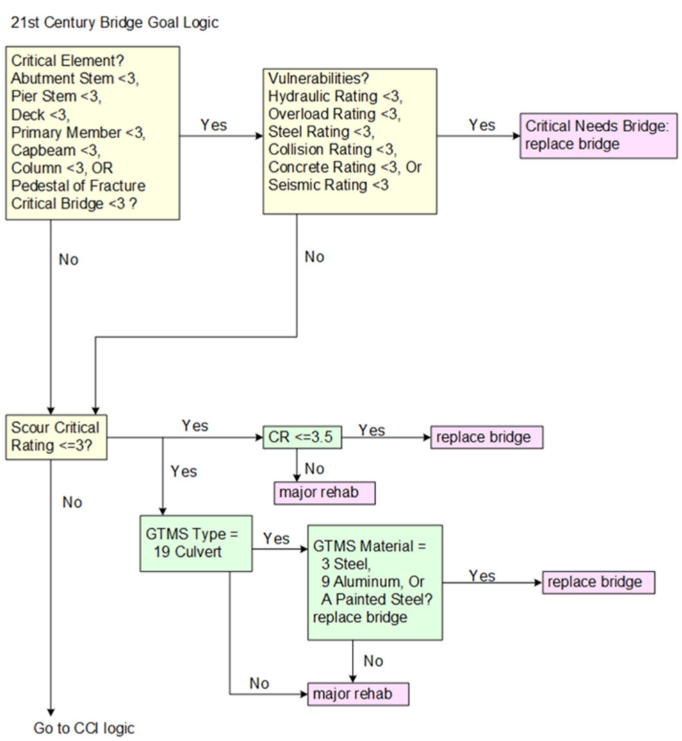
CHAPTER 4 –TREATMENTS AND PROJECT TYPES

4.1 INTRODUCTION

A major objective of this research project was to develop decision rules that apply AASHTO element condition data in selecting treatment levels for each element and in making project type recommendations for each structure. These decision rules are foundational to creating a bridge management system that makes effective use of the AASHTO element inspection data.

The NYSDOT Legacy System has a detailed logic programmed for what treatments to consider based on the Legacy System's condition inspection data. The logic identifies which of seven work types to recommend for further consideration and assigns a priority ranking to the work. The logic makes use of NYSDOT legacy element, component, and bridge condition indices on the legacy 1-7 rating scale (bridge index calculations were presented in Chapter 3). A small segment of the decision tree is shown in Exhibit 4-1 to illustrate an example of the decision logic.

Exhibit 4-1. Excerpt of Legacy Treatment Selection Logic



Currently the system is using a translation formula so that AASHTO element inspection data can be used in the Legacy System. However, the translation formula has been found to be unsatisfactory when applied in the treatment and project selection logic.

When this research project was initiated, it was envisioned that the research would build upon and refine the logic in the Legacy System to make better use of the AASHTO element data than is being realized with the rather simplistic translation formula referenced above. As the research unfolded, it became evident that this project presented an opportunity to build a new decision logic directly using the AASHTO elements that better served the purposes of bridge asset management in New York State. Objectives for the new logic are to be more transparent, to provide useful information to bridge managers without being overly complex and detailed, to align well with actual bridge management and planning practice, and to be readily adjustable in response to accumulated experience with AASHTO element inspection data.

The remainder of this chapter describes the results of this project to transition from the Legacy System to a completely new treatment and project selection system by defining treatments, selection logic, and treatment effects using AASHTO element inspection data. Section 4.2 discusses the element treatments and their thresholds. Section 4.3 presents the project type selection logic. Section 4.4 summarizes the logic for modeling the effect of the selected project types on element conditions. Appendix K contains a guide to developing software for implementing this logic, including SQL code.

Section 4.5 describes the approach to adapting the legacy treatment and project selection logic to use AASHTO element inspection data as an interim measure until the new system described in 4.2 to 4.4 would be implemented.

4.2 ELEMENT TREATMENTS

Subject matter experts from NYSDOT and the project consultant team met during a two-day workshop in June 2019 and participated in an expert elicitation process to define treatments and treatment selection rules based on AASHTO element condition data.

4.2.1 CLASSIFICATION OF TREATMENTS

The expert elicitation produced a new, three-level categorization of element treatments and described in general terms what each treatment category means for each element. The three general categories of treatment are: Light Repairs, Heavy Repairs, and Replacement.

Reinforced concrete deck slab will be used here as an example of treatment types and selection rules. For this element, repair levels are defined as follows:

- Light Repairs – Light patching with a protective coating or sealer.
- Heavy Repairs – Heavy patching (below the top mat of rebar) with a thin overlay.
- Replacement – Replacement of the entire deck slab in any given span.

Because of the large number of elements, the expert elicitation process did not elicit treatments and selection rules for every individual element. Treatments rules were grouped to cover similar elements that could have the same general treatments. Elements that were not specifically named were subsequently taken to be held to the same treatment rules as an analogous element with a different material composition, with certain exceptions permitted. For example, the only deck element specifically addressed in the elicitation process was Reinforced Concrete Deck (Element 12). Deck slabs made of other materials were not specifically addressed at the workshop; the panel reasoned that the decision logic for reinforced concrete decks could generally be applied to all decks (except those composed of prestressed concrete for reasons mentioned below).

The elements that were explicitly addressed at the workshop are listed in Exhibit 4-2 below.

Exhibit 4-2. Elements Included in the Expert Elicitation Workshop

Element ID	Element Name	Element ID	Element Name
12	Reinforced Concrete Deck	225	Steel Pile
102	Steel Closed Box Girder	227	Reinforced Concrete Pile
107	Steel Open Girder/Floorbeam	231	Steel Pier Cap
109	Prestressed Concrete Girders	234	Reinforced Concrete Pier Cap
110	Reinforced Concrete Girders	240	Steel Culvert
113	Steel Stringers	241	Reinforced Concrete Culvert
120	Steel Truss	310-316	Bearing Elements
141	Steel Arches	321	Reinforced Concrete Approach Slab
144	Reinforced Concrete Arches	330-334	Railing
152	Steel Floorbeams	510	Wearing Surface
161	Steel Pin and Hangers	515	Steel Protective Coating (Paint)
162	Steel Gusset Plate	800	Erosion or Scour
202	Steel Column	801	Stream Hydraulics
205	Reinforced Concrete Column	810	Sidewalks
206	Timber Column or Pile Extension	811	Curb
215	Reinforced Concrete Abutment	830	Secondary Superstructure Element
220	Reinforced Concrete Pile Cap	851,852	Pedestals

Among the categories of elements not addressed were cables, pier walls, and joints. Thresholds for these elements were developed by the project team over the course of the project.

Some elements had no light repair treatment defined because light treatments are either not effective in restoring capacity and improving the condition state, or they are not practical. The substructure elements Pier Wall (Elements 210-213) and Abutment (Elements 215-219) are examples of elements for which repairs are rarely made until their condition reaches the level where a heavier repair is needed.

Repair treatments were not defined for any elements composed of prestressed concrete. When the expert elicitation panel considered treatments for Prestressed Girders (Element 109), the panelists agreed that there were no common repairs available that could effectively restore capacity for this element. This conclusion for prestressed girders is being applied to prestressed elements in general; in most cases, repairs to restore capacity and improve the element's condition state are not readily available or practical. It is more practical to just replace the prestressed member.

4.2.2 ELEMENT TREATMENT SELECTION LOGIC

The selection of treatment levels is determined by the percentage of the element in the worse (higher-numbered) condition states. To continue the Element 12 (reinforced concrete deck slab) example, the June 2019 elicitation results for this element are displayed in Exhibit 4-3. The rightmost column lists candidate values for the percentage of the deck area in CS4 that would trigger a replacement of the deck. In initial polling, seven of the panelists voted that if at least 5 percent of the deck area is in Condition State 4, the deck should be replaced. One panelist voted for a 10 percent threshold value, and one voted for 20 percent. The “Default” values shown in the table are the values that were provided by the facilitator as starting values to use prior to polling. After the polling, the panelists’ candidate values were shared with the whole group along with the simple “Average” of the candidate values. Then the panelists discussed the polled values until they reached consensus on the threshold values that will be used. The selected value is shown in the bottom row, as “Result”.

Exhibit 4-3. Expert Elicitation Treatment Thresholds for Reinforced Concrete Deck (Element 12)

	Light Repair (Repair, protect)			Heavy Repair (Rehab, protect)			Element Replacement	
Participant	CS2	CS3	CS4	CS2	CS3	CS4	CS3	CS4
P1	30	10			20	5	40	10
P2	40			60	5	1	10	5
P3	40	1		60	5	1	10	5
P4	50	1			10	1	30	5
P5	80	1			10	1	30	5
P6	80	1			10	1	30	5
P7	50	1			10	1	30	5
P8	50	1			10	1	30	5
P9	67	10			20	10	35	20
Default	67	10	NA	55	20	10	35	0
Average	54.1	3.25	NA	60.0	11.1	2.44	27.2	7.22
Result	**50**	**1**	**NA**	**NA**	**10**	**1**	**30**	**5**

Reading from the bottom row of Exhibit 4-3, the Element Replacement threshold of 5 shown for CS4 means that deck replacement is triggered if at least 5 percent of the deck area is in CS4. The 30 percent Element Replacement threshold value for CS3 means that deck element replacement is triggered if the combined percentage of deck area in CS3 and CS4 is 30 percent or higher. If neither of these Element Replacement thresholds is met, then Heavy Repair is triggered if 1 percent (e.g., any minimal amount) of the deck area is in CS4 or if 10 percent is in CS3. Two panelists voted for including a 60 percent CS2 threshold for heavy repair, but ultimately the panel agreed that the quantity in CS2 would not contribute to the selection of a heavy repair. If neither replacement nor heavy repair are triggered, then 1 percent (e.g., any minimal amount) in CS3 or 50 percent in CS2 would trigger a Light Repair.

After the workshop, it became evident that application of CS2 thresholds for reinforced concrete would create a situation of circular logic, due to the guidance for assigning condition states. (The AASHTO manual rating guidance for reinforced concrete is provided in Appendix C.) Specifically, the guidance specifies that any patched area of concrete can be rated no better than CS2. Therefore, light repairs performed in response to a CS2 threshold for cracks, shallow spalls, or hollow areas would not change the patched area to CS1. Although a deck slab with half of its area in CS2 seems a reasonable candidate for some light repairs, the definition of CS1 necessitated the removal of this threshold to keep the BMS modeling from getting into an endless loop of needed light repairs. The revised treatment thresholds for the reinforced concrete deck element are as follows:

Exhibit 4-4. Revised Treatment Thresholds for Reinforced Concrete Deck (Element 12)

	Light Repair		Heavy Repair			Replacement	
Condition State	CS2	CS3	CS2	CS3	CS4	CS 3	CS4
Threshold (%)	none	1	none	10	1	30	5

Another change was made to CS2 thresholds for some elements, in this case for heavy repair. The elicitation process had set a CS2 threshold of 40 percent for heavy repairs of reinforced concrete abutments. After a review of project selections against some actual planned bridge projects and detailed bridge conditions, the project team realized that the modeling was selecting substructure rehabilitations too readily by using CS2 percentages as a threshold for heavy repairs to an abutment, and the heavy repair was found to explain some of this phenomenon. Again, the AASHTO rating guidance for reinforced concrete makes it impossible for any treatment of a CS2 reinforced concrete element to raise it to CS1 since a patched area (even if found to be sound) is still classified as CS2. The project team has concluded that, for any material type, the percentage of an element in CS2 does not provide a useful guide to the need for heavy repair of the element. The few instances of CS2 thresholds for heavy repair were removed.

In the latter stages of the project, when treatment effects assumptions were being developed (discussed in Section 4.4), the usefulness of CS2 quantities came further into question. It is not a routine practice at NYSDOT to repair the portions of elements in CS2 condition (unless repair involves element replacement). If CS2 areas are not repaired, then the amount of an element that is in Condition State 2 is not relevant to a treatment decision. Ultimately, CS2 thresholds were removed from light treatment selection rules for the 37 elements that had CS2 thresholds and from heavy treatments for the 19 elements that had CS2 thresholds.

Appendix E includes a table with all AASHTO elements used in New York State, showing treatment thresholds, associated component for BCI calculation purposes, and number of instances of the element in the New York state bridge network.

4.3 BRIDGE PROJECT TYPE SELECTION

4.3.1 SELECTION LOGIC OVERVIEW

This research project developed a logic to take element data from element treatment selection all the way to the identification of candidate bridge projects. It is a slightly complex logic, but the basic building blocks of the logic are straightforward. The building blocks are eleven *Work Types*. Work Types for each span of a bridge are determined from the treatments that are selected for the elements on that span. For example, Work Type 5, *Deck Replace*, is triggered for a bridge's span if that span's deck slab (Element 12) has met the treatment threshold for replacement. The Work Types and their triggers are presented in Exhibit 4-5. Any span can have multiple Work Types triggered.

Exhibit 4-5. NYSDOT Work Types and Triggers

Trigger (Element Treatment Selected)	Resulting Work Type	
Critical Substructure Element or Culvert Replace	1	Span Replace
Primary Member Replace	2	Superstructure Replace
Primary Member Heavy Treatment	3	Superstructure Rehab
Critical Substructure Element Heavy Treatment OR Other Substructure Element Replace	4	Substructure Rehab
Deck Element Replace	5	Deck Replace
Steel Protective Coating Replace	6	Repaint
Deck Element Heavy Treatment AND Joint Element Replace	7	Deck Rehab
Joint Element Replace AND Treatment on at least one substructure element	8	Vertical Down*
No Work Type 1-8 selected AND Any element treatment (except replacement of wearing surface or heavy repair of paint)	9	General Repairs
Wearing Surface Replace	10.1	Wearing Surface Replacement
Steel Protective Coating Heavy Treatment	10.2	Zone Paint

*Vertical Down - is a term used in NYSDOT to refer to projects to replace failing joints and repair structure damage that occurred below the leaky joints. NYSDOT also has referred to this Work Type as "Bridge 5 to 7" in reference to repairs commonly applied to move a bridge rating from 5 to 7 (on the NYSDOT Legacy System 1 to 7 scale).

After the triggered Work Types for each span are identified, the Work Types are compared to multi-span criteria that determine whether the Work Type should be applied for the whole bridge.

Then, after the application of multi-span criteria confirms the Work Types for the whole bridge, a bridge *Project Type* is composed as a combination of the Work Types. The bridge Project Types are combinations that make sense to package in BMS modeling based on considerations of capital planning, high level cost estimation, and work mobilization and execution.

Exhibit 4-6 lists the set of possible projects, identified as combinations of Work Types. The Project Type number starts with the primary Work Type “Group” and adds decimal numbers afterwards to show other Work Types included with the primary one in a given project. For example, Project Type number 3.2.2.1 would be output by the model with the label “Superstructure Rehab with Deck Rehab and Repainting”. If no Work Type is triggered, the bridge Project Type is simply “Cyclical Maintenance”. If Wearing Surface Replacement and Zone Paint are the only Work Types triggered, then the Project Type is “Wearing Surface Replacement”. If Zone Paint is the only Work Type triggered, then the Project Type is “Zone Painting”. The Project Type numbering scheme assigns progressively higher numbers to progressively lighter treatments.

Exhibit 4-6. Bridge Project Types

Bridge Replacement					
1	Bridge Replacement				
Major Rehabilitation Projects					
Group	ID	Work Type Included			
		Superstructure	Substructure	Deck	Paint
2 Superstructure Replacement	2.1	Super Replace (2)	Sub Rehab (1)	included	included
	2.2		No Sub Rehab (2)	included	included
3 Superstructure Rehab	3.1.1.1	Super Rehab (3)	Sub Rehab (1)	Deck Replace (1)	Repaint (1)
	3.1.1.2				No Repaint (2)
	3.1.2.1			Deck Rehab (2)	Repaint (1)
	3.1.2.2				No Repaint (2)
	3.1.3.1			No Deck Work (3)	Repaint (1)
	3.1.3.2				No Repaint (2)
	3.2.1.1		No Sub Rehab (2)	Deck Replace (1)	Repaint (1)
	3.2.1.2				No Repaint (2)
	3.2.2.1			Deck Rehab (2)	Repaint (1)
	3.2.2.2				No Repaint (2)
	3.2.3.1			No Deck Work (3)	Repaint (1)
	3.2.3.2				No Repaint (2)
4 Substructure Rehab	4.1.1	No Super Rehab	Sub Rehab (4)	Deck Replace (1)	Repaint (1)
	4.1.2				No Repaint (2)
	4.2.1			Deck Rehab (2)	Repaint (1)
	4.2.2				No Repaint (2)
	4.3.1			No Deck Work (3)	Repaint (1)
	4.3.2				No Repaint (2)
5 Deck Replacement	5.1	No Super Rehab	No Sub Rehab	Deck Replace (5)	Repaint (1)
	5.2				No Repaint (2)
Minor Rehabilitation Projects and Repainting Project					
6	Repaint				
7	Deck Rehab				
8	Vertical Down				
9	General Repairs				
Preservation Treatments					
10.1	Wearing Surface Replacement (1)				
10.2	Zone Painting (2)				
Cyclical Maintenance					
11	Cyclical Maintenance				

The following subsections present the detailed steps in Project Type selection. The project selection proceeds in three general stages.

4.3.2 STAGE 1 - WORK TYPE SELECTION AND INITIAL PROJECT TYPE SELECTION

STAGE 1A – SPAN WORK TRIGGERED

Step 1: From element inspections, calculate the percentage of total assessed element quantity in each Condition State.

Step 2: Compare these Condition State percentages to element treatment thresholds to determine what treatments are triggered for each element.

Step 3: *For each span*, compare the treatments triggered to the list of treatments triggering each Work Type. Step 3 determines the Work Type selections (there can be multiple different Work Types) for the span. See Exhibit 4-5 shown previously for the list of Work Types and generalizations of identified treatments. For a list of all of the specific element treatment triggers for each Work Type, see the Stage 1A Logic Chart and the Stage 1A Elements Table in Appendix H.

STAGE 1B – STAGE 1 BRIDGE PROJECT SELECTION

Stage 1B includes two steps to process the Work Types that were triggered for the spans of a bridge into a "first cut" Project Type selection for the entire bridge. The thirty Project Types that will result from Stage 1B were identified previously in Exhibit 4-6.

The Stage 1 logic is exclusively concerned with AASHTO element condition data. A second stage of project selection (Stage 2, described later) will apply a few additional criteria that will further refine the Project Type selections for a small number of bridges.

Stage 1B, Step 1: Apply Multi-Span Criteria to the Span Work Types Triggered

For each Work Type triggered on the bridge, Step 1 applies Multi-Span Criteria to the Work Type to determine Work Types for the whole bridge. The aim of the Multi-Span Criteria is to avoid anomalous project selections for large, multi-span bridges, in which a deteriorated condition on a very small portion of the bridge drives the model to select a very high level replacement or rehabilitation project. Accordingly, the Multi-Span Criteria are very generous, in that they allow for most span Work Types to be confirmed as Work Types for the entire bridge. Test application of the criteria to the April 2019 bridge inspection dataset found the criteria to affect Work Type selections in only a very small number of cases, as desired.

The four Multi-Span Criteria that are applied to each Work Type on each span are as follows:

(1) **Bridge Size** – If the bridge deck area is less than 100,000 square feet, the triggered span Work Type is applied to the entire bridge.
(2) **Span Length** – If the span is longer than 199 feet, any Work Type triggered on that span is applied to the bridge.
(3) **Percent of Span Count** – If the Work Type is triggered for at least five percent of all spans, the triggered Work Type is applied to the bridge.

(4) **Percent of Bridge Length** – If the Work Type is triggered for at least five percent of the total bridge length, the triggered work is applied to the bridge.

Only one criterion needs to be met for the Work Type to be applied to the bridge. As can be seen, Work Types for any bridge up to 100,000 square feet of deck area, or any bridge with 20 or fewer spans, will automatically meet the Multi-Span Criteria. The latter condition suffices because any one span on a twenty span bridge will account for five percent of the number of spans.

Step 1 of Stage 1B logic can produce multiple Work Types for a bridge. For example, one span may have *Superstructure Replacement* triggered and confirmed for the bridge while another span has *Superstructure Rehab* and *Deck Rehab* triggered and confirmed for the bridge. These multiples will be processed into a single bridge Project Type in Stage 1B, Step 2, of the project selection logic.

Stage 1B, Step 2 – Execute the Ordering and Combination Rules to Identify the Stage 1 Selected Project

Project Types are selected by moving down through the Work Types shown in Exhibit 4-5 and Project Types shown in Exhibit 4-6. For example, if Work Type *1: Span Replace* is selected, the Project Type is *1: Bridge Replace*, and the selector stops. If not, then the selector moves on to the Work Type *2: Superstructure Replace* and through its two combinations shown in Exhibit 4-6 (i.e., with and without *Substructure Rehab*). This process applies through all of the remaining Work Type combinations, stopping whenever one of the Project Types has been selected. If no Work Types are selected, then the Project Type is *11: Cyclical Maintenance*, meaning no element repairs or replacements were triggered for the bridge.

Project Types 6 *Repaint* through 10.2 *Zone Paint* are represented as standalone projects with the same title as the corresponding Work Type number. That is, they are not shown as combinations of multiple work types, as in the Major Rehabilitation Project Types in Groups 2 through 5. For example, for Project Type 6: *Repaint*, the Project Type selection logic will stop at the *Repaint* Work Type and not register or indicate any other Work Types with higher numbers, such as *7: Deck Rehab* or *8: Vertical Down*. Because bridge repainting costs are typically much higher than the costs of repairs for Project Types 7 through 10, it is sufficient for cost estimating for the logic to capture just the repainting. The fact that the selector stops at *Repainting* does not mean that in practice a project with other repair work would not ultimately be developed. This interpretation also applies to Project Types 7 through 10.1.

4.3.3 STAGE 2 – FINAL BRIDGE PROJECT TYPE SELECTION

Stage 1B Bridge Project Selection, which is based entirely on element condition data, provides useful information to bridge managers on the work needs for the system's bridges. However, it leaves selections that are either not consistent with NSDYOT capital planning standards, not cost-effective, or simply not practical. For example, it is reasonable to expect that it will be more cost-effective to replace the entire structure rather than rehabilitate the substructure and replace the deck. The additional selection rules to account for these considerations are presented in Exhibit 4-7 and explained in the text that follows. The table introduces a twelfth Project Type, "Supermaintenance", which is based strictly on bridge size and explained in the text that follows.

Exhibit 4-7. Stage 2 Project Type Selection Logic

	Stage 1 Project Type Selected		Additional Criterion	New Bridge Project Type Selection
(a)	Substructure Rehab & Deck or Superstructure Replace	*and*	no additional criterion	1: Replace Bridge
(b)	Any Major Rehab	*and*	Scour Critical (NBI 113 coded 0-3)	1: Replace Bridge
(c)	Deck Rehab	*and*	Deck Age over 50	5.2: Deck Replace
(d)	Any Project Type	*and*	Bridge Deck Area over 270,000 sq ft	12: Supermaintenance
(e)	Any Capital Project	*and*	Capital Project in Last Two Years	11: Cyclical Maintenance
(f)	Superstructure Rehab or Deck Replace	*and*	Jack Arch Span	1: Replace Bridge
(g)	Superstructure Replace	*and*	Culvert	1: Replace Bridge
(h)	Any Major Work Except Super Replace (Super Rehab down to Deck Rehab)	*and*	Culvert	9: General Repairs

(a) **Substructure Rehab and Deck or Superstructure Replacement** – Ideally, the BMS would calculate the cost of the Project Type and be able to compare that to a whole bridge replacement cost and select bridge replacement when the repair cost estimate exceeds some threshold percentage of bridge replacement. In the legacy logic this threshold is 85 percent. Cost research has not been done as part of this project. Until supporting unit cost data is available, this criterion is used as a proxy for such a cost comparison.

(b) **Scour Critical NBI Item** – A bridge that is rated Scour Critical (rated 3 or less for data item 113 in the NBI coding system) has a serious structural risk due to scour potential that requires replacement of the substructure to properly remedy this deficiency. Therefore, once any major rehabilitation project is needed on the bridge, it makes sense to replace the substructure, which effectively requires a full bridge replacement.

(c) **Deck Age** – In the unlikely event that a deck has not been replaced in over 50 years, it is not cost-effective to invest in a deck rehabilitation. The deck life expectancy has been reached and the deck should be replaced. This criterion cannot be implemented at this time because a deck age data item is not currently available in the NYSDOT inventory system. Deck age is a data item that should be considered for addition to bridge inventory information.

(d) **Extremely Large Bridges** (over 270,000 square feet deck area) – Bridges of this size are subject to their own unique maintenance regimen intended to keep them structurally sound and avoid the extremely high cost of replacement. Repairs are very costly as well as challenging to stage, so typical "rules of thumb" on treatments and costs may not apply. Moreover, work on these bridges is not entered in the funding pool with the rest of the state's bridges. For these reasons, NYSDOT places these bridges in their own capital project category called "Supermaintenance". Such bridges are subject to all of the selection logic and not assigned this special Project Type until Stage 2 of Project Type selection in order to provide the information on bridge conditions and repair needs that is generated by applying the treatment selection rules.

(e) **Recent Capital Project** – A similar consideration applies to bridges that have recently had a major capital project completed. Such bridges would not be considered for a major project. Nevertheless, it can be useful to bridge managers to see the work needs of these bridges. This is particularly true if the Project Type selection logic is being used to rate the overall bridge condition and to assess bridge network performance.

(f) **Jack Arch Spans** – It is not feasible to rehabilitate the superstructure or replace the deck of a jack arch bridge span because removal of the deck is very difficult and would cause serious damage to the beams. The entire jack arch superstructure in each span would need to be replaced. This criterion can be somewhat complex in practice because the jack arch is a span type, not a bridge type. A bridge in this situation may have other spans that are not jack arch and in practice, the bridge managers may elect to replace just the jack arch spans. For purposes of BMS modeling, the criterion will be applied simply—the Project Type selection will be changed to bridge replacement.

(g) **Culvert Replacements** – A few structures are categorized as culvert type, but the main load carrying member is classified as an arch element. When this element is selected for replacement, the Project Type registers as Superstructure Replacement because of the arch element, when in fact it should be recorded as needing a complete structure replacement. Stage 2 project selection will correct this anomaly.

(h) **Other Culvert Work** – NYSDOT does not typically regard culvert repairs as major rehabilitation projects. Any rehabilitation Project Types that are selected for culverts are changed to the General Repairs Project Types at Stage 2 of the Project Type selection logic.

4.3.4 STAGE 3 – PROJECT SELECTION ALERTS

A third stage is included in the project selection logic. At this stage, the BMS would not automatically change any project selections, but would simply generate an alert to the existence of one or more factors that may influence the bridge managers to consider some change to the project selected by the logic.

ALERTS FOR STRUCTURE AND FUNCTION CONSIDERATIONS

In some cases, the modeling logic will select a Project Type that might not be optimal for the bridge, given other considerations. For example, there may be some inadequacy or vulnerability that could be addressed when major work is being done. Some Project Types might not prove feasible or cost effective given the structure type. At Stage 3 of Project Selection, these considerations are applied to the selected bridge projects.

Exhibit 4-8 lists these considerations in table form. The cells indicate combinations of Project Types and bridge characteristics for which the BMS model should produce an alert notifying the bridge manager of the existence of the characteristic. A "CU" in the cell indicates that the bridge manager may want to consider moving *up* to a higher-level project (more work) than what is indicated by the Project Type selected by the modeling logic. An "Alert" is simply a neutral alert to the existence of the consideration. The alerts will be applied based on the Work Type Number in the table's column heading. For example, cell entries within the column headed Super Rehab (3) would apply for any of the twelve Superstructure Rehab Project Types in the Group 3 Project Types. Vertical Down is not included as a column because it is a specific type of project for a specific set of conditions. The text that follows describes the reasoning for including each of the alerts.

Exhibit 4-8. Stage 3 Project Selection Alerts for Structure and Function Considerations

Consideration	Criterion Value or Threshold Value	Super Replace 2	Super Rehab 3	Sub Rehab 4	Deck Replace 5	Deck Rehab 7	General Repairs 9	Any Work Type
Underclearance	< 14 ft clearance			CU	CU			
Hydraulics	Hydraulic Vulnerability <3	CU	CU	CU	CU			
Fracture Critical	Fracture Critical		CU	CU	CU			
Railings	Railing element replace triggered					CU		
Bridge age	80 years	CU	CU	CU	CU			
Deck Age	50 years		CU	CU			CU	
Superstructure Age	80 years		CU	CU	CU	CU		
Adjacent Box Beam	GTMS Type is Adjacent Box Beam		CU		CU			
Truss Superstructure	GTMS Type is Truss		CU	CU	CU			
Timber Construction	GTMS Material is Timber	CU	CU	CU	CU			
Average Annual Daily Traffic	>75,000 AADT					CU		
Very Large Bridges	>75,000 sq ft							Alert
Historical Significance	Listed or eligible for listing on the National Register							Alert

Notes: "CU" = alert to Consider moving Up to a higher Project Type "Alert" is simply a neutral alert to the existence of the consideration. Superstructure is shortened to "Super", Substructure is shortened to "Sub", and Rehabilitation is shortened to "Rehab".

Underclearance – When faced with a Substructure rehab or Deck Replacement on a bridge with insufficient underclearance, bridge managers should consider if it may be cost-effective to also correct the underclearance inadequacy by raising the superstructure, replacing the superstructure, or even (in some cases) replacing the bridge.

Hydraulic Vulnerability – Bridge managers should consider whether it makes more sense to replace a bridge with a serious hydraulic vulnerability rather than invest in a major rehabilitation project.

Fracture Critical – Similar to Hydraulic Vulnerability, bridge managers should consider a project to replace the fracture critical members (superstructure) when a major rehabilitation project is being planned. Due to the additional risks (crack that propagates and causes collapse of entire bridge) and the additional inspection requirements for these structures, it is desirable to upgrade to more redundant systems whenever possible.

Railing Replacement – New, more stringent federal standards for design loads on railings have made existing deck design capacities insufficient to support the new railing system. If the railings are found to need replacement, bridge managers should consider increasing the project level to deck replacement to accommodate meeting new railing standards.

Bridge Age, Deck Age, and Superstructure Age – Bridge managers should consider a replacement of these components whenever a major rehab project has been selected and the bridge or the component selected for rehab is over its standard design life. One of these age scenarios – a deck rehab selected for a deck beyond its design life—is not included in this alert table because it is included in the Stage 2 Bridge Project Type selection logic as an automatic change to a deck replacement. Bridge age can be calculated from the year of construction data item. On a structure that has had a major rehabilitation, bridge age will reflect the age of the oldest remaining component. It will not be possible to implement alerts for deck and superstructure age at this time since the supporting age data are not available in the NYSDOT inventory system.

Adjacent Box Beam Superstructure – It is not practical to perform a deck-only replacement on an adjacent box beam structure due to possible damage to the top of the box beams when removing the deck.

Truss Superstructure – A truss structure requires so much intense maintenance and inspection that consideration should be given to performing a superstructure replacement whenever a costly rehabilitation is being considered. However, historical resource considerations might limit replacement options for the structure.

Timber Substructure or Superstructure – Timber elements typically have a shorter life span than concrete or steel and consideration should be given to replacement rather than rehab. However, historical resource considerations might limit replacement options for the structure. The alert logic is kept simple and generic at the expense of possibly generating the occasional alert that is not relevant. The alert for superstructure rehab is relevant when the superstructure is timber while the alert for substructure applies when the substructure is timber. Superstructure and deck replacements should also be re-considered if the substructure is timber; it might be a poor investment to replace a deck and/or superstructure supported by a timber substructure.

Average Annual Daily Traffic – Bridge managers should consider doing full deck replacement rather than rehab to minimize the recurrence of traffic restrictions. It is also helpful to alert bridge managers to the likelihood of higher costs and faster deterioration associated with high-traffic bridges.

Very Large Bridges – Very large bridges will likely have different unit costs and different planning requirements that bridge managers should be alerted to.

Historical Significance – This data item is included to alert bridge managers to possible work restrictions due to historical resource listing status of the bridge.

ALERTS FOR BRIDGE AND COMPONENT CONDITION RATINGS

Stage 3 of Project Selection affords the opportunity to apply other condition rating information assigned by the inspectors. Bridge management decisions may benefit from considering whether the inspector's assessment of the bridge using NBI component ratings or the NYSDOT General Recommendation aligns with the Work Type selected by the modeling logic using AASHTO element data.

Exhibit 4-9 identifies two basic subsets of alert considerations relating to these condition ratings. The first subset applies when the assigned condition rating suggests that the Project Type might underestimate the repair needs of the bridge. The letters "CU" are indicated in the cells for these alerts, meaning that bridge managers should consider moving *up* to a higher-level project (more extensive work). For example, if the Project Type Selection logic selected a major rehab project when the NBI substructure general condition rating is "Poor", bridge managers should consider replacing the bridge.

The second subset of alerts notes situations in which bridge managers should reconsider whether the Work Type selected is excessive given the rated bridge or component condition. The letters "CD" are indicated in the cells for these alerts, meaning that bridge managers should consider moving *down* to a lower level project (less extensive work).

Exhibit 4-9. Stage 3 Project Selection Alerts, General Condition Rating Considerations

Consideration	Criterion Value or Threshold Value	Bridge Replace 1	Super Replace 2	Super Rehab 3	Sub Rehab 4	Deck Replace 5	Deck Rehab 7	General Repairs 9
Substructure Condition Rating	NBI sub <=4 (poor)		CU	CU	CU	CU		
Superstructure Condition Rating	NBI super <=4 (poor)			CU	CU	CU	CU	
Deck Condition Rating	NBI deck <=4 (poor)			CU	CU		CU	CU
NYSDOT General Recommendation*	GR <=3		CU	CU	CU	CU	CU	CU
Substructure Condition Rating	NBI sub>=6 (satisfactory)	CD						
Superstructure Condition Rating	NBI super >=6 (satisfactory)		CD					
Deck Condition Rating	NBI deck >=6 (satisfactory)					CD		
NYSDOT General Recommendation**	GR >=5	CD	CD					

Notes: CU = alert to Consider moving Up to a higher Project Type. CD = alert to Consider moving Down to a lower Project Type. Superstructure is shortened to “Super”, Substructure is shortened to “Sub”, and Rehabilitation is shortened to “Rehab”.

* GR 3 = Considerable deterioration of some or all bridge components.

** GR 5 = Primary members and substructures are in good condition and do not need major repairs.

4.3. BRIDGE PROJECT TYPE SELECTION RESULTS

The Stage 1 Project Type selection logic was applied to the April 2019 NBIS bridge dataset in an Excel workbook model. The dataset includes all highway bridges in New York State. The number of bridges in each Project Type is presented in Exhibit 4-10.

Exhibit 4-10. Project Types Assigned by Stage 1 Selection Logic, All Highway Bridges in New York State

Project Group	Project ID	Project Type	Number of Bridges		Group Percent of All Bridges
			Project Type	Group Subtotal	
1 Bridge Replacement	1	Bridge Replace	1,164	1,164	6.7%
2 Superstructure Replace Combinations	2.1	SuperReplace - Sub Rehab	533	1,491	8.5%
	2.2	SuperReplace Alone	958		
3 Superstructure Rehab Combinations	3.1.1.1	SuperRehab - SubRehab – DeckReplace - Paint	14	392	2.2%
	3.1.1.2	SuperRehab - SubRehab - DeckReplace	9		
	3.1.2.1	SuperRehab - SubRehab - DeckRehab - Paint	4		
	3.1.2.2	SuperRehab - SubRehab - DeckRehab	3		
	3.1.3.1	SuperRehab - SubRehab - Paint	32		
	3.1.3.2	SuperRehab - SubRehab	52		
	3.2.1.1	SuperRehab - DeckReplace - Paint	16		
	3.2.1.2	SuperRehab - DeckReplace	11		
	3.2.2.1	SuperRehab - DeckRehab - Paint	2		
	3.2.2.2	SuperRehab - DeckRehab	6		
	3.2.3.1	SuperRehab - Paint	73		
	3.2.3.2	SuperRehab Alone	170		
4 Substructure Rehab Combinations	4.1.1	SubRehab – DeckReplace - Paint	54	1,822	10.4%
	4.1.2	SubRehab - DeckReplace	134		
	4.2.1	SubRehab – DeckRehab - Paint	22		
	4.2.2	SubRehab - DeckRehab	46		
	4.3.1	SubRehab - Paint	253		
	4.3.2	Sub Rehab Alone	1,313		

(continued on following page)

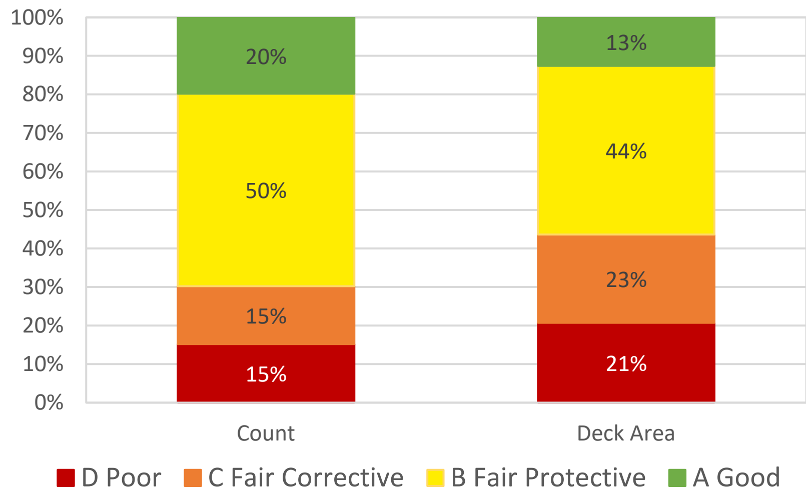
Exhibit 4-10. Project Types Assigned by Stage 1 Selection Logic *(continued from previous page)*

Project Group	Project ID	Project Type	Number of Bridges		Group Percent of All Bridges
			Project Type	Group Subtotal	
5 Deck Replacement combinations	5.1	Deck Replace - Paint	73	414	2.4%
	5.2	Deck Replace Alone	341		
6 Repaint	6	Bridge Repaint	722	722	4.1%
7 Deck Rehab	7	Deck Rehab	110	110	0.6%
8 Vertical Down	8	Vertical Down	600	600	3.4%
9 General Repairs	9	General Repairs	6,806	6,806	38.9%
10 Preservation Treatments	10.1	Wearing Surface Replacement	120	502	2.9%
	10.2	Zone Painting	382		
11 Cyclical	11	Cyclical Maintenance	3,467	3,735	19.8%
Total Number of Bridges			**17,490**		

Note: In Project Type nomenclature, Superstructure is shortened to "Super", Substructure is shortened to "Sub", and Rehabilitation is shortened to "Rehab".

The selected bridge Project Types can serve as an indicator of bridge condition. The alignment of Project Types to NYSDOT bridge condition categories was presented in Chapter 3, Exhibit 3-14. Project Types beginning with numbers 1 and 2 (Bridge Replacement and Superstructure Replacement) are on bridges that are "Poor". Project Types in groups 3, 4, and 5 (all are Major Rehab projects) indicate bridges that are "Fair-Corrective". Project Types 6 through 10 indicate bridges that are "Fair Protective". Bridges needing only Cyclical Maintenance (Project Type number 11) are considered to be in Good condition. Applying the condition category scheme to the selected Project Types, the percentage of bridge counts and deck area in each condition category is shown in Exhibit 4-11.

Exhibit 4-11. Bridge Condition Based on Selected Project Type, All NBIS Bridges in New York State



An evaluation of the use of the Project Type in characterizing bridge condition and network performance is presented in Chapter 3.

4.4 PROJECT TREATMENT EFFECTS

4.4.1 ELEMENT TREATMENT EFFECTS

In addition to establishing logic to select element treatments and bridge Project Types, this research project has produced a set of modeling assumptions regarding the *effects* of light and heavy treatments on the condition of each element after the treatment. These values will be used in the bridge management system to predict future system conditions resulting from applying a candidate Project Type.

The modeling assumptions for treatment effects specify a change in the quantity in each condition state as a result of the treatment. This subsection describes the treatment effects modeling, including some of the logical principles that went into developing the modeling assumptions. Section 4.4.2 describes the process for determining which element treatments to model for each Project Type. Together, these two sets of assumptions allow the BMS to take the Project Type selections for a bridge and predict the resulting condition of the bridge elements if the project type would be implemented.

Appendix I contains a table with the treatment effects assumptions for each element. Notes on the reasoning used in the development of treatment effects assumptions is included with the table in Appendix I. Exhibit 4-12 shows an excerpt from the table of treatment effects assumptions, for two kinds of closed box girders: steel and reinforced concrete.

Exhibit 4-12. Excerpts from Treatment Effects Modeling Assumptions Table

Element		Light Repair							
		From CS 2		From CS 3			From CS 4		
		to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3
102	Steel Closed Box Girder	**0**	**100**	**90**	**10**	**0**	**80**	**20**	**0**
105	Reinforced Conc. Closed Box Girder	**0**	**100**	**0**	**80**	**20**	**0**	**80**	**20**

Element		Heavy Repair							
		From CS 2		From CS 3			From CS 4		
		to CS1	to CS 2	to CS1	to CS2	to CS3	to CS 1	to CS 2	to CS 3
102	Steel Closed Box Girder	**0**	**100**	**90**	**10**	**0**	**80**	**20**	**0**
105	Reinforced Conc. Closed Box Girder	**0**	**100**	**0**	**90**	**10**	**0**	**80**	**20**

The entries for light repair of a Steel Box Girder (Element 102) instruct the BMS to model the effect of light repair as follows:

- From CS2 – The CS2 portions of the girder are not repaired; 100% remains as CS2.
- From CS3 – 90% moves to CS1 and the remainder (10%) moves to CS2. None is left at CS3.
- From CS4 – 80% moves to CS2, and the remainder (20%) moves to CS3. None is left at CS4.

Because steel can be repaired by plating, steel repairs can restore the capacity for a repaired portion of the element to CS1. However, the CS2 portions of steel superstructure elements are assumed to not be repaired and therefore to remain all in CS2. Heavy repairs are expected to have the same effects as light repairs. For steel primary members, the definitions of heavy and light repair do not differentiate in the repairs themselves, but rather in whether there is the need for temporary supports to perform the repairs.

Repairs of reinforced concrete superstructure elements (such as Element 105, shown in Exhibit 4-12) are different for heavy and light repairs. Also, the repairs are less effective than repairs of steel superstructure elements (such as Element 102, shown in Exhibit 4-12). Heavy repairs are modeled to move 90 percent of the CS3 portions to CS2 and the other 10 percent to remain as CS3. Heavy repairs would move 80 percent of CS4 portions to CS2 and 20 percent to CS3. It is not possible for any patching repairs to move the repaired portion to CS1 due to the coding guidance for reinforced concrete.

Some effects modeling assumptions are common to all or nearly all element treatments. One common assumption is that repairs are assumed never to leave any portions of an element in CS4. At the other extreme, repairs do not affect the portions of an element in Condition State 2. This latter assumption has two rationales. First, NYSDOT does not typically repair the defects of the limited severity that meet the coding guidelines for Condition State 2. Second, for some elements and materials (e.g., reinforced concrete), coding guidelines specify that any patched areas can be at best coded as condition state 2. Once a portion of an element has moved from CS1 to a lower state, repairs are not likely or simply not able to return it to CS1.

Superstructure elements are assumed to be more difficult to perform repairs as completely as deck and substructure elements. Reinforced concrete superstructure elements are assumed to have portions in Condition State 3 even after repairs.

4.4.2 WORK TYPE TREATMENT SELECTION LOGIC

As explained in Section 4.3, Work Types are triggered by the selection of a *particular treatment* on a *particular element* based on element condition state thresholds. To model the effects of a project on the bridge's elements, the logic needs instructions on *all* of the treatments to apply as part of all of the Work Types that are a part of the Project Type. This research project has produced a set of specifications of which treatments are bundled into each Work Type. This treatment bundling, detailed in Appendix J, would tell the BMS software which element treatment effects to apply for each of the Work Types that are a part of the Project Type selected by the BMS.

For example, the treatment bundling rules for the *Superstructure Replace* Work Type instruct the BMS to model that *all* superstructure and deck elements (including ancillary deck elements such as curbs and sidewalks) would be replaced, as well as any protective coatings that were in place. This means that all the superstructure and deck elements would go from the various percentages in CS2, CS3, or CS4 to 100 percent in CS1.

Rehabilitation Work Types would apply the *heavy* treatments (shown in the Table in Appendix I) to all elements on the rehabbed component. For example, in a Superstructure Rehab, *all* superstructure primary and secondary members would have the heavy treatment effects applied, regardless of whether the specific element condition states met any treatment threshold.

Bearing and pedestal elements would have treatments applied on a case-by-case basis, as their treatment thresholds are crossed.

In the *General Repairs* Work Type, element treatments would be applied only on elements that meet the treatment threshold.

The application of treatment effects based on Project Types will change the element condition state percentages for each element modeled as being treated. These changes will in turn change the condition indices of the element, component, and bridge (i.e., the condition measures described in Chapter 3). Besides this role in updating condition indices, modeling treatment effects is also necessary for the proper modeling of element and bridge deterioration. The quantities in each condition state must be "reset" properly in response to treatment so that the deterioration parameters will be applied to the correct post-treatment condition states.

4.5 ADAPTATION OF LEGACY TREATMENT SELECTION LOGIC

The selection logic described previously will not be implemented immediately. In the interim, NYSDOT is reliant on the logic that was developed for use with the NYSDOT Legacy System. The following discussion describes the shortcomings of the existing method for using AASHTO element data in the Legacy System and presents an approach to make more effective use of the AASHTO element data.

TRANSLATION OF AASHTO ELEMENT CONDITION DATA TO LEGACY CONDITION RATING SYSTEM

As noted in the chapter introduction, NYSDOT has an established logic for selecting treatments that is based on the legacy inspection system. The logic makes use of legacy component Condition Ratings, major component condition indices, and bridge Condition Ratings, all on the legacy 1-7 rating scale. The major component condition indices and the overall bridge rating are weighted averages of individual component Condition Ratings. Individual components in the Legacy System are roughly analogous to elements in the new inspection system.

Since the implementation of AASHTO element inspection, the bridge management system has used a translator formula to convert element condition state quantities to the legacy 1-7 Condition Rating (CR) scale. Exhibit 4-13 illustrates how the translation is applied. The example element ratings are actual reinforced concrete deck condition state percentages from the 2019 inspection data submission. The exhibit displays the translated Condition Rating, the element condition index (ECI, presented in Chapter 3), and the treatment selected by the legacy logic when applied to the translated Condition Rating. All of the seven example element condition state ratings meet the replacement thresholds for deck replacement in the proposed new treatment selection logic: 30 percent in CS3 or worse, or 5 percent in CS4.

The examples illustrate that an element can have a considerable extent of defects and still have a fairly high Condition Rating. Example 7 shows how extreme the extent of defects can be and still have a high translated Condition Rating, one that would not trigger *any* repair action according to legacy selection criteria.

Exhibit 4-13. Example Ratings for Reinforced Concrete Deck Elements (Element 12)

Condition State	CS1	CS2	CS3	CS4	CR	ECI	Treatment Triggered per Legacy Logic*
Weight Points for CR Translation	6.75	5	3.5	1			
Weight points for ECI	100	67	33	0			
Example 1	0	0	0	100%	1.00	0.0	Replace
Example 2	0	0	90%	10%	3.25	29.7	Replace
Example 3	0	0	100%	0	3.50	33.0	Replace
Example 4	0	28%	56%	16%	3.52	37.2	Replace or rehab
Example 5	0	75%	0	25%	4.00	50.3	Replace or rehab
Example 6	92%	1%	0	7%	6.33	92.7	No treatment
Example 7	65%	6%	16%	13%	5.38	74.3	No treatment

* Replacement in the legacy logic is selected for legacy deck components rated 3.5 or lower. For legacy deck components rated between 3.5 and 5.0, the legacy logic considers combinations of deck and wearing surface ratings to determine whether the deck should be replaced or rehabilitated.

The Element Condition Indices calculated for deck element examples 6 and 7 reveal that it is not helpful to simply substitute the element condition index for Condition Rating. The index suffers the same pitfall as the Condition Rating translation: important information on element condition is lost in the averaging of condition state percentages.

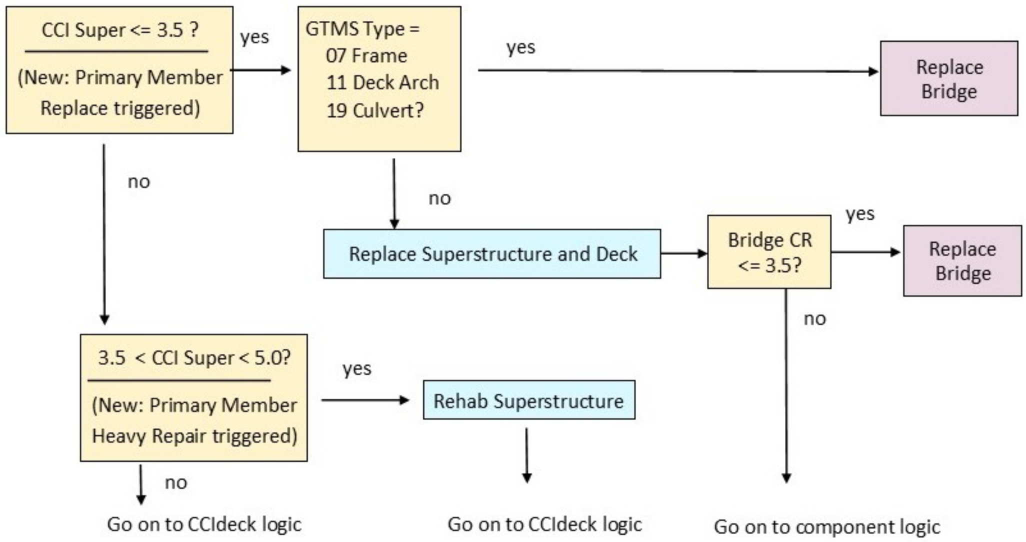
A MORE ROBUST ADAPATION: USE OF NEW TREATMENT LOGIC

Rather than translating condition state percentages to Condition Ratings, the proposed adaptation uses the treatment thresholds and Work Type triggers to substitute for the legacy component/element ratings and major component condition index thresholds. To continue the deck example begun previously, where the legacy logic indicates to select a deck replacement when the deck rating is less than or equal to 3.5, the adaptation would indicate to select a deck replacement if the deck replacement Work Type is selected in the new element-based logic. The Work Type would also need to pass the multi-span criteria test for it to be applied within the legacy logic.

ADAPTATION FOR SUPERSTRUCTURE COMPONENT REPLACEMENT AND REHAB SELECTIONS

Exhibit 4-14 presents the legacy logic tree branch concerning the superstructure component. It shows a superstructure replacement cut-off at a legacy superstructure component condition index of 3.5 and a superstructure rehab cut-off range of between 3.5 and 5.0. In the legacy system, the superstructure component condition index (CCI) is a weighted average of the primary and secondary members, with primary members accorded nine weighting points and secondary members one weighting point. The proposed adaptation would use the "confirmed" (after application of multi-span criteria) superstructure Work Type to determine whether the superstructure replacement criterion is met or the rehab criterion. Note that the Work Type decision in the new logic is based exclusively on the primary member.

Exhibit 4-14. Legacy Logic Decision Tree Branch for the Superstructure Component



USE OF INVENTORY DATA ITEMS IN LEGACY SELECTION LOGIC

The decision box shown in Exhibit 4-14 with "GTMS Type" is similar to the Stage 2 selection criteria in the new bridge Project Type selection logic, in which inventory information is taken into consideration to refine the condition-based selections. By moving this inventory consideration to Stage 2 of the selection process, the new logic has the benefit of preserving the information on condition-based Work Type selected, making the new system less "black box" than the legacy system, and therefore potentially more useful to bridge managers.

ADAPTATION FOR THE OVERALL BRIDGE CR RATING

The additional criterion of Bridge CR <= 3.5 in the second row of the decision tree excerpt in Exhibit 4-14 refers to the overall condition rating for the bridge. The idea of the logic is as follows: if the bridge is in poor condition overall, it will make more sense to replace the entire bridge rather than just the superstructure and deck. The adaptation needs to replace this legacy bridge Condition Rating with a measure that is available with the new inspection system. Several different candidate measures are available: (1) the element-based BCI or one of its CCI's (Component Condition Index); (2) the NYSDOT General Recommendation; (3) an NBI General Component Rating (GCR); (3) a measure computed as a composite of the NBI GCRs.

The substitute overall measure could be different in different contexts. For example, an overall substructure condition measure might be used where the legacy logic combines a superstructure condition index and an overall bridge condition rating. Conversely, a superstructure condition measure might be used where the legacy logic combines a legacy substructure component condition index with an overall bridge condition rating. In light of the findings discussed in Chapter 3, particularly the concerns with the element-based index measurement concept, a condition measure based on the NBI or GCR may be more appropriate for this use.

ADAPTATION FOR INDIVIDUAL ELEMENT RATINGS

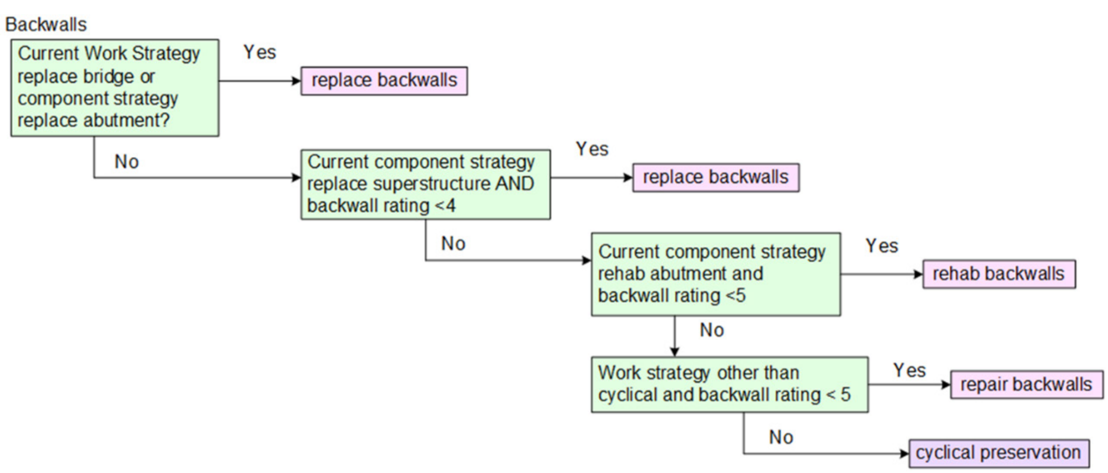
The legacy logic also has decision criteria based on the individual component Condition Rating. For example, a bridge replacement is selected if the bridge is deemed to have a vulnerability (e.g., hydraulic rating less than three) and at least one of the following legacy components is rated with a CR less than 3.0:

- Abutment stem
- Pier Stem
- Column
- Cap Beam
- Primary member
- Deck

In place of this test for legacy component Condition Rating, the adaptation substitutes the replacement treatment threshold for the analogous AASHTO element.

The legacy logic also has branches where specific elements are compared to a Condition Rating threshold for determining whether the element should receive a rehab treatment or possibly a replacement. Exhibit 4-15 presents an example. In these instances, the adaptation substitutes the replacement trigger for the element replacement. In the example shown, if the backwall replacement is triggered, the logic acts as if the backwall rating is less than 4. The heavy treatment trigger is used to determine element rehab. That is, if backwall heavy treatment is triggered, the logic acts as if the backwall rating is between 4 and 5.

Exhibit 4-15. Legacy Logic Decision Tree Branch with Individual Legacy Component Criteria



While this proposed way of using the new, AASHTO element-based thresholds and Work Types may make it seem that the logic adaptation is doing little more than placing the new logic in an old software framework, there are some differences. Some of the differences have already been referenced. For example, wearing surface is no longer used in deck Work Type selection. Overall bridge ratings are no longer used in making bridge replacement selections.

What the adaptation does is optimize the use of the AASHTO element inspection data without completely rewriting the software code in the existing AgileAssets-based enterprise asset management system. This adaptation allows the existing system to continue to be used in the period of transition to a bridge management system fully designed around the AASHTO element inspection data.

CHAPTER 5 –CONCLUSIONS

Motivation for the Research

For the past several decades, the New York State Department of Transportation has been well-served by a sophisticated bridge management system that uses detailed inspection data to monitor and report on bridge and network performance and to guide planning for bridge maintenance, rehabilitation, and replacement. The recent (2016) transition from a state-specific inspection and recording system to one based on AASHTO elements requires substantial reconfiguration of the NYSDOT bridge management system. While the bridge members that are rated are not substantially different under the two systems, the rating schemes are so conceptually different that it is not possible to simply map one rating scheme into the other and fit the new rating data into the existing management system. Therefore, this research project was undertaken to develop and evaluate potential changes to the NYSDOT bridge management system that would enable the system to use AASHTO element inspection data directly in bridge and network performance measurement and in identifying bridge treatment needs.

Condition and Performance Measurement

The research into a new bridge condition measure began with the concept of a bridge condition index (BCI). The basic approach behind deriving a bridge condition index is to apply successive steps of weighted averages. First, an element condition index is created for each element which is calculated as a weighted average of the quantities in the four levels of element condition states. Then a component condition index is created for each component on each span as a weighted average of the element condition indices. Finally, a bridge condition index is derived as a weighted average of span-component indices. Several variants of the indexing approach were created and evaluated.

NYSDOT found that the bridge condition index concept did not meet its needs for use in measuring network performance. The averaging that is integral to the index concept had differing effects on the resulting condition measures for small versus large bridges. The difference created anomalies in performance comparisons between different populations of bridges, particularly when the populations were of substantially different compositions in terms of bridge type and/or size. NYSDOT determined that it would need to develop an alternative to the index concept for use in measuring and reporting bridge network performance.

The project team evaluated an alternative performance measurement concept that is based on the identified treatment needs of a bridge. Development of the logic for identifying bridge treatment needs was a separate track of the research project. In this treatment logic, element treatment needs are identified by comparing inspection ratings to treatment trigger values/cutoffs, and then element treatment needs are rolled up to identify bridge treatment levels (“Project Types”) for each bridge. These treatment levels map readily into the existing four performance levels that NYSDOT has been using to characterize its bridge population (Good, Fair-

Protective, Fair-Corrective, and Poor). This element-based measurement concept continues to be viewed as a viable option for NYSDOT to use AASHTO element data for measuring network performance.

Following the conclusion of this research project, NSYDOT will continue to investigate performance measurement options: both those that use AASHTO element data directly and those that use other available inspection data, such as NBI component condition ratings and the NYSDOT General Recommendation.

General Comments and Findings

In the course of the research, NYSDOT project team members gained a better understanding of the analysis opportunities afforded by AASHTO element inspection data along with some of the particular data attributes that need to be accounted for when designing uses for the data.

Although NYSDOT concluded that the BCI did not meet their needs for network performance measurement, bridge managers who reviewed the analysis data found component (substructure, superstructure, and deck) condition indices to be of interest and potentially useful. Reviewers also noted that the BCI was useful in highlighting poor conditions among certain structures and structure types (notably metal culverts).

NYSDOT collects data on a span-by-span basis, which benefits both condition measurement and treatment selection. For example, when evaluating conditions on a single bridge, component and bridge index measures by span are useful for highlighting areas of the structure with relative condition deficiencies. Also, element treatment triggers, which are based on percentages in poor condition states, are more effective when applied to the more limited quantities in a span than quantities in an entire bridge.

NYSDOT has found that the condition state rating system of AASHTO element inspection, which combines severity and extent (quantity) of defects in a two-dimensional measurement concept, proves to be most effective for treatment selection when the bases for selection are the quantities in poor condition states rather than a condition index that is a weighted average of all of the condition state quantities. Relatively small portions of an element in condition state 3 (poor) or 4 (severe) can suggest the need for repair or replacement, while the condition index can still be a high value.

Integration of AASHTO element data into the NYSDOT bridge management system requires element level deterioration modeling. Detailed element level deterioration modeling specific to NYSDOT structures is not currently available; a research project to create these models is in progress. In the absence of this modeling, the BMS is limited to default deterioration models, which limits confidence in any outputs beyond those of short-term analysis.

In summary, the research project has made considerable progress on integrating AASHTO element inspection data into the NYSDOT bridge management system. Several performance measurement concepts were created and subject to initial evaluation, and viable candidates are being advanced for further consideration. Condition measures for individual bridges and for components of bridges were developed and appear useful to bridge managers. Models for element treatment and bridge project selection and for modeling the effects of treatments were developed. The research project also created logic and instructions for programmers to apply these models in the existing NYSDOT bridge database system.

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APPENDIX A - GLOSSARY

AASHTO – The American Association of State Highway and Transportation Officials, a standards setting body which publishes specifications, test protocols, and guidelines that are used in highway design and construction. AASHTO also sponsors research related to highway design, construction, and management.

AASHTOWare BrM ("BrM") – AASHTOWare Bridge Management, a bridge management system software application administered by AASHTO.

ADE – Agency-Defined Element – One of three categories of AASHTO Elements. An ADE is an element that is specified and defined at the discretion of the state transportation agency.

AgileAssets – a transportation asset management software vendor.

BCI – Bridge Condition Index. For this study, a BCI is an index number between 0-100 calculated using AASHTO elements inspection data for use as a measure of the condition of a bridge

BDIS – Bridge Data Information System. NYSDOT's web-based electronic records system for bridge inventory and inspection data.

BME – Bridge Management Element – A non-structural element that is defined in the AASHTO Manual for Bridge Element Inspection. The other two categories of AASHTO element are NBE and ADE.

BMS – Bridge Management System. A system for collecting, processing, and storing inventory and condition information, predicting bridge deterioration, developing and evaluating alternative actions for managing bridge conditions, identifying budget needs to manage bridge conditions, and recommending programs and implementation schedules to manage the condition of bridges within policy and budget constraints.

Bridge – as defined in the Uniform Code of Bridge Inspection, a "structure including supports erected over a depression or an obstruction such as water, highway, or railway, having a track or passageway for carrying public highway traffic and having an opening measured along the center of the roadway of *more than twenty feet* between under copings of abutments or spring lines or arches, or extreme ends of openings for multiple boxes and may include multiple pipes where the clear distance between openings is less than half of the smaller contiguous opening. The term bridge, as defined in this Part, shall also include the approach spans."

CCI – Component Condition Index. For this study, a CCI is an index number between 0-100 that measures the condition of a bridge major component (deck, superstructure, substructure) or grouping of non-structural elements referred to as a secondary component.

Component – For this report, a component is interpreted in the generic sense, as referring to a constituent part of a whole. A component can be a specific subcomponent such as an abutment, backwall, wearing surface, etc.; a major subdivision of a structure in the sense of the "NBI Component" (deck, superstructure, and substructure); or something at a scale and scope in between these extremes. Where necessary for clarity, the term "major component" will be used in reference to decks, superstructures, and substructures.

Condition State – A term used in AASHTO element inspection that refers to one of four levels of deterioration of an element. NYSDOT has a fifth condition state for recording quantities of an element that could not be assessed.

Condition Measure – a number (Condition Rating, Condition Index) or characteristic (Condition Category based on Project Type) assigned to a bridge by the inspector or based on a calculation algorithm applied to the inspection data and intended to characterize the overall condition of the bridge.

Condition Category – one of four levels of bridge condition: good, fair-protective, fair-corrective, poor. A bridge's condition category is determined from its condition measure through a correspondence established by NYSDOT. The condition category is generally aligned with the expected type/level of work required to restore the structure to a state of good repair. The condition categories are used in performance measurement of the bridge network by reporting the percentage (of number and deck area) of bridges in each condition category.

Culvert – a structure that allows water to flow under a road. Culverts with an opening length of 20' or greater are regulated under the National Bridge Inspection Standards and are included in all references to "bridge" in the NYSDOT inspection system and in this report.

ECI – Element Condition Index - An index number between 0-100 that uses the quantities of the element in each condition state to create a measure of the element's condition.

Element – a component or subcomponent of a structure that is significant from the standpoint of maintenance cost or functionality and that is distinguished from other subcomponents by one or more of the following: functional role in the structure, maintenance requirements, units of measurement relevant to costing and/or inspection, and how its condition is described

FHWA – United States Department of Transportation, Federal Highway Administration. The FHWA administers the federal regulations for bridge inspections, performance measurement for the National Highway System, and asset management of National Highway System pavement and bridge assets. It also administers federal highway grant programs.

Large Culvert – The New York State DOT Bridge Inspection Manual defines a Large Culvert as a structure with an opening between 5 and 20 feet. That is, a large culvert is a structure with a length less than the threshold length for an NBIS bridge. NYSDOT inspections of large culvert use the same condition rating system and guidance as NBIS bridges, with the exception of the assignment of NBI major component General Condition Ratings.

MAP-21 – The federal Moving Ahead for Progress in the 21st Century Act of 2012, P.L. 112-141.

Legacy Inspection System – The inspection and recording system in place at New York State DOT prior to implementation of AASHTO Element inspection

NBE – National Bridge Element –A subset of AASHTO Elements which are the primary load-carrying members of a bridge.

NBI - National Bridge Inventory – a database compiled by the Federal Highway Administration, with information on all bridges and tunnels in the United States that have roads passing above or below.

NBIS - **National Bridge Inspection Standards** – Federal regulations, first promulgated in 1971, establishing requirements for inspection procedures, frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of a State bridge inventory.

NHS – The National Highway System – A designation created by the National Highway System Designation Act of 1995 (P.L. 104–59), the NHS includes the Interstate Highway System as well as other roads important to the nation's economy, defense, and mobility. The NHS was developed by the Department of Transportation (DOT) in cooperation with the states, local officials, and metropolitan planning organizations (MPOs).

NYSDOT – The New York State Department of Transportation

Performance Measure – A metric that is used track how well the transportation network achieves an agency's objectives. For performance measurement of transportation infrastructure condition, an example performance measure is the percentage of the deck area on bridges that are classified as being in poor condition. The FHWA requires the state DOTs to track and report performance measures for infrastructure condition, safety, congestion, and others. NYSDOT measures the performance of its bridge network condition using the percentage of deck area in good, fair-protective, fair-corrective, and poor conditions.

Preservation – As used in this report "bridge preservation" refers to actions that are aimed primarily at slowing deterioration of structural bridge elements rather than measurably changing the condition state of the structural element being preserved. Replacements and repairs of protective elements such as wearing surface, paint, and joints are examples of preservation actions that improve the condition state of the protective element and thereby slow the deterioration of the protected parent element without changing the condition state of the parent element. Some repairs to the structural element can sometimes be regarded as preservation (e.g., patching spalls or cracks on reinforced concrete), depending on the circumstances.

Project Type – For this study, a Project Type is a bundle of one or more Work Types (defined below) that are selected by applying the selection logic in the NYSDOT bridge management system. Examples of Project Types are Bridge Replacement, Substructure Rehabilitation with Deck Replacement, and Repainting.

Rehabilitation – A treatment that improves the condition of a structural element but does not completely replace the element.

Treatment – For this study, a treatment is an action applied to an element to reduce or eliminate distress or deterioration. Treatments are classified into three levels: light repair, heavy repair, and replacement.

Work Type – For this study, a Work Type is a bundle of treatments that are related in terms of the bridge condition they are intended to address. Example Work Types include Superstructure Replacement, Superstructure Rehabilitation, Substructure Rehabilitation, Deck Replacement, Painting, and Vertical Down.

UCBI – The New York State Uniform Code of Bridge Inspection (17 CRR-NY IV C 165)

APPENDIX B – SAMPLE BRIDGE INSPECTION REPORTS

2014 Inspection

Using NYSDOT Legacy Inspection Recording System

Inspection Date: 6/24/2014 **Bridge Ratings** **RC: 16 BIN: 4416010**

Carried: FERRY RD. Crossed: BACKCHANNELMOHAWK CheckValue: 1,815,122,200

Inspection Agency: 10 - NYSDOT Type of Inspection: 1 - BIENNIAL
GTMS: B02 -- Unpainted Steel Continuous - Stringer/Multi-Beam or Girder
POSTINGS: See Gen Rec Page 1 for Postings at time of inspection.
Further Investigation Needed: No
State Highway Number: 000000 Milepoint: 0.09 AADT/Yr: 120 / 2006
Orientation: 2 - Northeast Political Unit: 0587 - Town of NISKAYUNA Year Built: 2010
Total Spans: 4 Ramp Bridge Attached To Span: NA BIN: NA
General Recommendation: 7 Computed Condition Rating: 6.535

Abutment Ratings:	Beg Abut	End Abut
Joint with Deck	6	6
Bearings, Bolts, Pads	7	7
Seats and Pedestals	7	7
Backwall	7	7
Stem (Breastwall)	7	7
Erosion or Scour	7	7
Footings	9	9
Piles	9	8
Recommendation	7	7

Wingwall Ratings:	Beg Abut	End Abut
Walls	4	7
Footings	9	9
Erosion or Scour	7	7
Piles	9	8

Channel Ratings:	Channel
Stream Alignment	7
Erosion and Scour	7
Waterway Opening	7
Bank Protection	7

Approach Ratings:	Approaches
Drainage	7
Embankment	7
Settlement	7
Erosion	5
Pavement	7
Guide Railing	7

Number of Flags Issued:

RED: 0 Yellow: 0 Safety: 0

Vulnerability Reviews Recommended: 1=Yes, 2=No, 3=NA, X=NotActive

Hydraulic: 2	Overload: X	Steel: 2
Collision: 2	Concrete: X	Seismic: X

Span Ratings

Carried: FERRY RD. Crossed: BACKCHANNELMOHAWK CheckValue: 1,815,122,200

Deck Element Ratings:	**001**	**002**	**003**	**004**
Wearing Surface	6	6	6	6
Curbs	8	8	8	8
Sidewalks, Fascias	6	6	6	6
Railings, Parapets	7	7	7	7
Scuppers	8	8	8	8
Gratings	8	8	8	8
Median	8	8	8	8
Mono Deck Surface	8	8	8	8

Superstructure Ratings:	**001**	**002**	**003**	**004**
Structural Deck	6	6	6	6
Primary Members	7	7	7	7
Secondary Members	7	7	7	7
Paint	7	7	7	7
Joints	8	8	8	8
Recommendation	7	7	7	7

Pier Ratings:	**001**	**002**	**003**	**004**
Bearings, Bolts, Pads	7	7	7	8
Pedestals	7	7	7	8
Top of Cap or Beam	7	7	7	8
Stem Solid Pier	7	7	7	8
Cap Beam	8	8	8	8
Pier Columns	8	8	8	8
Footings	9	9	9	8
Erosion or Scour	7	7	7	8
Piles	9	9	9	8
Recommendation	7	7	7	8

Utility Ratings:	**001**	**002**	**003**	**004**
Lighting	8	8	8	8
Sign Structure	7	8	8	7
Utilities and Support	8	8	8	8

Gen. Rec., Postings, Federal Ratings, etc.

Carried: FERRY RD. Crossed: BACKCHANNELMOHAWK CheckValue: 1,815,122,200

Overall Condition:

GENERAL RECOMMENDATION: 7

Computed Condition Rating: 6.535

Problems Requiring Action:

NO Further Investigation Needed

NO Flags Issued

POSTINGS:

Inspector Confirmed existing Posting data as correct.
Posted Vertical Clearance ON the bridge is: No Posting
Posted Vertical Clearance UNDER the bridge is: No Posting
No Load Restriction is posted on this bridge

Overloads Observed:

NO Overload Vehicles were observed on this bridge

FEDERAL RATINGS:

NBI Deck Condition: 8
NBI Superstruct Condition: 9
NBI Substruct Condition: 9
NBI Channel Condition: 8
NBI Culvert Condition: N

Diving Inspection Needs:

Diving Inspection Required? No Date of Last Diving Inspection: No Date

Inventory Problems:

Inventory Problems Exist? No

Miscellaneous:

Time Required to Inspect Bridge: 2.5 Hours

Lane Closure Needs: By Contract for 1 Hours

No Railroad Flagging Required

No Pedestrian Fence

No Snow Fence

The BIN Plate is in NEW condition

Gen. Rec., Postings, Federal Ratings, etc.

Carried: FERRY RD. **Crossed: BACKCHANNELMOHAWK** **CheckValue: 1,815,122,200**

Special Emphasis Inspection Required:

Non-Redundant/Fracture Critical Members - Yes
Pin and Hangers - No
Fatigue-Prone Welds - No
Non-Categorized Fatigue-Prone Details - No
Other (Specified in Text) - No

Special Emphasis Details:

Three girder bridge - 100% handson inspection required.

2014 - Special Emphasis details (Fracture Critical) as required, received 100% hands on inspection. Y. Mathias (Team Leader PE)

General Notes To the Next Inspector:

Bin plate is on end Rt wingwall..

Improvements Observed:

2018 Inspection

Using AASHTO Element Condition Rating System

General Bridge Inspection Report

Inspection Date: June 18, 2018

Structure Information

BIN: **4416010**

Feature Carried: FERRY RD.

Feature Crossed: BACKCHANNELMOHAWK

Orientation: 2 - NORTHEAST

Region: 01 - ALBANY

County: SCHENECTADY

Political Unit: Town of NISKAYUNA

Approximate Year Built: 2010

Primary Owner: New York State Department of Transportation

Primary Maintenance Responsibility: New York State Department of Transportation

General Type Main Span: B - Unpainted Steel (Continuous), 02 - Stringer/Multi-Beam or Girder

This Bridge is not a Ramp

Number of Spans: 4

Postings

Inventoried Posted Load: Not Posted

Posted Load Matches Inventory: N/A

Inventoried Vertical Clearances:

On: Not Posted

Under: Not Posted

Number of Flags Issued

Red PIA: 0

Red: 0

Yellow: 0

Safety PIA: 0

New York State Inspection Overview

General Recommendation: 7

Federal NBI Ratings

NBI Deck Condition: 8

NBI Superstructure Condition: 9

NBI Substructure Condition: 9

NBI Channel Condition: 8

NBI Culvert Condition: N

Action Items

Non-Structural Condition Observations noted: NO

Vulnerability Reviews Recommended: NO

Diving Inspection Requested: NO

Further Investigation Requested: NO

Additional Information

Overloads Observed

No overload vehicles observed during this inspection.

Notes to Next Inspector

BIN plate is on end abutment right side

Improvements Observed

2018 - None

Pedestrian Fence Height

None

Snow Fence

None

Bin Plate Condition

New

Scour Critical Rating

8 - Foundation stable for conditions; scour above footing

Element Assessment Summary Table							
Element	**Total Quantity**	**Unit**	**CS-1**	**CS-2**	**CS-3**	**CS-4**	**CS-5**
12 - Reinforced Concrete Deck	8294	ft^2	7464	830			0
107 - Steel Open Girder/Beam	1420	ft	1420				0
210 - Reinforced Concrete Pier Wall	72	ft	72				0
215 - Reinforced Concrete Abutment	62	ft	62				0
220 - Reinforced Concrete Pile/Cap Footing	354	ft					354
225 - Steel Pile	96	each					96
302 - Compression Joint Seal	34	ft	10		24		0
314 - Pot Bearing	15	each	15				0
321 - Reinforced Concrete Approach Slab	627	ft^2	224	387	16		0
330 - Metal Bridge Railing	952	ft	952				0
510 - Wearing Surfaces	6614	ft^2	6614				0
515 - Steel Protective Coating	22888	ft^2	19508	3374	6		0
800 - Erosion or Scour	352	ft	341	11			0
801 - Stream Hydraulics	1	each	1				0
830 - Secondary Members	4	each	4				0
831 - Steel Beam End	6	each	6				0
850 - Backwall	42	ft	42				0
851 - Abutment Pedestal	6	each	6				0
852 - Pier Pedestal	9	each	9				0
853 - Wingwall	209	ft	184	20	5		0

Element Assessment by Span							
Element**	**Total Quantity**	**Unit**	**CS-1**	**CS-2**	**CS-3**	**CS-4**	**CS-5**
Span Number : 1							
BA215 - Reinforced Concrete Abutment	31	ft	31				0
BA220 - Reinforced Concrete Pile/Cap Footing	31	ft					31
BA225 - Steel Pile	26	each					26
BA302 - Compression Joint Seal	17	ft	5		12		0
BA314 - Pot Bearing	3	each	3				0
515 - Steel Protective Coating	6	ft^2	2	1	3		0
BA321 - Reinforced Concrete Approach Slab	403	ft^2		387	16		0
BA800 - Erosion or Scour	31	ft	31				0
BA831 - Steel Beam End	3	each	3				0

Element**	Total Quantity	Unit	CS-1	CS-2	CS-3	CS-4	CS-5
BA850 - Backwall	21	ft	21				0
BA851 - Abutment Pedestal	3	each	3				0
BW220 - Reinforced Concrete Pile/Cap Footing	168	ft					168
BW225 - Steel Pile	10	each					10
BW800 - Erosion or Scour	168	ft	165	3			0
BW853 - Wingwall	168	ft	143	20	5		0
PR210 - Reinforced Concrete Pier Wall	25	ft	25				0
PR220 - Reinforced Concrete Pile/Cap Footing	27	ft					27
PR225 - Steel Pile	18	each					18
PR314 - Pot Bearing	3	each	3				0
515 - Steel Protective Coating	6	ft^2	4	2			0
PR800 - Erosion or Scour	25	ft	17	8			0
PR852 - Pier Pedestal	3	each	3				0
12 - Reinforced Concrete Deck	2152	ft^2	1937	215			0
510 - Wearing Surfaces	1700	ft^2	1700				0
107 - Steel Open Girder/Beam	366	ft	366				0
515 - Steel Protective Coating	4330	ft^2	3464	866			0
330 - Metal Bridge Railing	247	ft	247				0
515 - Steel Protective Coating	1563	ft^2	1563				0
801 - Stream Hydraulics	1	each	1				0
830 - Secondary Members	1	each	1				0
Span Number : 2							
PR210 - Reinforced Concrete Pier Wall	24	ft	24				0
PR220 - Reinforced Concrete Pile/Cap Footing	29	ft					29
PR225 - Steel Pile	24	each					24
PR314 - Pot Bearing	3	each	3				0
515 - Steel Protective Coating	6	ft^2	4	2			0
PR800 - Erosion or Scour	29	ft	29				0
PR852 - Pier Pedestal	3	each	3				0
12 - Reinforced Concrete Deck	1995	ft^2	1795	200			0
510 - Wearing Surfaces	1596	ft^2	1596				0
107 - Steel Open Girder/Beam	344	ft	344				0
515 - Steel Protective Coating	4087	ft^2	3270	817			0
330 - Metal Bridge Railing	229	ft	229				0
515 - Steel Protective Coating	1449	ft^2	1449				0
830 - Secondary Members	1	each	1				0
Span Number : 3							

Element**	Total Quantity	Unit	CS-1	CS-2	CS-3	CS-4	CS-5
PR210 - Reinforced Concrete Pier Wall	23	ft	23				0
PR220 - Reinforced Concrete Pile/Cap Footing	27	ft					27
PR225 - Steel Pile	18	each					18
PR314 - Pot Bearing	3	each	3				0
515 - Steel Protective Coating	6	ft^2	4	2			0
PR800 - Erosion or Scour	27	ft	27				0
PR852 - Pier Pedestal	3	each	3				0
12 - Reinforced Concrete Deck	1995	ft^2	1795	200			0
510 - Wearing Surfaces	1610	ft^2	1610				0
107 - Steel Open Girder/Beam	344	ft	344				0
515 - Steel Protective Coating	4087	ft^2	3270	817			0
330 - Metal Bridge Railing	229	ft	229				0
515 - Steel Protective Coating	1449	ft^2	1449				0
830 - Secondary Members	1	each	1				0
Span Number : 4							
EA215 - Reinforced Concrete Abutment	31	ft	31				0
EA220 - Reinforced Concrete Pile/Cap Footing	31	ft					31
EA302 - Compression Joint Seal	17	ft	5		12		0
EA314 - Pot Bearing	3	each	3				0
515 - Steel Protective Coating	6	ft^2	2	1	3		0
EA321 - Reinforced Concrete Approach Slab	224	ft^2	224				0
EA800 - Erosion or Scour	31	ft	31				0
EA831 - Steel Beam End	3	each	3				0
EA850 - Backwall	21	ft	21				0
EA851 - Abutment Pedestal	3	each	3				0
EW220 - Reinforced Concrete Pile/Cap Footing	41	ft					41
EW800 - Erosion or Scour	41	ft	41				0
EW853 - Wingwall	41	ft	41				0
12 - Reinforced Concrete Deck	2152	ft^2	1937	215			0
510 - Wearing Surfaces	1708	ft^2	1708				0
107 - Steel Open Girder/Beam	366	ft	366				0
515 - Steel Protective Coating	4330	ft^2	3464	866			0
330 - Metal Bridge Railing	247	ft	247				0
515 - Steel Protective Coating	1563	ft^2	1563				0
830 - Secondary Members	1	each	1				0

** Elements with a prefix designate the locations of BA-Begin Abutment, BW-Begin Wingwall, EA-End Abutment, EW-End Wingwall, CO-Culvert Outlet, and PR-Pier. No prefix generally indicates the element is part of the superstructure.

Inspection Notes

General Comments

The following quantity changes are noted:

Span 1:
Begin abutment footing 64 FT to 31 FT
Begin abutment steel piles 36 to 26
Begin abutment bearing coating 5 SF to 6 SF
Pier 1 bearing coating 5 SF to 6 SF
Pier 1 scour 54 FT to 25 FT
Begin wingwall 97 FT to 168 FT
Begin wingwall scour 97 FT to 168 FT

Span 2:
Pier 2 bearing coating 5 SF to 6 SF
Pier 2 scour 57 FT to 29 FT

Span 3:
Pier 3 bearing coating 5 SF to 6 SF
Pier 3 scour 54 FT to 27 FT
Rail coating 4087 SF to 1449 SF

Span 4:
End abutment footing 81 FT to 31 FT
End abutment bearing coating 5 SF to 6 SF

Element Condition Notes

	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
Span 1: BA302 - Compression Joint Seal	17	5	0	12	0	0
Span 4: EA302 - Compression Joint Seal	17	5	0	12	0	0

Condition State 3 Note

Referenced Photo(s): 3

Referenced Sketch(es): None

Foam block is debonded from the header up to 2 IN deep over 12 FT in the vicinity of the lane (foam block is 3 IN deep total). Areas along the ends are in good shape.

Begin and end side are similar.

Begin and end joint: 5 FT CS1, 12 FT CS3

	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
Span 1: BA314 - Pot Bearing-515 - Steel Protective Coating	6	2	1	3	0	0
Span 4: EA314 - Pot Bearing-515 - Steel Protective Coating	6	2	1	3	0	0

Condition State 3 Note

Referenced Photo(s): 2

Referenced Sketch(es): None

Begin and end abutment bearing coatings range from firm (CS1) to finish coat peeling with primer coat intact and no corrosion (CS2) to bubbled with rust bleeding (CS3).

For begin and end abutment bearings: 2 SF CS1, 1 SF CS2, 3 SF CS3

	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
Span 1: PR314 - Pot Bearing-515 - Steel Protective Coating	6	4	2	0	0	0
Span 2: PR314 - Pot Bearing-515 - Steel Protective Coating	6	4	2	0	0	0
Span 3: PR314 - Pot Bearing-515 - Steel Protective Coating	6	4	2	0	0	0

Condition State 2 Note

Referenced Photo(s): 1

Referenced Sketch(es): None

Bearings on all piers have scattered areas of finish paint coat loss with the primer coat intact, with no corrosion (CS2). Otherwise paint is in good shape.

For all pier bearings: 4 SF CS1, 2 SF CS2

	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
Span 1: BA321 - Reinforced Concrete Approach Slab	403	0	387	16	0	0

Condition State 3 Note

Referenced Photo(s): 4, 5

Referenced Sketch(es): None

Begin approach slab is almost entirely paved over and paved portions will be rated based on top surface observations.

End right corner exhibits horizontal plane cracking up to 2 IN deep over a 10 IN (parallel to traffic) x 21 IN (perpendicular to traffic) area.
2 SF CS3

Asphalt exhibits (2) wide transverse cracks - one 12 FT from the bridge joint, the other at the begin terminus, 1/8 to 1 IN wide. These cracks correspond to settlement in the vicinity of the first three modular wall panel columns on the left hand side. The first crack aligns with the joint between the end of the reinforced concrete wingwall and the first modular wall column, and the end crack aligns with the joint between modular wall columns 3 and 4. See photo 6 for clarity. The first crack closest to the bridge joint is more towards the slab center and suggests that the slab may be cracked.
14 SF CS3

Asphalt between the joint and the first crack exhibits up to 2-1/2 IN of settlement, measured along the top of the left modular wall on the inside face. See photo 6 for clarity.

Also refer to wingwall element commentary, and begin left modular wall displacement readings.

Overall
387 SF CS2, 16 SF CS3

	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
Span 1: 330 - Metal Bridge Railing-515 - Steel Protective Coating	1563	1563	0	0	0	0
Span 2: 330 - Metal Bridge Railing-515 - Steel Protective Coating	1449	1449	0	0	0	0
Span 3: 330 - Metal Bridge Railing-515 - Steel Protective Coating	1449	1449	0	0	0	0
Span 4: 330 - Metal Bridge Railing-515 - Steel Protective Coating	1563	1563	0	0	0	0

Condition State 1 Note

Referenced Photo(s): None

Referenced Sketch(es): None

Rail coating is rated CS1 with no CS2-warranting conditions found.

	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
Span 1: PR800 - Erosion or Scour	25	17	8	0	0	0

Condition State 2 Note

Referenced Photo(s): None

Referenced Sketch(es): None

Pier 1 in the in the vicinity of the left footing edge/end left quadrant exhibits active scour. Rod probing suggests that the top of the streambed has eroded to the top surface of the footing in this vicinity (footing is on piles).

Span 1: BW800 - Erosion or Scour	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
	168	165	3	0	0	0

Condition State 2 Note

Referenced Photo(s): 8

Referenced Sketch(es): None

Reinforced concrete wingwall/modular wall column 1 junction on the right flare has an erosion pocket that is 3 FT long (parallel to wall) x 2 FT wide x 3 FT deep.

Span 1: BW853 - Wingwall	TQ	CS-1	CS-2	CS-3	CS-4	CS-5
	168	143	20	5	0	0

Condition State 3 Note

Referenced Photo(s): 6, 7, 8

Referenced Sketch(es): None

At the left modular wall (rated as wingwall) 1st, 2nd, 3rd panel columns (counted from the reinforced concrete wingwall far terminus) exhibit slight vertical settlement, which is responsible for the asphalt cracking described under the begin approach slab element. Up to 1-1/4 IN and 5/8 IN settlement was measured at the joint between the reinforced concrete wingwall far terminus/panel column 1 and between panel columns 3 and 4, respectively. Measurement documentation at these locations have been initiated - refer to the begin left modular wall displacement readings. Otherwise good on the left side.
Panel columns 1,2,3 rated CS2 for 5 FT apiece.

At the right modular wall, panel column 1 exhibits significant displacement with respect to the reinforced concrete wingwall far terminus - up to 6-1/8 IN of horizontal separation parallel to the wall - refer to the begin right modular wall displacement reading 'C'. In addition, at column 1, blocks 7/8/9/10 (counted from the top block) exhibit slight counterclockwise rotation. Horizontal separation parallel to the wall between panel columns 1 and 2 is less severe, measured at 1-1/4 IN - refer to begin right modular wall displacement reading 'E'.
Panel column 1 rated CS3 for 5 FT
Panel column 2 rated CS2 for 5 FT

Overall
143 FT CS1
20 FT CS2
5 FT CS3

Sketch Number: **4** Sketch Filename: **4416010.JPG**

Agency Defined Element 801 - Stream Hydraulics
Defect History

BIN: 4416010

ADE 801 DEFECTS		CONDITION STATES (CS)			
		Previous Inspections			Current Inspection *mm/dd/yyyy*
		BASELINE *6/18/2018*			*6/18/2018*
6120	Channel Alignment	1			1
6130	Channel Scour	1			1
6140	Waterway Opening	1			1
6150	Scour Protection	1			1
6160	Bank Protection	1			1
6165	Bank Erosion	1			1
6180	Debris Near Bridge	1			1
6190	Countermeasures	N/A			N/A
		ADE 801 - Controlling Condition State =			1

Inspector's Comment (comment required for each defect assessed CS-3 or CS-4):
No comments.

Sketch Description: Stream hydraulics

APPENDIX C – EXAMPLE RATING AND CODING GUIDES

Legacy NYSDOT Inspection Rating Guide for Reinforced Concrete Structural Deck

7	Deck is new or near new, almost no sign of deterioration.
6	Used to shade between 5 and 7.
5	Only localized areas of leakage (e.g., single longitudinal crack with leakage, or deck edges showing only spotty leakage. From the top, cracks are open and obviously allow infiltration of water and chlorides but with minimal signs of rebar corrosion or deck deterioration).
4	Used to shade between 3 and 5.
3	75 percent or more of the deck has leakage. Only localized spalled areas and remaining concrete is sound. Efflorescence along the girder top flanges.
2	Used to shade between 1 and 3.
1	Heavy spalling. Heavy efflorescence. Punch through has occurred or is likely. Deck saturated to point that concrete is rubble.

Source: *NYSDOT Bridge Inspection Manual.* 2014.

AASHTO Manual for Bridge Inspection - Coding Guide for Elements Composed of Reinforced Concrete

Partial, for illustrative purposes only. Not all defects are shown.

Defects	Condition State 1	Condition State 2	Condition State 3	Condition State 4
	GOOD	FAIR	POOR	SEVERE
Delamination/ Spall/ Patched Area	None	Delaminated. Spall 1 in or less deep or 6 in. or less in diameter. Patched area that is sound.	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsounds or showing distress. Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge. OR A structural review has been completed, and the defects impact strength or serviceability of the element or bridge.
Exposed Rebar	None	Present without measurable section loss.	Present with measurable section loss, but does not warrant structural review.	
Efflorescence/ Rust Staining	None	Surface white without buildup or leaching without rust staining.	Heavy buildup with rust staining.	
Cracking	Insignificant cracks or moderate-width cracks that have been sealed.	Unsealed moderate width cracks, or unsealed moderate pattern (map) cracking.	Wide cracks or heavy pattern cracking.	
Abrasion/Wear	No abrasion or wearing	Abrasion or wearing has exposed coarse aggregate but the aggregate remains secure in the concrete.	Coarse aggregate is loose, or has popped out of the concrete matrix due to abrasion or wear.	
Settlement	None	Exists within tolerable limits or arrested with no observed structural distress	Exceeds tolerable limits but does not warrant structural review.	
Scour	None	Exists within tolerable limits or has been arrested with effective countermeasures.	Exceeds tolerable limits but is less than critical limits determined by scour evaluation and does not warrant structural review.	

Source: *AASHTO Manual for Bridge Element Inspection, Second Edition*. 2019

The Federal Rating Scale for NBI General Component Ratings

The rating guidance for the federal scale is from the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges*.[1]

The rating Scale for Deck (Item 58), Superstructure (Item 59), and Substructure (Item 60) is as follows:

CODE DESCRIPTION

N **NOT APPLICABLE**

9 **EXCELLENT CONDITION**

8 **VERY GOOD CONDITION** - no problems noted.

7 **GOOD CONDITION** - some minor problems.

6 **SATISFACTORY CONDITION** - structural elements show some minor deterioration

5 **FAIR CONDITION** - all primary structural elements are sound, but may have minor section loss, cracking, spalling or scour.

4 **POOR CONDITION** - advanced section loss, deterioration, spalling or scour.

3 **SERIOUS CONDITION** - loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.

2 **CRITICAL CONDITION** - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until collective action is taken.

1 **"IMMINENT" FAILURE CONDITION** - major deterioration or section loss present in critical structural components, or obvious vertical or horizontal movement effecting structure stability. Bridge is closed to traffic, but corrective action may put the bridge back in light service.

0 **FAILED CONDITION** - out of service beyond corrective action.

Rating Guidance for Deck (Item 58)

This item describes the overall condition rating of the deck. Rate and code the condition in accordance with the above general condition ratings. Code N for culverts and other structures without decks e.g., filled arch bridge.

Concrete decks should be inspected for cracking, scaling, spalling, leaching, chloride contamination, potholing, delamination, and full or partial depth failures. Steel grid decks should be inspected for broken welds, broken grids, section loss, and growth of filled grids from corrosion. Timber decks should be inspected for splitting, crushing, fastener failure, and deterioration from rot.

The condition of the wearing surface/protective system, joints, expansion devices, curbs, sidewalks, parapets, fascias, bridge rail, and scuppers shall not be considered in the overall deck evaluation. However, their condition should be noted on the inspection form.

Decks integral with the superstructure will be rated as a deck only and not how they may influence the superstructure rating (for example, rigid frame, slab, deck, girder or T-beam, voided slab, box girder, etc.). Similarly, the superstructure of an integral deck-type bridge will not influence the deck rating.

Rating Guidance for Superstructure (Item 59)

[1] FHWA Report No. PD-96-001, https://www.fhwa.dot.gov/BRIDGE/mtguide.pdf

This item describes the physical condition of all structural members. Rate and code the condition in accordance with the previously described general condition ratings. Code N for all culverts.

The structural members should be inspected for signs of distress which may include cracking, deterioration, section loss, and malfunction and misalignment of bearings.

The condition of bearings, joints, paint system, etc. shall not be included in this rating, except in extreme situations, but should be noted on the inspection form.

On bridges where the deck is integral with the superstructure, the superstructure condition rating may be affected by the deck condition. The resultant superstructure condition rating may be lower than the deck condition rating where the girders have deteriorated or been damaged.

Fracture critical components should receive careful attention because failure could lead to collapse of a span or the bridge.

Rating Guidance for Substructure (Item 60)

This item describes the physical condition of piers, abutments, piles, fenders, footings, or other components. Rate and code the condition in accordance with the previously described general condition ratings. Code N for all culverts.

All substructure elements should be inspected for visible signs of distress including evidence of cracking, section loss, settlement, misalignment, scour, collision damage, and corrosion. The rating given by Item 113 - Scour Critical Bridges, may have a significant effect on Item 60 if scour has substantially affected the overall condition of the substructure.

The substructure condition rating shall be made independent of the deck and superstructure. Integral-abutment wingwalls to the first construction or expansion joint shall be included in the evaluation. For non-integral superstructure and substructure units, the substructure shall be considered as the portion below the bearings. For structures where the substructure and superstructure are integral, the substructure shall be considered as the portion below the superstructure.

Rating Guidance for Channel and Channel Protection (Item 61).

This item describes the physical conditions associated with the flow of water through the bridge such as stream stability and the condition of the channel, riprap, slope protection, or stream control devices including spur dikes. The inspector should be particularly concerned with visible signs of excessive water velocity which may affect undermining of slope protection, erosion of banks, and realignment of the stream which may result in immediate or potential problems. Accumulation of drift and debris on the superstructure and substructure should be noted on the inspection form but not included in the condition rating.

Rate and code the condition in accordance with the previously described general condition ratings and the following descriptive codes:

Code	Description
N	Not applicable. Use when bridge is not over a waterway (channel).
9	There are no noticeable or noteworthy deficiencies which affect the condition of the channel.
8	Banks are protected or well vegetated. River control devices such as spur dikes and embankment protection are not required or are in a stable condition.
7	Bank protection is in need of minor repairs. River control devices and embankment protection have a little minor damage. Banks and/or channel have minor amounts of drift.
6	Bank is beginning to slump. River control devices and embankment protection have widespread minor damage. There is minor stream bed movement evident. Debris is restricting the channel slightly.
5	Bank protection is being eroded. River control devices and/or embankment have major damage. Trees and brush restrict the channel.
4	Bank and embankment protection is severely undermined. River control devices have severe damage. Large deposits of debris are in the channel.
3	Bank protection has failed. River control devices have been destroyed. Stream bed aggradation, degradation or lateral movement has changed the channel to now threaten the bridge and/or approach roadway.
2	The channel has changed to the extent the bridge is near a state of collapse.
1	Bridge closed because of channel failure. Corrective action may put back in light service.
0	Bridge closed because of channel failure. Replacement necessary.

Rating Guidance for Culverts

This item evaluates the alignment, settlement, joints, structural condition, scour, and other items associated with culverts. The rating code is intended to be an overall condition evaluation of the culvert. Integral wingwalls to the first construction or expansion joint shall be included in the evaluation. For a detailed discussion regarding the inspection and rating of culverts, consult Report No. FHWA-IP-86-2, Culvert Inspection Manual, July 1986.

Code	Description
N	Not applicable. Use if structure is not a culvert.
9	No deficiencies.
8	No noticeable or noteworthy deficiencies which affect the condition of the culvert. Insignificant scrape marks caused by drift.
7	Shrinkage cracks, light scaling, and insignificant spoiling which does not expose reinforcing steel. Insignificant damage caused by drift with no misalignment and not requiring corrective action. Some minor scouring has occurred near curtain walls, wingwalls, or pipes. Metal culverts have a smooth symmetrical curvature with superficial corrosion and no pitting.
6	Deterioration or initial disintegration, minor chloride contamination, cracking with some leaching, or spalls on concrete or masonry walls and slabs. Local minor scouring at curtain walls, wingwalls, or pipes. Metal culverts have a smooth curvature, non-symmetrical shape, significant corrosion or moderate pitting.
5	Moderate to major deterioration or disintegration, extensive cracking and leaching, or spalls on concrete or masonry walls and slabs. Minor settlement or misalignment. Noticeable scouring or

erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection in one section, significant corrosion or deep pitting.

4 Large spalls, heaving scaling, wide cracks, considerable efflorescence, or opened construction joint permitting loss of backfill. Considerable settlement or misalignment. Considerable scouring or erosion at curtain walls, wingwalls, or pipes. Metal culverts have significant distortion and deflection throughout, extensive corrosion or deep pitting.

3 Any condition described in Code 4, but which is excessive in scope. Severe movement or differential settlement of the segments, or loss of fill. Holes may exist in walls or slabs. Integral wingwalls nearly severed from culvert. Severe scour or erosion at curtain walls, wingwalls, or pipes. Metal culverts have extreme distortion and deflection in one section, extensive corrosion, or deep pitting with scattered perforations.

2 Integral wingwalls collapsed, severe settlement of roadway due to loss of fill. Section of culvert may have failed and can no longer support embankment. Complete undermining at curtain walls and pipes. Corrective action required to maintain traffic. Metal culverts have extreme distortion and deflection throughout with extensive perforations due to corrosion.

1 Bridge closed. Corrective action may put bridge back in light service

0 Bridge closed. Replacement necessary.

APPENDIX D – EXAMPLE BCI CALCULATION

BCI Calculation for hypothetical two span steel multi-girder.
Part 1: Element Condition States to Element Condition Indices (Step 1) and Element Condition Indices to Span Component Condition Indices (Step 2)

Component	Span	Element Number	Element Name	Element Weighting Points->	STEP 1 - Element Condition Index (ECI): Percentage in Condition State CS 1 100 (1)	CS 2 55 (2)	CS 3 20 (3)	CS 4 0 (4)	STEP 2 - Span Component Condition Index (Span CCI): Element Condition Index (ECI) ECI (5) = (1) x 100 + (2) x 55 + (3) x 20	Weight in Component (6)	Total Points (7) = (5) x (6)	Span CCI (8) = (7) / (6)
Deck	Span 1	12	Re Concrete Deck		0%	94%	6%	0%	52.87	100	5,287	52.87
	Span 2	12	Re Concrete Deck		0%	95%	5%	0%	53.40	100	5,340	53.40
Super-structure	Span 1	107	Steel Opn Girder/Beam		100%	0%	0%	0%	100.00	100	10,000	100.00
	Span 2	107	Steel Opn Girder/Beam		0%	100%	0%	0%	55.00	100	5,500	55.00
Sub-structure	Span 1	210	Re Conc Pier Wall		0%	50%	0%	50%	27.50	125	3,438	
		215	Re Conc Abutment		0%	98%	0%	2%	53.75	100	5,375	
		851	Abutment pedestal		0%	100%	0%	0%	55.00	60	3,300	
		852	Pier pedestal		0%	100%	0%	0%	55.00	60	3,300	
		Total for	Span-Component							345	15,413	44.67
	Span 2	215	Re Conc Abutment		0%	70%	30%	0%	44.50	100	4,450	
		851	Abutment pedestal		0%	100%	0%	0%	55.00	100	5,500	
		Total for	Span-Component							200	9,950	49.75
Secondary	Span 1	510	Wearing Surfaces		0%	100%	0%	0%	55.00	10	550	
		515	Steel Protective Coating		0%	0%	0%	100%	0.00	10	0	
		Total for	Span-Component							20	550	27.50
	Span 2	510	Wearing Surfaces		0%	100%	0%	0%	55.00	10	550	
		515	Steel Protective Coating		0%	0%	0%	100%	0.00	10	0	
		Total for	Span-Component							20	550	27.50

Part 2: Span-Component Condition Indices to Component Condition Indices (Step 3) and Component Condition Indices to Bridge Index (Step 4)

Component	Span CCI		Component		
	Span 1 32 ft (40%) (1)	Span 2 48 ft (60%) (2)	CCI (3) = 40% x (1) + 60% x (2)	Weighting Points (4)	Weight Used this Structure* (5)
Deck	52.87	53.40	53.19	25	25%
Superstructure	100.00	55.00	73.00	35	35%
Substructure	44.67	49.75	47.72	30	30%
Culvert	NA	NA	NA	90	0%
Secondary	27.50	27.50	27.50	10	10%
					100%
BCI = Weighted Average of Components =			∑ [(3) x (5)]	=	55.91

* Weight is proportional to share of total points of the components that are included in the BCI. For example, a bridge with just superstructure and substructure components has 65 total points, and superstructure CCI will be weighted by 54% (35 ÷ 65) and substructure by 46% (30 ÷ 65).

APPENDIX E - AASHTO ELEMENT DATA

Element		Units	Weight in CCI	Number of Instances*	Component	Treatment Thresholds**					
						Light Repair		Heavy Repair		Replacement	
						CS3	CS4	CS3	CS4	CS3	CS4
12	Re Concrete Deck	sf.	100	26,543	Deck	1	0	10	1	30	5
13	Pre Concrete Deck	sf.	100	114	Deck	1	0	10	1	30	5
15	Pre Concrete Top Flange	sf.	100	1,830	Deck	1	0	10	1	30	5
16	Re Conc Top Flange	sf.	100	364	Deck	1	0	10	1	30	5
28	Steel Deck - Open Grid	sf.	100	625	Deck	1	0	10	1	30	5
29	Steel Deck - Conc Fill Grid	sf.	100	1,253	Deck	1	0	10	1	30	5
30	Steel Deck - Orthotropic	sf.	100	544	Deck	1	0	10	1	30	5
31	Timber Deck	sf.	100	1,095	Deck	1	0	10	1	30	5
38	Re Concrete Slab	sf.	100	2,678	Deck	1	0	10	1	30	5
54	Timber Slab	sf.	100	404	Deck	1	0	10	1	30	5
60	Other Deck	sf.	100	61	Deck	1	0	10	1	30	5
65	Other Slab	sf.	100	16	Deck	1	0	10	1	30	5
102	Steel Clsd Box Gird	lf.	100	138	Super	5	1	10	10	20	15
104	Pre Clsd Box Girder	lf.	100	3,813	Super	0	0	0	0	15	5
105	Re Clsd Box Girder	lf.	100	60	Super	5	1	10	10	20	15
106	Othr Clsd Web/Box Girder	lf.	100	3	Super	5	1	10	10	20	15
107	Steel Opn Girder/Beam	lf.	100	24,507	Super	5	1	10	10	20	15
109	Pre Opn Conc Girder/Beam	lf.	100	923	Super	0	0	0	0	15	5
110	Re Conc Opn Girder/Beam	lf.	100	774	Super	5	1	10	10	20	15
111	Timber Open Girder	lf.	100	258	Super	5	1	10	10	20	15
112	Other Open Girder/Beam	lf.	100	46	Super	5	1	10	10	20	15
113	Steel Stringer	lf.	100	3,673	Super	5	1	10	10	20	15
115	Pre Conc Stringer	lf.	100	1	Super	0	0	0	0	15	5
116	Re Conc Stringer	lf.	100	89	Super	5	1	10	10	20	15
117	Timber Stringer	lf.	100	30	Super	5	1	10	10	20	15

Element		Units	Weight in CCI	Number of Instances*	Component	Treatment Thresholds**					
						Light Repair		Heavy Repair		Replacement	
						CS3	CS4	CS3	CS4	CS3	CS4
118	Other Stringer	lf.	100	2	Super	5	1	10	10	20	15
120	Steel Truss	lf.	225	880	Super	1	1	10	5	25	15
135	Timber Truss	lf.	225	7	Super	1	1	10	5	25	15
136	Other Truss	lf.	225	4	Super	1	1	10	5	25	15
141	Steel Arch	lf.	225	113	Super	1	1	10	5	25	15
142	Other Arch	lf.	225	8	Super	1	1	10	5	25	15
143	Pre Conc Arch	lf.	225	11	Super	5	1	20	10	30	20
144	Re Conc Arch	lf.	225	968	Super	5	1	20	10	30	20
145	Masonry Arch	lf.	225	241	Super	5	1	20	10	30	20
146	Timber Arch	lf.	225	5	Super	1	1	10	5	25	15
147	Stl Main Cables	lf.	250	113	Super	5	1	10	10	20	15
148	Sec Steel Cables	ea.	100	45	Super	5	1	10	10	20	15
149	Otr Secondary Cable	ea.	100	0	Super	5	1	10	10	20	15
152	Steel Floor Beam	lf.	120	4,479	Super	5	1	10	10	20	15
154	Prestress Floor Beam	lf.	120	67	Super	0	0	0	0	15	5
155	Re Conc Floor Beam	lf.	120	280	Super	5	1	10	10	20	15
156	Timber Floor Beam	lf.	120	23	Super	5	1	10	10	20	15
157	Other Floor Beam	lf.	120	2	Super	5	1	10	10	20	15
161	Stl Pin Pin/Han both	ea.	100	271	Super	1	0	25	1	50	25
162	Stl Gus Plate	ea.	130	841	Super	1	0	20	1	50	30
202	Steel Column	ea.	125	3,685	Sub	1	1	70	20	0	50
203	Other Column	ea.	125	53	Sub	1	0	35	0	0	35
204	Pre Conc Column	ea.	125	31	Sub	1	0	35	0	0	35
205	Re Conc Column	ea.	125	11,002	Sub	1	0	35	0	0	35
206	Tim Col or Pile Ext	ea.	125	65	Sub	1	0	35	0	0	35
207	Stl Tower	lf.	225	128	Sub	1	0	35	0	0	35
208	Timber Trestle	lf.	125	2	Sub	1	1	10	5	25	15
210	Re Conc Pier Wall	lf.	125	7,167	Sub	0	0	30	1	60	25
211	Other Pier Wall	lf.	125	85	Sub	0	0	30	1	60	25
212	Timber Pier Wall	lf.	125	8	Sub	0	0	30	1	60	25
213	Masonry Pier Wall	lf.	125	302	Sub	0	0	30	1	60	25
215	Re Conc Abutment	lf.	100	24,774	Sub	0	0	30	1	60	25

Element		Units	Weight in CCI	Number of Instances*	Component	Treatment Thresholds**					
						Light Repair		Heavy Repair		Replacement	
						CS3	CS4	CS3	CS4	CS3	CS4
216	Timber Abutment	lf.	100	397	Sub	0	0	30	1	60	25
217	Masonry Abutment	lf.	100	949	Sub	0	0	30	1	60	25
218	Other Abutments	lf.	100	147	Sub	0	0	30	1	60	25
219	Stl Abutment	lf.	100	365	Sub	0	0	30	1	60	25
220	Re Conc Pile Cap/Ftg	lf.	100	64,833	Sub	0	0	0	0	0	1
225	Steel Pile	ea.	100	14,179	Sub	0	0	0	0	0	50
226	Pre Conc Pile	ea.	100	261	Sub	0	0	0	0	0	35
227	Re Conc Pile	ea.	100	11,373	Sub	0	0	0	0	0	35
228	Timber Pile	ea.	100	3,341	Sub	0	0	0	0	0	35
229	Other Pile	ea.	100	450	Sub	0	0	0	0	0	35
231	Steel Pier Cap	lf.	125	4,994	Sub	0	0	50	1	0	30
233	Pre Conc Pier Cap	lf.	125	55	Sub	1	0	50	1	0	25
234	Re Conc Pier Cap	lf.	125	11,241	Sub	1	0	50	1	0	25
235	Timber Pier Cap	lf.	125	484	Sub	1	0	50	1	0	25
236	Other Pier Cap	lf.	125	37	Sub	1	0	50	1	0	25
240	Steel Culvert	lf.	100	1,310	Culvert	25	5	45	10	0	25
241	Re Conc Culvert	lf.	100	2,174	Culvert	5	1	20	10	30	20
242	Timber Culvert	lf.	100	0	Culvert	5	1	20	10	30	20
243	Other Culvert	lf.	100	108	Culvert	5	1	20	10	30	20
244	Masonry Culvert	lf.	100	9	Culvert	5	1	20	10	30	20
245	Pre Concrete Culvert	lf.	100	10	Culvert	5	1	20	10	30	20
300	Strip Seal Exp Joint	lf.	10	2,470	Secondary	10	0	20	10	40	20
301	Pourable Joint Seal	lf.	10	4,367	Secondary	0	0	20	10	40	20
302	Compressn Joint Seal	lf.	10	11,575	Secondary	0	0	20	10	40	20
303	Assem Jnt With Seal	lf.	10	1,099	Secondary	0	0	20	10	40	20
304	Open Expansion Joint	lf.	10	517	Secondary	0	0	20	10	40	20
305	Assem Jnt w/o Seal	lf.	10	423	Secondary	0	0	20	10	40	20
306	Other Joint	lf.	10	1,724	Secondary	0	0	20	10	40	20

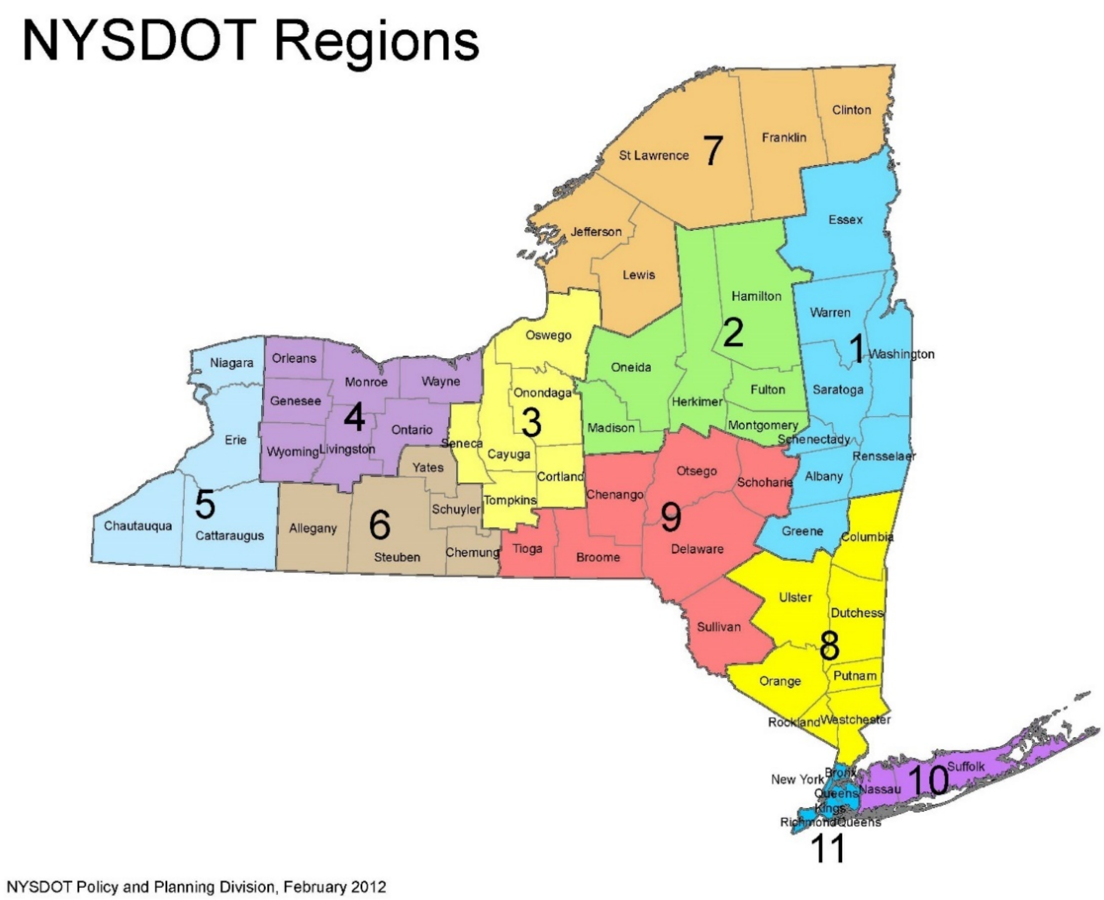
Element		Units	Weight in CCI	Number of Instances*	Component	Treatment Thresholds**					
						Light Repair		Heavy Repair		Replacement	
						CS3	CS4	CS3	CS4	CS3	CS4
310	Elastomeric Bearing	ea.	60	18,217	Sub	10	0	20	1	40	20
311	Moveable Bearing	ea.	60	9,131	Sub	10	0	20	1	40	20
312	Enclosed Bearing	ea.	60	881	Sub	10	0	20	1	40	20
313	Fixed Bearing	ea.	60	10,011	Sub	10	0	20	1	40	20
314	Pot Bearing	ea.	60	3,042	Sub	10	0	20	1	40	20
315	Disk Bearing	ea.	60	763	Sub	10	0	20	1	40	20
316	Other Bearing	ea.	60	1,304	Sub	10	0	20	1	40	20
320	Pre Conc Appr Slab	ea.	0	36	Unused	0	0	30	10	45	25
321	Re Conc Approach Slab	ea.	0	13,945	Unused	0	0	30	10	45	25
330	Metal Bridge Railing	lf.	0	25,905	Unused	0	0	20	10	40	20
331	Re Conc Bridge Railing	lf.	0	15,137	Unused	0	0	20	10	40	20
332	Timb Bridge Railing	lf.	0	674	Unused	0	0	20	10	40	20
333	Other Bridge Railing	lf.	0	174	Unused	0	0	20	10	40	20
334	Masry Bdge Railing	lf.	0	556	Unused	0	0	20	10	40	20
510	Wearing Surfaces	sf.	10	33,760	Secondary	0	0	0	0	30	10
515	Steel Protective Coating	sf.	10	108,402	Secondary	0	0	20	1	0	10
520	Conc Re Prot Sys	sf.	0	149	Unused	0	0	0	0	0	0
521	Conc Prot Coating	sf.	0	701	Unused	0	0	0	0	0	0
800	Erosion or scour	lf.	0	76,595	Unused	20	1	80	20	0	0
801	Stream hydraulics	ea.	0	12,125	Unused	1	0	0	1	0	0
810	Sidewalk	sf.	0	12,621	Unused	0	0	0	0	40	40
811	Curb	lf.	0	19,826	Unused	0	0	0	0	45	30
830	Secondary members	ea.	30	25,367	Super	0	0	1	0	0	1
831	Steel beam end	ea.	0	20,976	Unused	0	0	0	0	0	0
850	Backwall	lf.	0	22,235	Unused	0	0	30	1	60	25
851	Abutment pedestal	ea.	60	24,316	Sub	0	0	20	1	55	30
852	Pier pedestal	ea.	60	16,587	Sub	0	0	20	1	55	30
853	Wingwall	lf.	100	24,755	Sub	0	0	30	1	60	25
860	Headwall	lf.	20	3,245	Super	0	0	30	1	60	25
870	Unknown	ea.	0	140	Unused	0	0	0	0	0	0

* Number of element instances in NYSDOT inspection data for inspections conducted in 2017 and 2018.

** Minimum percentage in condition state at which treatment is triggered. For example, replacement of a wingwall (853) or headwall (860) is triggered if 25% or more of the linear feet is in CS4, or if 60% or more of the linear feet is in CS3 and CS4 combined. If both CS3 and CS4 are entered as "0", that treatment level does not exist for that element. CS2 thresholds were removed, for reasons stated in Section 4.2 of the Report.

APPENDIX F – NYSDOT REGIONS

The New York State transportation system is managed in eleven administrative regions, depicted in the map below.



Source: NYSDOT. http://www.dot.ny.gov/regional-offices. Retrieved April 12, 2021.

APPENDIX G – BCI DETAILS FOR THREE STRUCTURES

This appendix contains excerpts from a bridge inspection results observer tool for NYSDOT staff to use to view how the BCI calculation formula and weighting assumptions as well as element treatment thresholds apply to any selected bridge, using the bridge's inspection data from the period 2017-2018. The excerpts are provided to add insight into some of the ways that element condition state data can convert into component and bridge condition indices and into treatment selections.

The bridge summary includes the calculated BCI and, for comparison, the Condition Rating calculated using the Legacy Condition Rating formula, with element inspection data translated into legacy CR ratings.

The elements section of the table highlights elements with light repair, heavy repair, or replacement triggered by color-coding the element name column: yellow for light repair, orange for heavy repair, and red for replacement. The fractions in condition states 3 and 4 are shaded for values of 10% or higher. The element condition index is color-coded to the associated component, with the color key indicated above the column. Weight shading indicates the weight applied to the element condition index in calculating the component condition index; elements with a weight of 100 have darker shading in the weight cell.

The bridges were selected to represent the diverse points highlighted in Exhibit 3-9 in Chapter 3. The first two bridges shown have nearly the same BCI—65.82 and 65.54—but quite different CRs—6.02 and 4.52. The second and third bridges shown have the same CR—4.52—but different BCI's—65.54 and 43.82.

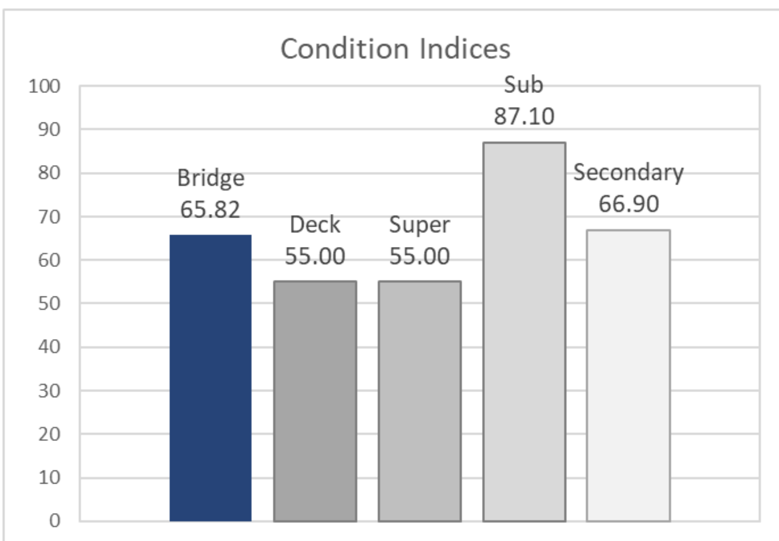
BIN 3309600

BIN	3309600
Type	Stringer/Multi-Beam or Girder
Material	Steel
Deck Area	782
Spans	1
BCI	65.82
CR	6.02
GR	5

Compone	Weight	CCI/BCI
Deck	0.25	55.00
Super	0.35	55.00
Sub	0.3	87.10
Culvert	0	0.00
Secondary	0.1	66.90
BCI		65.82

Comp. Color Code
Deck
Super
Sub
Secondary
Culvert

Element Number	Element Name	Component	Quantity	Fraction by condition state State 1	State 2	State 3	State 4	Element Results Condition Index	Weight Shading
12	Re Concrete Deck	Deck	782	0.0%	100.0%	0.0%	0.0%	55.00	100
107	Steel Opn Girder/Beam	Super	209	0.0%	100.0%	0.0%	0.0%	55.00	100
215	Re Conc Abutment	Sub	23	100.0%	0.0%	0.0%	0.0%	100.00	100
215	Re Conc Abutment	Sub	23	100.0%	0.0%	0.0%	0.0%	100.00	100
220	Re Conc Pile Cap/Ftg	Sub	23	0.0%	0.0%	100.0%	0.0%	20.00	100
510	Wearing Surfaces	Secondary	630	100.0%	0.0%	0.0%	0.0%	100.00	10
515	Steel Protective Coating	Secondary	210	0.0%	47.6%	38.1%	14.3%	33.81	10
851	Abutment pedestal	Sub	5	100.0%	0.0%	0.0%	0.0%	100.00	60
851	Abutment pedestal	Sub	5	100.0%	0.0%	0.0%	0.0%	100.00	60
853	Wingwall	Sub	12	100.0%	0.0%	0.0%	0.0%	100.00	100
853	Wingwall	Sub	12	100.0%	0.0%	0.0%	0.0%	100.00	100



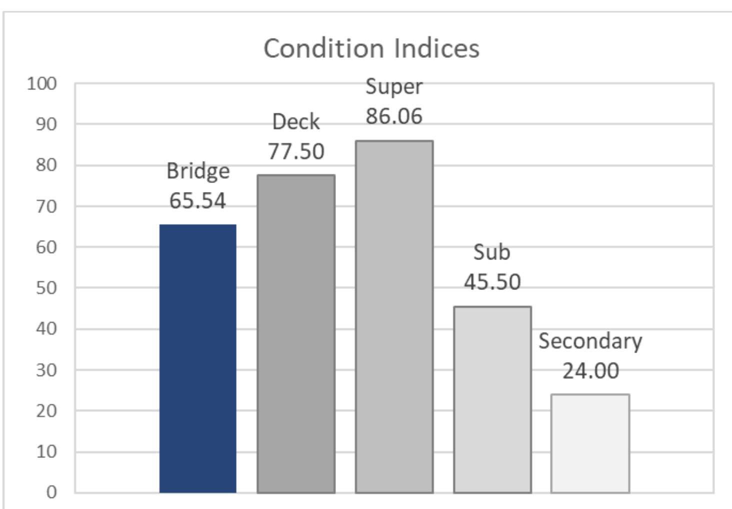
BIN 1063319

BIN	1063319
Type	Stringer/Multi-Beam or Girder
Material	Steel
Deck Area	5,692
Spans	1
BCI	65.54
CR	4.52
GR	6

Compone	Weight	CCI/BCI
Deck	0.25	77.50
Super	0.35	86.06
Sub	0.30	45.50
Culvert	0	0.00
Secondary	0.1	24.00
BCI		65.54

Comp. Color Code
Deck
Super
Sub
Secondary
Culvert

Element Number	Element Name	Component	Quantity	Fraction by condition state State 1	State 2	State 3	State 4	Element Results Condition Index	Weight Shading
12	Re Concrete Deck	Deck	5,773	50.0%	50.0%	0.0%	0.0%	77.50	100
107	Steel Opn Girder/Bear	Super	728	89.8%	10.0%	0.1%	0.0%	95.38	100
215	Re Conc Abutment	Sub	73	0.0%	32.9%	67.1%	0.0%	31.51	100
215	Re Conc Abutment	Sub	74	0.0%	100.0%	0.0%	0.0%	55.00	100
302	Compressn Joint Seal	Secondary	69	0.0%	100.0%	0.0%	0.0%	55.00	10
311	Moveable Bearing	Sub	9	0.0%	0.0%	100.0%	0.0%	20.00	60
313	Fixed Bearing	Sub	9	0.0%	100.0%	0.0%	0.0%	55.00	60
510	Wearing Surfaces	Secondary	5,547	0.0%	100.0%	0.0%	0.0%	55.00	10
515	Steel Protective Coati	Secondary	730	0.0%	0.0%	50.0%	50.0%	10.00	10
515	Steel Protective Coati	Secondary	9	0.0%	0.0%	0.0%	100.0%	0.00	10
515	Steel Protective Coati	Secondary	9	0.0%	0.0%	0.0%	100.0%	0.00	10
830	Secondary members	Super	1	0.0%	100.0%	0.0%	0.0%	55.00	30
851	Abutment pedestal	Sub	9	0.0%	22.2%	77.8%	0.0%	27.78	60
851	Abutment pedestal	Sub	9	0.0%	100.0%	0.0%	0.0%	55.00	60
853	Wingwall	Sub	21	0.0%	100.0%	0.0%	0.0%	55.00	100
853	Wingwall	Sub	27	0.0%	100.0%	0.0%	0.0%	55.00	100



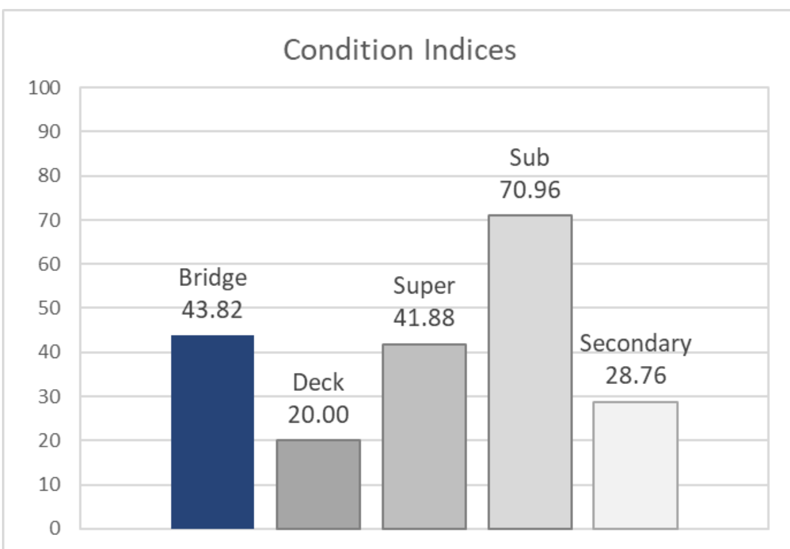
BIN 1009410

BIN	1009410
Type	Stringer/Multi-Beam or Girder
Material	Steel
Deck Area	1,600
Spans	1
BCI	43.82
CR	4.52
GR	5

Componen	Weight	CCI/BCI
Deck	0.25	20.00
Super	0.35	41.88
Sub	0.3	70.96
Culvert	0	0.00
Secondary	0.1	28.76
BCI		43.82

Comp. Color Code
Deck
Super
Sub
Secondary
Culvert

Element Number	Element Name	Component	Quantity	Fraction by condition state State 1	State 2	State 3	State 4	Element Results Condition Index	Weight Shading
12	Re Concrete Deck	Deck	1,470	0.0%	0.0%	100.0%	0.0%	20.00	100
107	Steel Opn Girder/Beam	Super	360	0.0%	62.5%	37.5%	0.0%	41.88	100
215	Re Conc Abutment	Sub	33	69.7%	30.3%	0.0%	0.0%	86.36	100
215	Re Conc Abutment	Sub	33	60.6%	39.4%	0.0%	0.0%	82.27	100
220	Re Conc Pile Cap/Ftg	Sub	30	0.0%	100.0%	0.0%	0.0%	55.00	100
220	Re Conc Pile Cap/Ftg	Sub	4	0.0%	100.0%	0.0%	0.0%	55.00	100
510	Wearing Surfaces	Secondary	1,422	0.0%	60.1%	39.9%	0.0%	41.02	10
515	Steel Protective Coating	Secondary	1,170	0.0%	30.0%	0.0%	70.0%	16.50	10
515	Steel Protective Coating	Secondary	334	0.0%	0.0%	100.0%	0.0%		
851	Abutment pedestal	Sub	8	75.0%	25.0%	0.0%	0.0%	88.75	60
851	Abutment pedestal	Sub	8	50.0%	50.0%	0.0%	0.0%	77.50	60
853	Wingwall	Sub	36	0.0%	100.0%	0.0%	0.0%	55.00	100
853	Wingwall	Sub	36	50.0%	50.0%	0.0%	0.0%	77.50	100



APPENDIX H – WORK TYPES AND TRIGGERS

Exhibit H-1. Work Types Logic for Spans

Item	Element or Component Condition	Elements Included	Work Triggered
1	Abutment, Column, Pier Wall, Pier Cap Culvert, or Foundation Group Replace	202-245	Span Replace
2	Any Superstructure Primary Member Replace	102-162	Superstructure Replace
3	Any Superstructure Primary Member Heavy Repair	102-162	Superstructure Rehab
4	Abutment, Column, Pier Wall, Pier Cap Heavy Repair OR Backwall, Pedestals, Wingwall Replace	202-236 850-853	Substructure Rehab
5	Element in Deck Group Replace	12-65	Deck Replace
6	Steel Protective Coating Replace*	515	Repainting
7	Element in Deck Group Heavy Repair AND Element in Joint Group Replace	12-65 300-306	Deck Rehab
8	Element in Joint Group Replace AND Bearing Replace OR Substructure Element Heavy or Light Repair	300-306 AND 310-316 or 202-240	Vertical Down
9	NO Work types Replace through Vertical Down (brown boxes above) AND Any treatments other than wearing surface replace or paint heavy treatment		General Repairs
10.1	Wearing Surface Replace	510	Wearing Surface Replace
10.2	Steel Protective Coating Heavy Repair?	515	Zone Paint
11	No element requiring treatment?		Cyclical Maintenance **
BR	Bearing Replace ***	310-316	Bearing Replace

See following page for notes to Exhibit H-1.

Notes to Exhibit H-1:
* Paint replace must be on parent element 102-136: primary member or critical substructure element.
**Although shown in this chart, Cyclical Maintenance is not selected as a work type. It is not identified for a bridge until Stage 1B Project Type Selection Logic.
***Bearing Replace is not used in Project Type Selection. It is identified for purposes of effects modeling, as explained in Appendix J.

Exhibit H-2. Table of Element Triggers for Work Types (page 1 of 4)

No.	Element Name	Units	Com-ponent	Span Replace	Super Replace	Super Rehab	Sub Rehab	Deck Replace	Deck Rehab*	Vertical Down^	Wearing Surface	Repaint	Zone Paint	Repaint Parent**	Bearing Replace
12	Re Concrete Deck	sf.	Deck					replace	heavy						
13	Pre Concrete Deck	sf.	Deck					replace	heavy						
15	Flange	sf.	Deck					replace	heavy						
16	Re Conc Top Flange	sf.	Deck					replace	heavy						
28	Grid	sf.	Deck					replace	heavy						
29	Grid	sf.	Deck					replace	heavy						
30	Orthotropic	sf.	Deck					replace	heavy						
31	Timber Deck	sf.	Deck					replace	heavy						
38	Re Concrete Slab	sf.	Deck					replace	heavy						
54	Timber Slab	sf.	Deck					replace	heavy						
60	Other Deck	sf.	Deck					replace	heavy						
65	Other Slab	sf.	Deck					replace	heavy						
102	Steel Clsd Box Gird	lf.	Super		replace	heavy								Y	
104	Pre Clsd Box Girder	lf.	Super		replace	heavy								Y	
105	Re Clsd Box Girder	lf.	Super		replace	heavy								Y	
106	Girder	lf.	Super		replace	heavy								Y	
107	Girder/Beam	lf.	Super		replace	heavy								Y	
109	Girder/Beam	lf.	Super		replace	heavy								Y	
110	Girder/Beam	lf.	Super		replace	heavy								Y	
111	Timber Open Girder	lf.	Super		replace	heavy								Y	
112	Girder/Beam	lf.	Super		replace	heavy								Y	
113	Steel Stringer	lf.	Super		replace	heavy								Y	
115	Pre Conc Stringer	lf.	Super		replace	heavy								Y	
116	Re Conc Stringer	lf.	Super		replace	heavy								Y	
117	Timber Stringer	lf.	Super		replace	heavy								Y	

Exhibit H-2. Table of Element Triggers for Work Types (page 2 of 4)

No.	Element Name	Units	Com-ponent	Span Replace	Super Replace	Super Rehab	Sub Rehab	Deck Replace	Deck Rehab*	Vertical Down^	Wearing Surface	Repaint	Zone Paint	Repaint Parent**	Bearing Replace
118	Other Stringer	lf.	Super		replace	heavy								Y	
120	Steel Truss	lf.	Super		replace	heavy								Y	
135	Timber Truss	lf.	Super		replace	heavy								Y	
136	Other Truss	lf.	Super		replace	heavy								Y	
141	Steel Arch	lf.	Super		replace	heavy								Y	
142	Other Arch	lf.	Super		replace	heavy								Y	
143	Pre Conc Arch	lf.	Super		replace	heavy								Y	
144	Re Conc Arch	lf.	Super		replace	heavy								Y	
145	Masonry Arch	lf.	Super		replace	heavy								Y	
146	Timber Arch	lf.	Super		replace	heavy								Y	
147	Stl Main Cables	lf.	Super		replace	heavy								Y	
148	Sec Steel Cables	ea.	Super		replace	heavy								Y	
149	Otr Secondary Cable	ea.	Super		replace	heavy								Y	
152	Steel Floor Beam	lf.	Super		replace	heavy								Y	
154	Beam	lf.	Super		replace	heavy								Y	
155	Re Conc Floor Beam	lf.	Super		replace	heavy								Y	
156	Timber Floor Beam	lf.	Super		replace	heavy								Y	
157	Other Floor Beam	lf.	Super		replace	heavy								Y	
161	Stl Pin Pin/Han both	ea.	Super		replace	heavy								Y	
162	Stl Gus Plate	ea.	Super		replace	heavy								Y	
202	Steel Column	ea.	Sub	replace			heavy			light				Y	
203	Other Column	ea.	Sub	replace			heavy			light				Y	
204	Pre Conc Column	ea.	Sub	replace			heavy			light				Y	
205	Re Conc Column	ea.	Sub	replace			heavy			light				Y	
206	Tim Col or Pile Ext	ea.	Sub	replace			heavy			light				Y	
207	Stl Tower	lf.	Sub	replace			heavy			light				Y	
208	Timber Trestle	lf.	Sub	replace			heavy			light				Y	
210	Re Conc Pier Wall	lf.	Sub	replace			heavy			NA				Y	
211	Other Pier Wall	lf.	Sub	replace			heavy			NA				Y	
212	Timber Pier Wall	lf.	Sub	replace			heavy			NA				Y	
213	Masonry Pier Wall	lf.	Sub	replace			heavy			NA				Y	

Exhibit H-2. Table of Element Triggers for Work Types (page 3 of 4)

No.	Element Name	Units	Com-ponent	Span Replace	Super Replace	Super Rehab	Sub Rehab	Deck Replace	Deck Rehab*	Vertical Down^	Wearing Surface	Repaint	Zone Paint	Repaint Parent**	Bearing Replace
215	Re Conc Abutment	lf.	Sub	replace			heavy			NA				Y	
216	Timber Abutment	lf.	Sub	replace			heavy			NA				Y	
217	Masonry Abutment	lf.	Sub	replace			heavy			NA				Y	
218	Other Abutments	lf.	Sub	replace			heavy			NA				Y	
219	Stl Abutment	lf.	Sub	replace			heavy			NA				Y	
220	Re Conc Pile Cap/Ftg	lf.	Sub	replace			no heavy			NA				Y	
225	Steel Pile	ea.	Sub	replace			heavy			NA				Y	
226	Pre Conc Pile	ea.	Sub	replace			heavy			NA				Y	
227	Re Conc Pile	ea.	Sub	replace			heavy			NA				Y	
228	Timber Pile	ea.	Sub	replace			heavy			NA				Y	
229	Other Pile	ea.	Sub	replace			heavy			NA				Y	
231	Steel Pier Cap	lf.	Sub	replace			heavy			light				Y	
233	Pre Conc Pier Cap	lf.	Sub	replace			heavy			light				Y	
234	Re Conc Pier Cap	lf.	Sub	replace			heavy			light				Y	
235	Timber Pier Cap	lf.	Sub	replace			heavy			light				Y	
236	Other Pier Cap	lf.	Sub	replace			heavy			light				Y	
240	Steel Culvert	lf.	Culvert	replace											
241	Re Conc Culvert	lf.	Culvert	replace											
242	Timber Culvert	lf.	Culvert	replace											
243	Other Culvert	lf.	Culvert	replace											
244	Masonry Culvert	lf.	Culvert	replace											
245	Pre Concrete Culvert	lf.	Culvert	replace											
300	Strip Seal Exp Joint	lf.	Secondary						replace	replace					
301	Pourable Joint Seal	lf.	Secondary						replace	replace					
302	Seal	lf.	Secondary						replace	replace					
303	Assem Jnt With Seal	lf.	Secondary						replace	replace					
304	Joint	lf.	Secondary						replace	replace					
305	Seal	lf.	Secondary						replace	replace					
306	Other Joint	lf.	Secondary						replace	replace					

Exhibit H-2. Table of Element Treatment Triggers for Work Types (page 4 of 4)

No.	Element Name	Units	Com-ponent	Span Replace	Super Replace	Super Rehab	Sub Rehab	Deck Replace	Deck Rehab*	Vertical Down^	Wearing Surface	Repaint	Zone Paint	Repaint Parent**	Bearing Replace
310	Elastomeric Bearing	ea.	Sub							replace					replace
311	Moveable Bearing	ea.	Sub							replace					replace
312	Enclosed Bearing	ea.	Sub							replace					replace
313	Fixed Bearing	ea.	Sub							replace					replace
314	Pot Bearing	ea.	Sub							replace					replace
315	Disk Bearing	ea.	Sub							replace					replace
316	Other Bearing	ea.	Sub							replace					replace
320	Pre Conc Appr Slab	ea.	Unused												
321	Slab	ea.	Unused												
330	Metal Bridge Railing	lf.	Unused												
331	Railing	lf.	Unused												
332	Timb Bridge Railing	lf.	Unused												
333	Other Bridge Railing	lf.	Unused												
334	Masry Bdge Railing	lf.	Unused												
510	Wearing Surfaces	sf.	Secondary								replace				
515	Coating	sf.	Secondary									replace	heavy		
520	Conc Re Prot Sys	sf.	Unused												
521	Conc Prot Coating	sf.	Unused												
800	Erosion or scour	lf.	Unused												
801	Stream hydraulics	ea.	Unused												
810	Sidewalk	sf.	Unused												
811	Curb	lf.	Unused												
830	Secondary members	ea.	Super												
850	Backwall	lf.	Unused				replace			hvy/NA					
851	Abutment pedestal	ea.	Sub				replace			hvy/NA					
852	Pier pedestal	ea.	Sub				replace			hvy/NA					
853	Wingwall	lf.	Sub				replace								
860	Headwall	lf.	Super												

*Deck Rehab - must have both deck heavy repair and joint replacement triggered.

^Vertical Down - must have both joint replacement and a substructure element (including bearing) needing repair.

**Element 515 in replace must be on one of these parent elements to mark as repainting project (Maintenance Project)

APPENDIX I - ELEMENT TREATMENT EFFECTS

INTRODUCTION

This research project has produced a set of modeling assumptions regarding the effects of light and heavy treatments on the condition of each element after the treatment. These values will be used in the bridge management system to predict future system conditions resulting from applying a candidate project type. The modeling assumptions for treatment effects specify the change in the quantity in each condition state as a result of the treatment.

Some effects modeling assumptions are common to all or nearly all element treatments. One such assumption is that repairs never leave any portion of an element in CS4. At the other extreme, repairs only very seldom affect the portions of an element in Condition State 2. This latter assumption has two rationales. First, NYSDOT does not typically repair the defects of the limited severity that meet the coding guidelines for condition state 2. Second, for some elements and materials coding guidelines severely limit or preclude a repaired area from being rated CS1.

The full set of effects assumptions is presented in table form at the end of this appendix as Exhibit I-7. The remainder of the appendix text presents discussion of the treatment effects assumptions for specific materials and specific types of elements. The discussion includes references to treatment definitions and thresholds determined at the expert elicitation workshop held in June 2019. Complete notes from that workshop are presented in Appendix F.

These modeling assumptions are based on engineering judgement. As NYSDOT gains experience with element inspections it will be possible to refine this starting set of assumptions with data on actual element rating changes that occur following repairs.

CULVERTS

Steel Culvert (240) – The elicitation workshop defined light and heavy treatments and thresholds as follows: Light repair means simply to repair the culvert or to pave the invert. Heavy repair is rehabilitating or sliplining the culvert.

Reinforced Concrete Culvert (241) – The elicitation workshop noted that treatment thresholds for reinforced concrete arches could be applied to reinforced concrete culverts. However, the project team determined that effects assumptions for steel culverts could be applied to concrete culverts. These steel culvert effects are different than effects for concrete arches.

Timber Culvert (242) – Steel culvert thresholds and effects are applied to timber culverts. There are no instances of a timber culvert among NBIS-sized culverts.

Other Culverts (243) – Other culvert materials could include metals such as aluminum and cast iron or plastics. They will be modeled as having the same repair effects as the steel and concrete culverts.

Masonry Culverts (244) – Masonry is an obsolescent culvert construction that is likely to be more expensive to repair than to replace. If a heavy repair threshold is met, the effects are modeled as if there is a replacement; the entire element moves to CS1.

Prestressed Concrete Culvert (245) – There are no light or heavy treatments modeled for prestressed concrete elements, including prestressed concrete culverts.

Exhibit I-1. Treatment Effects for Culverts

Effects on Culverts																
	Light Repair								Heavy Repair							
	From CS 2		From CS 3			From CS4			From CS 2		From CS 3			From CS4		
	to CS1	to CS2	to CS1	to CS2	to CS3	to CS1	to CS2	to CS3	to CS1	to CS2	to CS1	to CS2	to CS3	to CS1	to CS2	to CS3
Steel	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
Reinforced Concrete	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
Timber	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
Other	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
Masonry	No light treatments for masonry culverts								100	0	100	0	0	100	0	0
Prestressed	No light treatments for prestressed concrete								No heavy treatments for prestressed concrete							

Reinforced Concrete Elements

Light treatment of a reinforced concrete element is defined as patching.

Heavy treatment of reinforced concrete can involve replacement of sections or heavy patching. Heavy repairs of a superstructure element are distinguished from light repairs by the need for temporary supports.

AASHTO inspection guidance does not allow for rating any patched portions of a concrete element as CS1. So there will be no movement into CS1 resulting from repairs of reinforced concrete elements. In reality there may be replacement of a section of concrete (particularly in a deck repair), which would return some of the defective area to CS1. Nevertheless, because it is impossible to predict at the modeling level when and where such repairs will occur, the effects modeling remains simplistic and does not account for the possibility of replacing a section.

Exhibit I-2. Treatment Effects for Reinforced Concrete

Effects on Reinforced Concrete Elements																
	Light Repair								Heavy Repair							
	From CS 2		From CS 3			From CS4			From CS 2		From CS 3			From CS4		
	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3
Deck	0	100	0	100	0	NA	NA	NA	0	100	0	100	0	0	100	0
Substructure	0	100	0	100	0	NA	NA	NA	0	100	0	100	0	0	100	0
Super-structure	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20

NA = No heavy treatment. Any quantity in CS 4 triggers at least heavy treatment

Reinforced Concrete Deck Elements - Effects shown for deck elements apply to Reinforced Concrete Deck (12), Reinforced Concrete Top Flange (16), Reinforced Concrete Slab (38) , Other Deck (60), Other Slab (65), Prestressed Concrete Deck and Top Flange (13, 15), and Timber Deck and Slab (31,54).

Reinforced Concrete Substructure Elements - Effects shown for Substructure apply to the following reinforced concrete elements: Columns (205), Pier Wall (210), Abutment (215), Pier Cap (234), Backwall (850), Pedestal (851, 852), and Wingwall (853). Pier walls, abutments, pedestals, and wingwalls have no light treatments defined.

Reinforced Concrete Superstructure Elements - Effects shown for superstructure elements apply to the following reinforced concrete elements: Closed Web/Box Girder (105), Open Girder/Beam (110), Stringer (116), Arch (144), Floor Beam (155). Superstructure repairs are modeled as being less effective than deck and substructure repairs, due to the greater stress on the typically repaired portions of concrete superstructure elements (i.e., the undersides of beams and girders).

Prestressed Concrete Elements

The expert elicitation workshop determined that it is not feasible to repair prestressed concrete. There are no repairs that truly restore capacity to prestressed structural members. Therefore, no light or heavy treatment thresholds were established. In the course of considering treatment effects, the project team determined that in some situations it can be reasonable to perform certain repairs to prestressed decks and approach slabs. These two elements were assigned the same thresholds and treatment effects as reinforced concrete decks and approach slabs.

Steel Elements

Steel Deck Repair Effects - In a *light repair*, the repairs effects are expected to be similar among all steel decks since the initiated defects would be minor to moderate. Under the conditions that would trigger a *heavy repair* a difference in effects among deck types can be expected. Steel Deck with Concrete Filled Grid (Element 29) have the additional protection of the concrete, so an assumption was made that more of the percentage would be restored to a CS2 condition than if the steel grid were open (no concrete) Steel Deck with Open Grid (Element 28). Heavy repairs to Steel Deck Corrugated/Orthotropic/Etc (Element 30) are less effective than other steel deck repairs due to the specialized design.

Steel Superstructure and Substructure Repair Effects - Steel repair effects are based on the principle that the defective area would be repaired by plating, which could restore some of the repair section to CS1. The difference between light repair and heavy repair is in the need for temporary support; the nature of the repair and therefore the modeled effects are the same. CS2 sections would not be targeted for repairs. Some portions might be affected by the plating incidentally, but not to any extent and with any predictability that support including an effect on CS2 quantities in the modeling.

Exhibit I-3. Treatment Effects for Steel Elements

Effects on Steel Elements																		
	Light Repair									Heavy Repair								
	From CS 2		From CS 3			From CS4			From CS 2		From CS 3			From CS4		
	to CS 1	to CS 2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3
Open Grid Steel Deck	0	100	0	90	10	NA	NA	NA	0	100	0	80	20	0	70	30
Concrete Fill Steel Deck	0	100	0	90	10	NA	NA	NA	0	100	0	90	10	0	80	20
Orthotropic Steel Deck	0	100	0	90	10	NA	NA	NA	0	100	0	75	25	0	50	50
Superstructure and Substructure	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0

NA = No heavy treatment. Any quantity in CS4 triggers at least heavy treatment.

TIMBER ELEMENTS

The elicitation workshop did not explicitly address timber elements, with the exception of timber columns. The panelists determined that timber columns should have the same treatment thresholds as reinforced concrete columns. Subsequently, the project team has decided to assign the reinforced concrete thresholds and effects to all corresponding timber elements. Timber Truss (135) and Timber Trestle (208) have no reinforced concrete analog; steel thresholds and effects will be used.

Masonry Elements

The elicitation workshop did not address masonry elements. Masonry elements (arch, pier wall, and abutment) use the thresholds and effects for the analogous reinforced concrete element.

Other Materials

Other Deck (Element 60) and Other Slab (Element 65) use the thresholds and effects for reinforced concrete deck elements.

Other superstructure elements use the thresholds and effects for steel superstructure elements.

Other substructure elements use the thresholds and effects for reinforced concrete substructure elements.

Joints

The elicitation workshop did not address joints.

Light treatment - There is no light repair for joints. A CS2 condition would be debris in the strip seal and could include minor leakage. That would be addressed in cyclical maintenance cleaning, not as a light repair.

Heavy Treatment – In general, heavy repair would be replacing the seal and light patching.

Strip Seal Expansion Joint (300), Assembly Joint with Seal (303) Assembly Joint without Seal (305) - Heavy Repairs would involve the replacement of a section of the joint.

Pourable Joint Seal (301), Compression Joint Seal (302) - A heavy repair would involve simply replacing the joint seal.

Open Expansion Joint (304) - Assumed to have the same results as Reinforced Concrete Deck. Open expansion joints are assumed to be concrete edges with no sealing element to fill the gap.

Other Joint (306) - Other Joint would be replaced rather than repaired because they would not meet current standards.

Exhibit I-4. Treatment Effects for Joints

Effects on Joints																
	Light Repair								Heavy Repair							
	From CS 2		From CS 3			From CS4			From CS 2		From CS 3			From CS4		
	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	To CS 3
Strip Seal	No light repair of joints								0	100	100	0	0	100	0	0
Pourable Seal									0	100	100	0	0	100	0	0
Compression									0	100	100	0	0	100	0	0
Assembly w/ Seal									0	100	100	0	0	100	0	0
Open									0	100	0	100	0	0	100	0
Assembly w/o Seal									0	100	100	0	0	100	0	0
Other									0	100	100	0	0	100	0	0

BEARINGS

Light treatment - The elicitation workshop defined light treatment for bearings as involving cleaning and/or repainting. Light Repair of any bearing except enclosed and fixed bearings would include the cleaning of the steel of the bearing, debris removal, tightening of anchor bolts, etc.

Heavy treatment – Heavy treatment includes anything more than cleaning and repainting, but short of replacing the entire line of bearings (i.e., the entire element). Replacement of any single bearing characterizes the repair as a heavy repair.

Elastomeric, Moveable, and Disk Bearing (Elements 310, 311, 315) – All of these bearing types have the same modeled effects. Repairs on elastomer itself are not likely, but the steel plates can be repaired

Enclosed/Concealed Bearing (Element 312*)* - Light repair of an Enclosed Bearing is assumed to be less effective than repairs of other bearing types due to the enclosed part of the bearing being inaccessible.

Enclosed/Concealed Bearing and Other Bearing (Elements 312 and 316) - Heavy repair of these outdated bearing types is modeled as a replacement by a NYSDOT standard bearing.

Fixed Bearing (Element 313) – Because they are all steel, fixed bearings lend themselves well to repairs. Repair effects for fixed bearings are modeled as higher than for the other types.

Pot Bearing (Element 314) – Pot bearings do not provide accessibility to the elastomer; a heavy repair will return less to CS1 than a repair of an elastomeric bearing. Light repairs for pot bearings would be similar to that of elastomeric bearings.

Exhibit I-5. Treatment Effects for Bearings

Effects on Bearings																
	Light Repair								Heavy Repair							
	From CS 2		From CS 3			From CS4			From CS 2		From CS 3			From CS4		
	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3
Elastomeric	0	100	50	50	0	NA	NA	NA	0	100	50	50	0	25	75	0
Moveable	0	100	50	50	0	NA	NA	NA	0	100	50	50	0	25	75	0
Enclosed	0	100	0	75	25	NA	NA	NA	0	100	100	0	0	100	0	0
Fixed	0	100	80	20	0	NA	NA	NA	0	100	75	25	0	50	50	0
Pot	0	100	50	50	0	NA	NA	NA	0	100	25	75	0	10	90	0
Disk	0	100	50	50	0	NA	NA	NA	0	100	50	50	0	25	75	0
Other	0	100	50	50	0	NA	NA	NA	0	100	100	0	0	100	0	0

NA = No heavy treatment. Any quantity in CS4 triggers at least heavy treatment.

Miscellaneous Other Elements

Steel Protective Coating (515) – There is no light repair of paint. Heavy repair is spot or zone painting.

Erosion or Scour (800) - Light Repair would be the placement of rip rap. Heavy Repair would include underpin, concrete wall, sheet pile, etc. Scour issues are also recorded with a Scour Criticality Rating (NBIS Item 113)

Stream Hydraulics (801) – Light repair would be armoring banks. Heavy repair would include gabions, realignment, etc. Stream hydraulics issues are also recorded with a Hydraulic Vulnerability rating. Hydraulic vulnerability is an alert criterion in Stage 3 project selection and a bridge replacement criterion (when combined with certain component condition ratings) in the Legacy System project selection logic.

Exhibit I-6. Treatment Effects for Paint, Erosion or Scour, and Stream Hydraulics

Miscellaneous Element Effects																
	Light Repair								Heavy Repair							
	From CS 2		From CS 3			From CS4			From CS 2		From CS 3			From CS4		
	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3	to CS1	to CS2	to CS 1	to CS 2	to CS 3	to CS 1	to CS 2	to CS 3
Steel Protective Coating	No light treatments for paint								0	100	90	10	0	80	20	0
Erosion or Scour	0	100	75	25	0	50	50	0	0	100	75	25	0	50	50	0
Stream Hydraulics	0	100	0	100	0	NA	NA	NA	0	100	0	100	0	0	100	0

NA = No heavy treatment. Any quantity in CS4 triggers at least heavy treatment.

Exhibit I-7. Treatment Effects Modeling Assumptions (page 1 of 4)

Element		Light Repair								Heavy Repair							
		From CS 2		From CS 3			From CS 4			From CS 2		From CS 3			From CS 4		
		CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3	CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3
12	Re Concrete Deck	0	100	0	100	0	no light repairs when CS4			0	100	0	100	0	0	100	0
13	Pre Concrete Deck	0	100	0	100	0	no light repairs when CS4			0	100	0	100	0	0	100	0
15	Pre Concrete Top Flange	*no light repairs for Prestressed Concrete*								*no heavy repairs for Prestressed Concrete*							
16	Re Conc Top Flange	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
28	Steel Deck - Open Grid	0	100	0	90	10	*no light repairs when CS4 >0*			0	100	0	80	20	0	70	30
29	Steel Deck - Conc Fill Grid	0	100	0	90	10	*no light repairs when CS4 >0*			0	100	0	90	10	0	80	20
30	Steel Deck - Orthotropic	0	100	0	90	10	*no light repairs when CS4 >0*			0	100	0	75	25	0	50	50
31	Timber Deck	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
38	Re Concrete Slab	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
54	Timber Slab	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
60	Other Deck	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
65	Other Slab	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
102	Steel Clsd Box Gird	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
104	Pre Clsd Box Girder	*no light repairs for Prestressed Concrete*								*no heavy repairs for Prestressed Concrete*							
105	Re Clsd Box Girder	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
106	Othr Clsd Web/Box Girde	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
107	Steel Opn Girder/Beam	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
109	Pre Opn Conc Girder/Bea	*no light repairs for Prestressed Concrete*								*no heavy repairs for PreStressed Concrete*							
110	Re Conc Opn Girder/Bear	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
111	Timber Open Girder	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
112	Other Open Girder/Beam	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
113	Steel Stringer	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
115	Pre Conc Stringer	*no light repairs for Prestressed Concrete*								*no heavy repairs for Prestressed Concrete*							
116	Re Conc Stringer	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
117	Timber Stringer	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
118	Other Stringer	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
120	Steel Truss	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
135	Timber Truss	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
136	Other Truss	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0

Exhibit I-7. Treatment Effects Modeling Assumptions (page 2 of 4)

Element		Light Repair								Heavy Repair							
		From CS 2		From CS 3			From CS 4			From CS 2		From CS 3			From CS 4		
		CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3	CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3
141	Steel Arch	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
142	Other Arch	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
143	Pre Conc Arch	*no light repairs for PreStressed Concrete*								*no heavy repairs for PreStressed Concrete*							
144	Re Conc Arch	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
145	Masonry Arch	0	100	0	90	10	0	80	20	0	100	0	90	10	0	80	20
146	Timber Arch	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
147	Stl Main Cables	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
148	Sec Steel Cables	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
149	Otr Secondary Cable	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
152	Steel Floor Beam	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
154	Prestress Floor Beam	*no light repairs for PreStressed Concrete*								*no heavy repairs for PreStressed Concrete*							
155	Re Conc Floor Beam	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
156	Timber Floor Beam	0	100	0	80	20	0	80	20	0	100	0	90	10	0	80	20
157	Other Floor Beam	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
161	Stl Pin Pin/Han both	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
162	Stl Gus Plate	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
202	Steel Column	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
203	Other Column	0	100	90	10	0	80	20	0	100	0	90	10	0	*replace if CS4 >0*		
204	Pre Conc Column	*no light repairs for PreStressed Concrete*								*no heavy repairs for PreStressed Concrete*							
205	Re Conc Column	0	100	0	100	0	o light repairs when CS4 >			0	100	0	100	0	*replace if CS4 >0*		
206	Tim Col or Pile Ext	0	100	0	100	0	o light repairs when CS4 >			0	100	0	100	0	*replace if CS4 >0*		
207	Stl Tower	0	100	90	10	0	no light repairs when CS4			0	100	90	10	0	*replace if CS4 >0*		
208	Timber Trestle	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
210	Re Conc Pier Wall	*no light repairs for Pier Walls*								0	100	0	100	0	0	100	0
211	Other Pier Wall	*no light repairs for Pier Walls*								0	100	0	100	0	0	100	0
212	Timber Pier Wall	*no light repairs for Pier Walls*								0	100	0	100	0	0	100	0
213	Masonry Pier Wall	*no light repairs for Pier Walls*								0	100	0	90	10	0	80	20

Exhibit I-7. Treatment Effects Modeling Assumptions (page 3 of 4)

Element	Light Repair								Heavy Repair							
	From CS 2		From CS 3			From CS 4			From CS 2		From CS 3			From CS 4		
	CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3	CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3
215 Re Conc Abutment	*no light repairs for Abutments*								0	100	0	100	0	0	100	0
216 Timber Abutment	*no light repairs for Abutments*								0	100	0	100	0	0	100	0
217 Masonry Abutment	*no light repairs for Abutments*								0	100	0	90	10	0	80	20
218 Other Abutments	*no light repairs for Abutments*								0	100	0	100	0	0	100	0
219 Stl Abutment	*no light repairs for Abutments*								0	100	90	10	0	80	20	0
220 Re Conc Pile Cap/Ftg			*no light repairs for Pile Caps*							*no heavy repairs for Pile Caps*						
225 Steel Pile			*no light repairs for Piles*								*no heavy repairs for Piles*					
226 Pre Conc Pile			*no light repairs for Piles*								*no heavy repairs for Piles*					
227 Re Conc Pile			*no light repairs for Piles*								*no heavy repairs for Piles*					
228 Timber Pile			*no light repairs for Piles*								*no heavy repairs for Piles*					
229 Other Pile			*no light repairs for Piles*								*no heavy repairs for Piles*					
231 Steel Pier Cap	0	100	90	10	0	*no light repairs when CS4 >0*			0	100	90	10	0	80	20	0
233 Pre Conc Pier Cap		*no light repairs for PreStressed Concrete*							*no heavy repairs for PreStressed Concrete*							
234 Re Conc Pier Cap	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
235 Timber Pier Cap	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
236 Other Pier Cap	0	100	90	10	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
240 Steel Culvert	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
241 Re Conc Culvert	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
242 Timber Culvert	0	100	0	100	0	0	100	0	0	100	0	100	0	0	100	0
243 Other Culvert		*no light repairs for Other Culverts*								*no heavy repairs for Other Culverts*						
244 Masonry Culvert		*no light repairs for Masonry Culverts*							*no heavy repairs for Masonry Culverts*							
245 Pre Concrete Culvert	*no light repairs for Prestressed Concrete*								*no heavy repairs for Prestressed Concrete*							
300 Strip Seal Exp Joint			*no light repairs for joints*						0	100	100	0	0	100	0	0
301 Pourable Joint Seal			*no light repairs for joints*						0	100	100	0	0	100	0	0
302 Compressn Joint Seal			*no light repairs for joints*						0	100	100	0	0	100	0	0
303 Assem Jnt With Seal			*no light repairs for joints*						0	100	100	0	0	100	0	0
304 Open Expansion Joint			*no light repairs for joints*						0	100	0	100	0	0	100	0
305 Assem Jnt Wthout Seal			*no light repairs for joints*						0	100	100	0	0	100	0	0
306 Other Joint			*no light repairs for joints*						0	100	100	0	0	100	0	0

Exhibit I-7. Treatment Effects Modeling Assumptions (page 4 of 4)

Element		Light Repair								Heavy Repair							
		From CS 2		From CS 3			From CS 4			From CS 2		From CS 3			From CS 4		
		CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3	CS1	CS 2	CS 1	CS 2	CS 3	CS 1	CS 2	CS 3
310	Elastomeric Bearing	0	100	50	50	0	*no light repairs when CS4 >0*			0	100	50	50	0	25	75	0
311	Moveable Bearing	0	100	50	50	0	*no light repairs when CS4 >0*			0	100	50	50	0	25	75	0
312	Enclosed Bearing	0	100	0	75	25	*no light repairs when CS4 >0*			0	100	100	0	0	100	0	0
313	Fixed Bearing	0	100	80	20	0	*no light repairs when CS4 >0*			0	100	75	25	0	50	50	0
314	Pot Bearing	0	100	50	50	0	*no light repairs when CS4 >0*			0	100	25	75	0	10	90	0
315	Disk Bearing	0	100	50	50	0	*no light repairs when CS4 >0*			0	100	50	50	0	25	75	0
316	Other Bearing	0	100	50	50	0	*no light repairs when CS4 >0*			0	100	100	0	0	100	0	0
320	Pre Conc Appr Slab	*no light repairs for approach slabs*								0	100	0	100	0	0	100	0
321	Re Conc Approach Slab	*no light repairs for approach slabs*								0	100	0	100	0	0	100	0
330	Metal Bridge Railing	*no light repairs for railings*								0	100	0	90	10	0	80	20
331	Re Conc Bridge Railing	*no light repairs for railings*								0	100	0	90	10	0	80	20
332	Timb Bridge Railing	*no light repairs for railings*								0	100	100	0	0	100	0	0
333	Other Bridge Railing	*no light repairs for railings*								0	100	100	0	0	100	0	0
334	Masry Bdge Railing	*no light repairs for railings*								0	100	100	0	0	100	0	0
510	Wearing Surfaces	*no light repairs for wearing surfaces*									*no heavy repairs for Wearing Surfaces*						
515	Steel Protective Coating	*no light repairs for paint*								0	100	90	10	0	80	20	0
520	Conc Re Prot Sys	*no thresholds set*								*no treatments or thresholds established*							
521	Conc Prot Coating	*no thresholds set*								*no treatments or thresholds established*							
800	Erosion or scour	0	100	75	25	0	50	50	0	0	100	75	25	0	50	50	0
801	Stream hydraulics	0	100	0	100	0	no light repairs when CS4			0	100	0	100	0	0	100	0
810	Sidewalk	*no light repairs for sidewalk*									*no heavy repairs for Sidewalk*						
811	Curb	*no light repairs for Curb*								*no heavy repairs for Curb*							
830	Secondary members	*no light repairs for secondary members*								0	100	90	10	0	*replace if CS4 >0*		
831	Steel beam end	0	100	90	10	0	80	20	0	0	100	90	10	0	80	20	0
850	Backwall	*no light repairs for backwalls*								0	100	0	100	0	0	100	0
851	Abutment pedestal	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
852	Pier pedestal	0	100	0	100	0	*no light repairs when CS4 >0*			0	100	0	100	0	0	100	0
853	Wingwall		*no light repairs for wingwalls*							0	100	0	100	0	0	100	0
860	Headwall	*no light repairs for headwalls*								0	100	0	90	10	0	80	20

APPENDIX J – WORK TYPE TREATMENT BUNDLES

This research project has produced a set of specifications of which treatments are bundled into each Work Type. This treatment bundling instructs the BMS software which element treatment effects to apply for each of the Work Types that are a part of the Project Type selected by the BMS. The modeling assumptions for the effects of the element treatments is presented in Appendix I. Together, the two sets of modeling assumptions create an action-effectiveness model for the Project Types. Appendix K contains the logic for programming this model into a bridge management database system.

Table J-1 indicates how to model treatments for the element grouping under the Work Type. For example, the treatment bundling rules for the *Superstructure Replace* Work Type instruct the BMS to model that *all* superstructure and deck elements (including ancillary deck elements such as curbs and sidewalks) would be replaced, as well as any protective coatings that were in place on these elements. This means that all the superstructure and deck elements would go from the various percentages in CS2, CS3, or CS4 to 100 percent in CS1.

Rehabilitation Work Types apply the *heavy* treatment effects (shown in Table I-7 in Appendix I) to all elements on the rehabbed component. For example, in a *Superstructure Rehab*, *all* superstructure primary and secondary members have the heavy treatment effects applied, regardless of whether the specific element condition states met any treatment threshold.

In the *General Repairs* Work Type (which is also a Project Type), element treatment effects are applied only to elements that meet the treatment threshold for heavy or light repairs. Replacements are not considered under General Repairs. This threshold-driven approach means that the treatment effects modeling will be span-specific.

Bearing and pedestal element treatment effects are modeled in a unique way. Replacing a bearing is a costly and involved process, from planning and design through execution. If any span's bearing element has a replacement triggered, a bearing replacement should be considered for *all* of the bearings. Further, if all of the bearings are replaced, it makes sense to replace the pedestals in the same project. In this sense a bearing replacement is like a component Work Type. To accomplish this modeling of bearing replacements, a special "work type" for bearing replacement is considered in Stage 1A (Work Type triggering) and Step 1 of Stage 1B (multi-span criteria application). The Work Type does not enter into the Project Type selection; it is simply noted for reference during effects modeling.

If a Bearing Replacement Work Type is not triggered and confirmed by multi-span criteria, then bearing and pedestal treatments (except for bearing replacement) are applied on a case-by-case basis, as their treatment thresholds are crossed.

The effects modeling will apply all of the Work Types named within the Stage 2 Project Type, plus apply the Bearing Replacement "work type" if it was triggered. For example, Project Type 3.1.3.1 is Superstructure Rehab with Substructure Rehab and Repainting. The effects logic will model effects for the element treatment bundles under the columns labeled Superstructure Rehab, Substructure Rehab, and Repainting. Also, if a bearing replacement was triggered, the effects logic will model a replacement of all bearing and pedestal elements.

Bridge Replacement is not shown in the table because the effects are obvious: all elements would be replaced and be reset to CS1. In reality, the new bridge would likely have different elements and element quantities, but this assumption is sufficient for modeling.

Blank cells indicate that the element treatment would not be a part of that that work type. Alternative treatments divided by a slash are applied based on thresholds applied to individual elements.

Minor Rehab B are minor projects to address a few isolated elements, when higher level rehabs are not triggered. Repairs under Minor Rehab B are modeled as being done according to the thresholds applied to conditions on each element on each span.

Exhibit J-1. Treatment Bundles for Select Work Types *(page 1 of 2)*

Element Group		Units	Superstructure Replace (2)	Superstructure Rehab (3)	Substructure Rehab (4)	Deck Replace (5)	Deck Rehab (7)	Vertical Down (8)
12-65	Deck Elements	sf.	replace			replace	rehab	
300-306	Joints	lf.	replace	per threshold	per threshold	replace	replace	replace
510	Wearing Surfaces	sf.	replace			replace	replace	
320-321	Approach Slab	ea.	replace			replace	rehab	
330-334	Bridge Railing	lf.	replace			replace	rehab	
810	Sidewalk	sf.	replace			replace	rehab	
811	Curb	lf.	replace			replace	rehab	
310-316	Bearings*	ea.	replace	hvy/lt/none	hvy per cutoff	hvy/lt/none	hvy/lt/none	hvy/lt/none
851-852	Pedestals*	ea.	replace	rpl/hvy/lt/none	repl/hvy/none	repl/hvy/lt/none	repl/hvy/lt/none	hvy/lt/none
102-162	Superstructure Primary		replace	rehab				
830	Superstructure Secondary	ea.	replace	rehab				
860	Headwall	lf.	replace	rehab				
831	Steel beam end	ea.	replace	rehab				
202-236	Substructure Elements				rehab			hvy/lt/none
853	Wingwall	lf.			rehab			hvy/none
850	Backwall	lf.			replace/heavy/ none			hvy/none
240-245	Culvert Elements	lf.			heavy			
515	Steel Protective Coating	sf.	repl w/parent	hvy w parent/null	hvy w parent/null			
520	Concrete Re Prot Sys	sf.	repl w/parent			repl w/parent		
521	Concrete Prot Coating	sf.	repl w/parent			repl w/parent		
800	Erosion or scour	lf.	hvy/lt/none	hvy/lt/none	hvy/lt/none			
801	Stream hydraulics	ea.						

Exhibit J-1. Treatment Bundles for Select Work Types *(page 2 of 2)*

Element Group		Units	Repainting (6)	General Repairs^ (9)	10.1 Wearing Surface Replacement	10.2 Zone Repainting	Bearing Replacement*
12-65	Deck Elements	sf.		Per thresholds			
300-306	Joints	lf.		Per thresholds	rpl/hvy/lt/none		
510	Wearing Surfaces	sf.		Per thresholds	replace		
320-321	Approach Slab	ea.		Per thresholds			
330-334	Bridge Railing	lf.		Per thresholds			
810	Sidewalk	sf.		Per thresholds			
811	Curb	lf.		Per thresholds			
310-316	Bearings*	ea.		Per thresholds			replace
851-852	Pedestals*	ea.		Per thresholds			replace
102-162	Superstructure Primary			Per thresholds			
830	Superstructure Secondary	ea.		Per thresholds			
860	Headwall	lf.		Per thresholds			
831	Steel beam end	ea.		Per thresholds			
202-236	Substructure Elements			Per thresholds			
853	Wingwall	lf.		Per thresholds			
850	Backwall	lf.		Per thresholds			
240-245	Culvert Elements	lf.		Per thresholds			
515	Steel Protective Coating	sf.	replace	Per thresholds		heavy	
520	Concrete Re Prot Sys	sf.		Per thresholds			
521	Concrete Prot Coating	sf.		Per thresholds			
800	Erosion or scour	lf.		Per thresholds			
801	Stream hydraulics	ea.		Per thresholds			

APPENDIX K – SOFTWARE IMPLEMENTATION LOGIC

K.0 Introduction and Overview

This Appendix provides a precise description of the desired calculations discussed in earlier chapters, using the medium of Structured Query Language (SQL). It is intended for use by software developers who wish to build the calculations into a bridge management system or other reports that support business processes needing these calculations. The following functionality is described:

- Computation of the element-based Bridge Condition Index (BCI), including:
  - Element condition indexes
  - Span and component condition indexes
  - Bridge and component condition indexes
- Project type selection, including:
  - Element and span work type selection
  - Bridge and project work type selection
  - Generation of project alerts (additional data that may affect project scoping)
  - Application of selected project work types to elements
  - Estimation of the effects on element conditions

To facilitate efficient use of this documentation, the SQL statements are organized in a manner that closely follows the engineering discussion presented earlier in this report. Software developers can use this Appendix to find precise a description of the logic, and can refer to the earlier chapters to understand the engineering rationale for the logic.

The SQL statements are organized in a way that facilitates understanding, but not necessarily in a way that most efficiently supports a given report or platform. It is assumed that the software developer will tailor the queries to fit each application as the need arises. For example, the developer may wish to remove parts of the queries that are not needed for a given report, may wish to restructure data access to optimize performance for a given database or reporting technology, and may wish to limit queries to the records desired for a given application.

No assumption is made about the business requirements or technical specifications of any software that is to be developed in the future. The SQL statements described here are formatted for Microsoft Access, but the syntax can be modified or restructured to fit any applications and platforms needing these calculations. A Microsoft Access database was provided to the authors by NYSDOT to assist in the development and validation of the logic. The SQL queries presented here were developed and tested on that database, which closely follows the NYSDOT inventory and inspection manuals.

A separate set of Excel spreadsheets were also developed to assist in the engineering discussions during development of the logic. The spreadsheets investigate many alternative approaches. There may be minor differences between these queries and the earlier spreadsheets, especially for steps that were not fully specified in spreadsheet form, or that have changed in subsequent discussions. If any differences are found, the SQL queries presented in this Appendix are meant to be the final word.

Some of the calculations, especially the BCI, are largely table-driven. To support the calculations, tables and columns were added to the NYSDOT Access database to hold necessary parameters. In particular:

- The Elements table was expanded to classify element weights for the BCI, provide condition thresholds for element treatment selection, and store a transition probability matrix to forecast the conditions immediately following a project.
- The Groups and Components tables were added to hold weights used in the BCI calculations.

The software developer will need to ensure that these tables and columns are added to any bridge management database that is meant to support these computations.

If these queries are to be used in Microsoft Access, database performance depends strongly on having indexes built for all the columns used in WHERE clauses (mostly primary and foreign key columns). With appropriate indexes built, all the queries are reasonably speedy in a single-user Access database containing 19,899 bridges. In an enterprise database, however, considerable benefit may obtain for optimizing the queries for the specific platform used.

K.1 Bridge Condition Index

The Bridge Condition Index is a weighted average of element condition state percentages, with weights that vary by type of element, as described in Chapter 3. The weighted average is computed first at the element level, then aggregated to the component, span, or bridge levels. Components are combined using component-level weights, and spans are combined using span length as a weight. The following sections present SQL queries to calculate the BCI at various levels of aggregation.

K.1.01 Element level BCI

At its most detailed level, the element BCI is a weighted average of the percent of an element in each condition state. Condition state 1 always has 100% weight, and state 4 always has 0% weight. In theory the weights for condition states 2 and 3 could vary by element, but in the interest of simplicity it has been decided to give state 2 a uniform weight of 67% and state 3 a weight of 33%. In NYSDOT practice each span of each bridge has its own separate list of elements. The following query reports the element-level BCI by bridge, span, and element.

```
1 SELECT BIN, Span, Element,
2   (100*Quantity_CS1+67*Quantity_CS2+33*Quantity_CS3)
3     /(Quantity_CS1+Quantity_CS2+Quantity_CS3+Quantity_CS4) AS CEV,
4   100.0 AS TEV,
5   100.0*CEV/TEV as BCI
6 FROM AASHTO_BYSPAN
7 ORDER BY BIN, Span, Element
```

In this query CEV (lines 2-3) is Current Element Value, a weighted sum of percent by condition state representing the current condition of the element. TEV (line 4) is Total Element Value, the maximum possible value of CEV. In this simplest case TEV is always 100.0, but at higher levels of aggregation it will represent the maximum weighted value of CEV. The ORDER BY clause in line 7 is not strictly necessary for the calculation but makes the resulting report easier to follow for a human reader.

In the Access database used for development, this query returns 789,329 rows. A WHERE clause could be added if desired to limit the report to a specific bridge, element, or other desired subset of the database.

K.1.02 Span and component BCI

The element-level BCI query is a very detailed report. For most applications, a less detailed presentation is needed. Elements are aggregated to components, and then to spans, using a system of weights to determine how much emphasis to give each element and component. To facilitate a uniform determination of element weights, each element is assigned to a group, where each group represents a set of elements serving a similar structural function and thus having the same weight. Table K-1 lists all of the elements in the NYSDOT database with their classification into groups and components. This information must appear in the Elements table of the database. Table K-2 then shows the group and component weights, which must appear in the Groups and Components tables, respectively. Elements classified as “Unused” are ignored in the BCI calculation.

Table K-1 Classification of elements for the BCI calculation

Element	Group	Component
12 Re Concrete Deck	Deck	Deck
13 Pre Concrete Deck	Deck	Deck
15 Pre Concrete Top Flange	Deck	Deck
16 Re Conc Top Flange	Deck	Deck
28 Steel Deck - Open Grid	Deck	Deck
29 Steel Deck - Conc Fill Grid	Deck	Deck
30 Steel Deck - Orthotropic	Deck	Deck
31 Timber Deck	Deck	Deck
38 Re Concrete Slab	Deck	Deck
54 Timber Slab	Deck	Deck
60 Other Deck	Deck	Deck
65 Other Slab	Deck	Deck
102 Steel Clsd Box Gird	BeamGir	Super
104 Pre Clsd Box Girder	BeamGir	Super
105 Re Clsd Box Girder	BeamGir	Super
106 Othr Clsd Web/Box Girder	BeamGir	Super
107 Steel Opn Girder/Beam	BeamGir	Super
109 Pre Opn Conc Girder/Beam	BeamGir	Super
110 Re Conc Opn Girder/Beam	BeamGir	Super
111 Timber Open Girder	BeamGir	Super
112 Other Open Girder/Beam	BeamGir	Super
113 Steel Stringer	BeamGir	Super
115 Pre Conc Stringer	BeamGir	Super
116 Re Conc Stringer	BeamGir	Super
117 Timber Stringer	BeamGir	Super
118 Other Stringer	BeamGir	Super
120 Steel Truss	ArchTruss	Super
135 Timber Truss	ArchTruss	Super
136 Other Truss	ArchTruss	Super
141 Steel Arch	ArchTruss	Super
142 Other Arch	ArchTruss	Super
143 Pre Conc Arch	ArchTruss	Super
144 Re Conc Arch	ArchTruss	Super
145 Masonry Arch	ArchTruss	Super
146 Timber Arch	ArchTruss	Super
147 Stl Main Cables	MainCbl	Super
148 Sec Steel Cables	SecCbl	Super
149 Otr Secondary Cable	SecCbl	Super
152 Steel Floor Beam	FloorBm	Super
154 Prestress Floor Beam	FloorBm	Super
155 Re Conc Floor Beam	FloorBm	Super
156 Timber Floor Beam	FloorBm	Super
157 Other Floor Beam	FloorBm	Super
161 Stl Pin Pin/Han both	PinHang	Super
162 Stl Gus Plate	Guss	Super
202 Steel Column	Piers	Sub
203 Other Column	Piers	Sub
204 Pre Conc Column	Piers	Sub
205 Re Conc Column	Piers	Sub
206 Tim Col or Pile Ext	Piers	Sub
207 Stl Tower	Towers	Sub
208 Timber Trestle	Piers	Sub
210 Re Conc Pier Wall	Piers	Sub
211 Other Pier Wall	Piers	Sub
212 Timber Pier Wall	Piers	Sub
213 Masonry Pier Wall	Piers	Sub
215 Re Conc Abutment	Abutments	Sub
216 Timber Abutment	Abutments	Sub
217 Masonry Abutment	Abutments	Sub
218 Other Abutments	Abutments	Sub
219 Stl Abutment	Abutments	Sub
220 Re Conc Pile Cap/Ftg	Foundation	Sub
225 Steel Pile	Foundation	Sub
226 Pre Conc Pile	Foundation	Sub
227 Re Conc Pile	Foundation	Sub
228 Timber Pile	Foundation	Sub
229 Other Pile	Foundation	Sub
231 Steel Pier Cap	Piers	Sub
233 Pre Conc Pier Cap	Piers	Sub
234 Re Conc Pier Cap	Piers	Sub
235 Timber Pier Cap	Piers	Sub
236 Other Pier Cap	Piers	Sub
240 Steel Culvert	Barrel	Culvert
241 Re Conc Culvert	Barrel	Culvert
242 Timber Culvert	Barrel	Culvert
243 Other Culvert	Barrel	Culvert
244 Masonry Culvert	Barrel	Culvert
245 Pre Concrete Culvert	Barrel	Culvert
300 Strip Seal Exp Joint	Joint	Secondary
301 Pourable Joint Seal	Joint	Secondary
302 Compressn Joint Seal	Joint	Secondary
303 Assem Jnt With Seal	Joint	Secondary
304 Open Expansion Joint	Joint	Secondary
305 Assem Jnt Wthut Seal	Joint	Secondary
306 Other Joint	Joint	Secondary
310 Elastomeric Bearing	Bearing	Sub
311 Moveable Bearing	Bearing	Sub
312 Enclosed Bearing	Bearing	Sub
313 Fixed Bearing	Bearing	Sub
314 Pot Bearing	Bearing	Sub
315 Disk Bearing	Bearing	Sub
316 Other Bearing	Bearing	Sub
320 Pre Conc Appr Slab	Unused	Unused
321 Re Conc Approach Slab	Unused	Unused
330 Metal Bridge Railing	Unused	Unused
331 Re Conc Bridge Railing	Unused	Unused
332 Timb Bridge Railing	Unused	Unused
333 Other Bridge Railing	Unused	Unused
334 Masry Bdge Railing	Unused	Unused
510 Wearing Surfaces	Wearing	Secondary
515 Steel Protective Coating	Paint	Secondary
520 Conc Re Prot Sys	Unused	Unused
521 Conc Prot Coating	Unused	Unused
800 Erosion or scour	Unused	Unused
801 Stream hydraulics	Unused	Unused
810 Sidewalk	Unused	Unused
811 Curb	Unused	Unused
830 Secondary members	Misc	Super
831 Steel beam end	Unused	Unused
850 Backwall	Unused	Unused
851 Abutment pedestal	Bearing	Sub
852 Pier pedestal	Bearing	Sub
853 Wingwall	Abutments	Sub
860 Headwall	Wall	Super
870 Unknown	Unused	Unused

Table K-2. Group and component weights for the BCI calculation

Group	GroupName	Weight
Abutments	Abutments	100
ArchTruss	Arches, Trusses	225
Barrel	Barrel	100
BeamGir	Beams, Girders	100
Bearing	Bearing	60
Deck	Deck, slab, sidewalk, curb	100
FloorBm	Floorbeam	120
Foundation	Foundation	100
Guss	Gusset	130
Joint	Expansion joint	10
MainCbl	Main Cable	250
Misc	Miscellaneous	30
Paint	Paint, coatings	10
Pedestals*	Pedestals	60
Piers	Piers	125
PinHang	Pin & Hanger	100
SecCbl	Secondary Cable	100
Towers	Towers	225
Unused	Unused	0
Wall	Headwall	20
Wearing	Wearing surface	10

Component	Weight
Culvert	0.90
Deck	0.25
Secondary	0.10
Sub	0.30
Super	0.35

*Pedestals was in the bearings group for BCI calculation, but a separate group was created to facilitate application of treatment selection logic.

The following query reports the BCI by component and span, incorporating these weights.

```
SELECT sc.BIN,sc.Span,
 iif(sum(iif(sc.Component='Deck',1,0))=0,-1,sum(iif(sc.Component='Deck',sc.BCI,0))) AS DkBCI,
 iif(sum(iif(sc.Component='Super',1,0))=0,-1,sum(iif(sc.Component='Super',sc.BCI,0))) AS SpBCI,
 iif(sum(iif(sc.Component='Sub',1,0))=0,-1,sum(iif(sc.Component='Sub',sc.BCI,0))) AS SbBCI,
 iif(sum(iif(sc.Component='Culvert',1,0))=0,-1,sum(iif(sc.Component='Culvert',sc.BCI,0))) AS CvBCI,
 iif(sum(iif(sc.Component='Secondary',1,0))=0,-1,sum(iif(sc.Component='Secondary',sc.BCI,0))) AS ScBCI,
 sum(c.Weight*sc.BCI)/sum(c.Weight) AS BCI
FROM Components AS c,
 (SELECT eb.BIN,eb.Span, eb.Component, sum(eb.CEV)/sum(eb.TEV) AS BCI
  FROM
   (SELECT ei.BIN, ei.Span, ei.Element, e.Component,
    g.Weight
     *(100*ei.Quantity_CS1+66*ei.Quantity_CS2+33*ei.Quantity_CS3)
     /(ei.Quantity_CS1+ei.Quantity_CS2+ei.Quantity_CS3+ei.Quantity_CS4) AS CEV,
    g.Weight AS TEV
   FROM AASHTO_BYSPAN AS ei, Elements AS e, Groups AS g
   WHERE ei.Element=e.Element and e.Group=g.Group
    and (ei.Quantity_CS1+ei.Quantity_CS2+ei.Quantity_CS3+ei.Quantity_CS4)>0
    and e.Component<>'Unused' and e.Group<>'Unused' and g.Weight>0
    and not(e.Group='Paint' and
     (select iif(isnull(ei.[PARENT ELEMENT]),'',pe.Component)
      from Elements pe where pe.Element=ei.[PARENT ELEMENT])
     in ('Secondary','Unused','')
     )
```

```
25      ) AS eb
26      GROUP BY eb.BIN, eb.Span, eb.Component
27    ) AS sc
28  WHERE sc.Component=c.Component
29  GROUP BY sc.BIN, sc.Span
30  ORDER BY sc.BIN, sc.Span
```

This is a nested set of queries that performs three steps:

- Computes the element BCI in subquery eb (lines 11-25).
- Aggregates the result of the eb subquery to the level of components of spans in subquery sc (lines 9-27), applying the element weight as accessed from the Groups table.
- Aggregates the result of subquery sc further to the span level, applying the component weight as accessed from the Components table.

This version of the element BCI query filters out certain elements that should not be included in the higher-level BCI calculations. Specifically:

- Elements classified as Unused, or having weights of 0, are ignored.
- Paint elements that are associated with secondary or unused elements are ignored.

For any of the components that do not occur on a given span, the component BCI is reported as -1 in this query. In particular, culverts usually lack deck elements, and bridges usually lack culvert elements.

K.1.03 Bridge and component BCI

For reports that are intended to report BCI at the bridge level, the spans of each bridge are combined by weighting by span length, which is found in the RC15 table. Other than incorporating span length, the query is very similar to the span and component query presented in the preceding section.

```
SELECT bc.BIN,
 iif(sum(iif(bc.Component='Deck',1,0))=0,-1,sum(iif(bc.Component='Deck',bc.BCI,0))) AS DkBCI,
 iif(sum(iif(bc.Component='Super',1,0))=0,-1,sum(iif(bc.Component='Super',bc.BCI,0))) AS SpBCI,
 iif(sum(iif(bc.Component='Sub',1,0))=0,-1,sum(iif(bc.Component='Sub',bc.BCI,0))) AS SbBCI,
 iif(sum(iif(bc.Component='Culvert',1,0))=0,-1,sum(iif(bc.Component='Culvert',bc.BCI,0))) AS CvBCI,
 iif(sum(iif(bc.Component='Secondary',1,0))=0,-1,sum(iif(bc.Component='Secondary',bc.BCI,0))) AS ScBCI,
 sum(c.Weight*bc.BCI)/sum(c.Weight) AS BCI
FROM Components AS c,
 (SELECT eb.BIN, eb.Component, sum(eb.CEV)/sum(eb.TEV) AS BCI
  FROM
   (SELECT ei.BIN, ei.Span, ei.Element, e.Component,
    g.Weight*s.[SPAN LENGTH (FT)]
     *(100*ei.Quantity_CS1+67*ei.Quantity_CS2+33*ei.Quantity_CS3)
     /(ei.Quantity_CS1+ei.Quantity_CS2+ei.Quantity_CS3+ei.Quantity_CS4) AS CEV,
    g.Weight*s.[SPAN LENGTH (FT)] AS TEV
   FROM AASHTO_BYSPAN AS ei, Elements AS e, Groups AS g, RC15 AS s
   WHERE ei.Element=e.Element and e.Group=g.Group and ei.BIN=s.BIN and ei.Span=s.[SPAN NUMBER]
    and (ei.Quantity_CS1+ei.Quantity_CS2+ei.Quantity_CS3+ei.Quantity_CS4)>0
    and e.Component<>'Unused' and e.Group<>'Unused' and g.Weight>0 and s.[SPAN LENGTH (FT)]>0
    and not(e.Group='Paint' and
```

```
          (select iif(isnull(ei.[PARENT ELEMENT]),'',pe.Component)
            from Elements pe where pe.Element=ei.[PARENT ELEMENT])
          in ('Secondary','Unused','')
          )
      ) AS eb
      GROUP BY eb.BIN, eb.Component
    ) AS bc
WHERE bc.Component=c.Component
GROUP BY bc.BIN
ORDER BY bc.BIN
```

The iif syntax is specific to Microsoft Access and is usually expressed as if..then..else..endif in other SQL languages. Depending on the database platform selected for the future bridge management system, other changes in syntax may be needed.

K.2 Project Type Selection

Similar to the BCI calculation, the project selection logic starts at the element level, then builds up to the span level and then bridge level. Decisions made at each level reflect the combined effect of decisions made at the previous level. The initial stages can select multiple work types on each span or bridge, but then the project selection criteria select just one project type for the bridge. This choice then is applied back to the individual elements to estimate the effect on condition. Figure K-1 shows all the steps.

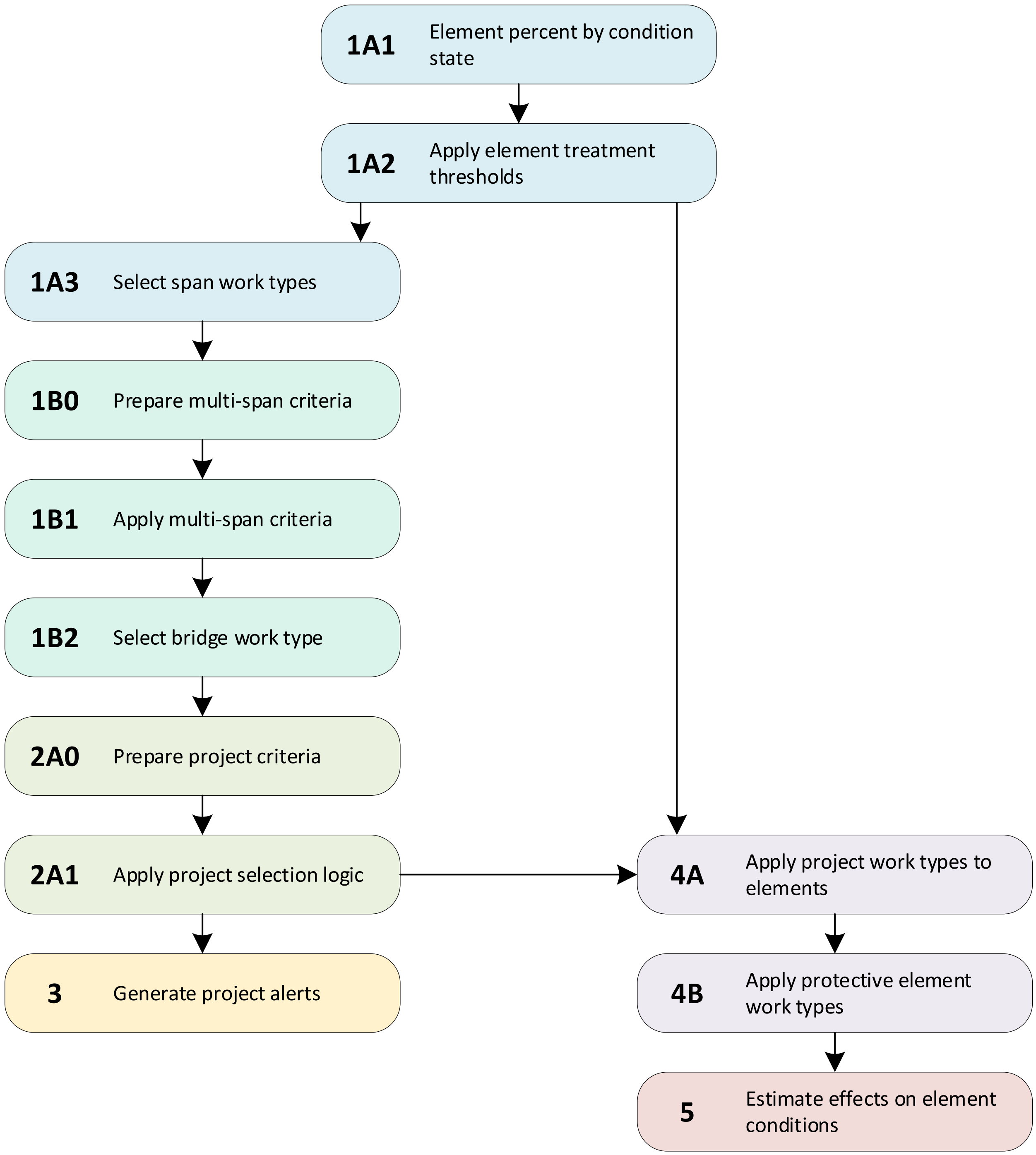


Figure K-1. Map of data flows and logical dependencies in the project selection logic

Logically all the calculations are organized into a sequence of steps, as in Figure K-1 and as presented in Chapter 4. The steps can be combined into SQL queries by nesting within each query (in the FROM clause) the result of the preceding step. Since this is a common and appropriate pattern in database programming, the presentation in this Appendix assumes that applications will use nested queries in this way. However, such queries can become quite complex for humans to follow, and Microsoft Access imposes tight limitations on query complexity. Therefore, the following presentation breaks up the SQL queries into separate steps, as in Figure K-1, for documentation purposes. At certain stages the queries write their results to database tables, but this operation (using the INTO clause) is not strictly necessary in an enterprise application and can be kept or removed at the software developer’s convenience.

K.2.01. Stage 1A, Step1 – Element percent by condition state

This first step, similar to the BCI calculation, converts quantities by condition state into percent, and omits elements having zero as the total quantity.

```
1 SELECT BIN,Span,Element,[Element Suffix] as ElmSuffix,
2  [Parent Element] as Parent,[Parent Suffix] as ParSuffix,
3  Quantity_CS1/(Quantity_CS1+Quantity_CS2+Quantity_CS3+Quantity_CS4)*100 as Pct1,
4  Quantity_CS2/(Quantity_CS1+Quantity_CS2+Quantity_CS3+Quantity_CS4)*100 as Pct2,
5  Quantity_CS3/(Quantity_CS1+Quantity_CS2+Quantity_CS3+Quantity_CS4)*100 as Pct3,
6  Quantity_CS4/(Quantity_CS1+Quantity_CS2+Quantity_CS3+Quantity_CS4)*100 as Pct4
7 FROM AASHTO_BYSPAN
8 WHERE (Quantity_CS1+Quantity_CS2+Quantity_CS3+Quantity_CS4)>0
```

Note that the primary key of the AASHTO_BYSPAN table has six parts, all included in this report (lines 1 and 2). The two suffix columns [Element Suffix] and [Parent Suffix] in this primary key may be null.

K.2.02 Stage 1A, Step 2 – Apply element treatment thresholds

For each element, an initial determination of treatments is made based on the percent by condition state. The Pct2, Pct3, and Pct4 columns produced by Step 1 are compared to a set of corresponding thresholds provided in the Elements table, which is reproduced in Appendix D. Each condition state is evaluated separately, triggering a work type if any of the thresholds are met. The naming convention for the threshold columns is as follows:

- T1 Light treatments
- T2 Heavy treatments
- T3 Replacement treatments
- Min2 Minimum percent in condition state 2 or worse
- Min3 Minimum percent in condition state 3 or worse
- Min4 Minimum percent in condition state 4

So, for example, if an element’s value of Pct3+Pct4 (percent of the element quantity found to be in condition state 3 or worse) equals or exceeds the value in Elements.T2Min3, then a heavy treatment is triggered. A threshold is ignored if its value is non-positive.

The following SQL query performs the evaluation of element treatment thresholds. Note that each element can trigger more than one treatment level in the result set columns T1, T2, and T3. When this happens the highest triggered treatment level is selected for the element, and the result is placed in the TmtLevel column of the SQL result set. The T1, T2, and T3 columns are intermediate results that are not used further in any subsequent steps, so it is not strictly necessary that they be returned by the query.

```
SELECT ei.BIN,ei.Span,ei.Element,ei.ElmSuffix,ei.Parent,ei.ParSuffix,ed.Group,
 ei.Pct1,ei.Pct2,ei.Pct3,ei.Pct4,
 (ed.T1Min2>0 and ei.Pct2+ei.Pct3+ei.Pct4>=ed.T1Min2)
  or (ed.T1Min3>0 and ei.Pct3+ei.Pct4>=ed.T1Min3)
  or (ed.T1Min4>0 and ei.Pct4>=ed.T1Min4) as T1,
 (ed.T2Min2>0 and ei.Pct2+ei.Pct3+ei.Pct4>=ed.T2Min2)
  or (ed.T2Min3>0 and ei.Pct3+ei.Pct4>=ed.T2Min3)
  or (ed.T2Min4>0 and ei.Pct4>=ed.T2Min4) as T2,
 (ed.T3Min2>0 and ei.Pct2+ei.Pct3+ei.Pct4>=ed.T3Min2)
  or (ed.T3Min3>0 and ei.Pct3+ei.Pct4>=ed.T3Min3)
  or (ed.T3Min4>0 and ei.Pct4>=ed.T3Min4) as T3,
 iif(T3,'Replace',iif(T2,'Heavy',iif(T1,'Light',''))) as TmtLevel,
 ed.TmtGroup as TmtGroup
FROM Stage_1A1 ei, Elements ed
WHERE ei.element=ed.element
```

After determination of the TmtLevel, this query also classifies the type of treatment according to the type of element. This is determined in the Elements.TmtGroup column, which is reproduced in Table K-3. As indicated in Figure K-1 above, the TmtLevel and TmtGroup results of this query are subsequently used in determining the span work type, and later when applying project work types back to individual elements.

K.2.03 Stage 1A, Step 3 – Select span work types

In the NYSDOT database each span typically has multiple elements, so the next step is to select a work type for the whole span, based on the identified element treatments. The engineering rationale of this step, discussed in detail in Chapter 4, generally follows the typical decision-making process used by NYSDOT engineers when making an initial determination of the type of work needed on a given span. In most cases this is governed by the highest treatment level identified on individual elements in the TmtLevel column from Step 2.

The following SQL query performs all these calculations. Multiple work types can be generated for each span in this step (lines 2-14 and 25-32), all return values of either 0 or 1, and all are potentially used in the Stage 1B bridge work selection logic.

The columns generated in lines 16-23 are intermediate variables which do not necessarily have to be returned in the result set since they are not used outside this query.

In line 34 of this query the INTO clause writes the results of Stage 1A into a table of the database. This may be helpful in presenting the results and also helps Microsoft Access to reduce the complexity of the subsequent query that uses these results. In an enterprise application using a more powerful database engine, it may be more efficient to omit the INTO clause. Similarly, the ORDER BY clause is helpful for presentation but can be omitted if the results are merely intended to feed into Stage 1B.

Table K-3 Classification of elements to determine the element treatment group

Element	TmtGroup	Element	TmtGroup
12 Re Concrete Deck	Deck	217 Masonry Abutment	SubCrit
13 Pre Concrete Deck	Deck	218 Other Abutments	SubCrit
15 Pre Concrete Top Flange	Deck	219 Stl Abutment	SubCrit
16 Re Conc Top Flange	Deck	220 Re Conc Pile Cap/Ftg	SubCrit
28 Steel Deck - Open Grid	Deck	225 Steel Pile	SubCrit
29 Steel Deck - Conc Fill Grid	Deck	226 Pre Conc Pile	SubCrit
30 Steel Deck - Orthotropic	Deck	227 Re Conc Pile	SubCrit
31 Timber Deck	Deck	228 Timber Pile	SubCrit
38 Re Concrete Slab	Deck	229 Other Pile	SubCrit
54 Timber Slab	Deck	231 Steel Pier Cap	SubCrit
60 Other Deck	Deck	233 Pre Conc Pier Cap	SubCrit
65 Other Slab	Deck	234 Re Conc Pier Cap	SubCrit
102 Steel Clsd Box Gird	Super	235 Timber Pier Cap	SubCrit
104 Pre Clsd Box Girder	Super	236 Other Pier Cap	SubCrit
105 Re Clsd Box Girder	Super	240 Steel Culvert	Culvert
106 Othr Clsd Web/Box Girder	Super	241 Re Conc Culvert	Culvert
107 Steel Opn Girder/Beam	Super	242 Timber Culvert	Culvert
109 Pre Opn Conc Girder/Beam	Super	243 Other Culvert	Culvert
110 Re Conc Opn Girder/Beam	Super	244 Masonry Culvert	Culvert
111 Timber Open Girder	Super	245 Pre Concrete Culvert	Culvert
112 Other Open Girder/Beam	Super	300 Strip Seal Exp Joint	Joint
113 Steel Stringer	Super	301 Pourable Joint Seal	Joint
115 Pre Conc Stringer	Super	302 Compressn Joint Seal	Joint
116 Re Conc Stringer	Super	303 Assem Jnt With Seal	Joint
117 Timber Stringer	Super	304 Open Expansion Joint	Joint
118 Other Stringer	Super	305 Assem Jnt Wthut Seal	Joint
120 Steel Truss	Super	306 Other Joint	Joint
135 Timber Truss	Super	310 Elastomeric Bearing	Bearing
136 Other Truss	Super	311 Moveable Bearing	Bearing
141 Steel Arch	Super	312 Enclosed Bearing	Bearing
142 Other Arch	Super	313 Fixed Bearing	Bearing
143 Pre Conc Arch	Super	314 Pot Bearing	Bearing
144 Re Conc Arch	Super	315 Disk Bearing	Bearing
145 Masonry Arch	Super	316 Other Bearing	Bearing
146 Timber Arch	Super	320 Pre Conc Appr Slab	
147 Stl Main Cables	Super	321 Re Conc Approach Slab	
148 Sec Steel Cables	Super	330 Metal Bridge Railing	
149 Otr Secondary Cable	Super	331 Re Conc Bridge Railing	
152 Steel Floor Beam	Super	332 Timb Bridge Railing	
154 Prestress Floor Beam	Super	333 Other Bridge Railing	
155 Re Conc Floor Beam	Super	334 Masry Bdge Railing	
156 Timber Floor Beam	Super	510 Wearing Surfaces	Wearing
157 Other Floor Beam	Super	515 Steel Protective Coating	Paint
161 Stl Pin Pin/Han both	Super	520 Conc Re Prot Sys	
162 Stl Gus Plate	Super	521 Conc Prot Coating	
202 Steel Column	SubCrit	800 Erosion or scour	
203 Other Column	SubCrit	801 Stream hydraulics	
204 Pre Conc Column	SubCrit	810 Sidewalk	
205 Re Conc Column	SubCrit	811 Curb	
206 Tim Col or Pile Ext	SubCrit	830 Secondary members	
207 Stl Tower	SubCrit	831 Steel beam end	
208 Timber Trestle	SubCrit	850 Backwall	SubOther
210 Re Conc Pier Wall	SubCrit	851 Abutment pedestal	SubOther
211 Other Pier Wall	SubCrit	852 Pier pedestal	SubOther
212 Timber Pier Wall	SubCrit	853 Wingwall	SubOther
213 Masonry Pier Wall	SubCrit	860 Headwall	
215 Re Conc Abutment	SubCrit	870 Unknown	
216 Timber Abutment	SubCrit		

```
SELECT BIN,Span,iif(sum(iif((TmtGroup='SubCrit' and TmtLevel='Replace') or (TmtGroup='Culvert' and
TmtLevel='Replace'),1,0))>0,1,0) AS SpanRepl,
iif(sum(iif(TmtGroup='Super' and TmtLevel='Replace',1,0))>0,1,0) AS SuperRepl,
iif(sum(iif(TmtGroup='Super' and TmtLevel='Heavy',1,0))>0  and SuperRepl=0,1,0) AS SuperRehab,
iif(sum(iif((TmtGroup='SubCrit' and TmtLevel='Heavy') or (TmtGroup='SubOther' and TmtLevel='Replace'),1,0))>0 and
SpanRepl=0,1,0) AS SubRehab,
iif(sum(iif(TmtGroup='Deck' and TmtLevel='Replace',1,0))>0,1,0) AS DeckRepl,
iif(sum(iif(TmtGroup='Paint' and TmtLevel='Replace' and Parent>100 and Parent<237,1,0))>0,1,0) AS PaintProj,
iif(Sum(IIf(TmtGroup='Deck' And TmtLevel='Heavy',1,0))>0,1,0) AS DeckHvy,
iif(Sum(IIf (TmtGroup='Joint' And TmtLevel='Replace',1,0))>0,1,0) AS JointRepl,
iif(DeckHvy=1 And JointRepl=1 and DeckRepl=0,1,0) AS DeckRehab,
iif(sum(iif((TmtGroup='SubCrit' and TmtLevel='Light')  or (TmtGroup='SubOther' and (TmtLevel='Heavy' or
TmtLevel='Light'))or (TmtGroup='Bearing' and (TmtLevel='Replace' or TmtLevel='Heavy' or TmtLevel='Light')),1,0))>0,1,0)
AS SubVertDown,

iif(SubVertDown=1 and JointRepl = 1 and SuperRepl+SuperRehab+SubRehab+DeckRepl+PaintProj+DeckRehab=0,1,0) AS
VertDown,
sum(iif(TmtGroup='Joint' and TmtLevel='Light',1,0)) AS JointLt,
sum(iif(TmtLevel='Light',1,0)) AS SpanLight,

sum(iif(TmtGroup='Paint' and TmtLevel='Heavy',1,0)) AS PaintHvy,
sum(iif(TmtGroup='Joint' and TmtLevel='Heavy',1,0)) AS JointHvy,
sum(iif(TmtLevel='Heavy',1,0))-PaintHvy AS SpanHvy,

sum(iif(TmtGroup='Wearing' and TmtLevel='Replace',1,0)) AS WearRepl,
sum(iif(TmtGroup='Paint' and TmtLevel='Replace' and Parent>100 and Parent<237,1,0)) AS PaintRepl,
sum(iif(TmtLevel='Replace',1,0))-WearRepl-PaintRepl AS SpanReplace,
iif(SpanLight+SpanHvy+SpanReplace>0,0,1) AS Good,
iif(SpanRepl+SuperRepl+SuperRehab+SubRehab+DeckRepl+PaintProj+DeckRehab+VertDown=0 and Good=0,1,0) AS
GenRepair,
iif(WearRepl>0,1,0) AS WearingSfc, iif(PaintHvy>0,1,0) AS ZonePaint, iif(sum(iif(TmtGroup='Bearing' and
TmtLevel='Replace',1,0))>0,1,0) AS BearingRepl

INTO Stage_1A_Result
FROM Stage_1A2
GROUP BY BIN,Span
ORDER BY BIN,Span
```

K.2.04 Stage 1B, Step 0 – Prepare multi-span criteria

This step prepares additional span-level columns that are subsequently used in the Stage 1B multi-span analysis. It serves to isolate certain logic and numerical constants in order to simplify maintenance of the multi-span criteria. Chapter 4 discusses the engineering rationale for these formulas.

```
SELECT s.*,
 iif(b.[Deck Area (Sq Ft)]<100000,1,0) as SmBridge,
 sp.[SPAN LENGTH (FT)] as SpanLen,
 iif(SpanLen>199,1,0) as BigSpan,
 0.05*(SELECT count(*) FROM RC15 t WHERE t.BIN=s.BIN and t.[SPAN LENGTH (FT)]>0) as CntCrit,
 0.05*(SELECT sum(t.[SPAN LENGTH (FT)]) FROM RC15 t WHERE t.BIN=s.BIN) as LenCrit
FROM Stage_1A_Result s, RC15 sp, SUBSETS as b
WHERE s.BIN=sp.BIN and s.Span=sp.[SPAN NUMBER] and s.BIN=b.BIN and sp.[SPAN LENGTH (FT)]>0
```

K.2.05 Stage 1B, Step 1 – Apply multi-span criteria

The multi-span criteria described in Chapter 4 have four separate qualification checks, any one of which can trigger a work type for the bridge. The bridge work types are evaluated separately and any combination of one or more of them can be returned, all with values of either 0 or 1.

```
SELECT BIN,
 iif(sum(SmBridge*SpanRepl)>0 or sum(BigSpan*SpanRepl)>0 or sum(SpanRepl)>max(CntCrit)
  or sum(SpanLen*SpanRepl)>max(LenCrit),1,0) as BrRepl,
 iif(sum(SmBridge*SuperRepl)>0 or sum(BigSpan*SuperRepl)>0 or sum(SuperRepl)>max(CntCrit)
  or sum(SpanLen*SuperRepl)>max(LenCrit),1,0) as BrSuperRepl,
 iif(sum(SmBridge*SuperRehab)>0 or sum(BigSpan*SuperRehab)>0 or sum(SuperRepl+SuperRehab)>max(CntCrit)
  or sum(SpanLen*(SuperRepl+SuperRehab))>max(LenCrit) and BrSuperRepl=0,1,0) as BrSuperRehab,
 iif(sum(SmBridge*SubRehab)>0 or sum(BigSpan*SubRehab)>0 or sum(SpanRepl+SubRehab)>max(CntCrit)
  or sum(SpanLen*(SpanRepl+SubRehab))>max(LenCrit) and BrRepl=0,1,0) as BrSubRehab,
 iif(sum(SmBridge*DeckRepl)>0 or sum(BigSpan*DeckRepl)>0 or sum(DeckRepl)>max(CntCrit)
  or sum(SpanLen*DeckRepl)>max(LenCrit),1,0) as BrDeckRepl,
 iif(sum(SmBridge*PaintProj)>0 or sum(BigSpan*PaintProj)>0 or sum(PaintProj)>max(CntCrit)
  or sum(SpanLen*PaintProj)>max(LenCrit),1,0) as BrPaintProj,
 iif(sum(SmBridge*DeckRehab)>0 or sum(BigSpan*DeckRehab)>0 or sum(DeckRepl+DeckRehab)>max(CntCrit)
  or sum(SpanLen*(DeckRepl+DeckRehab))>max(LenCrit) and BrDeckRepl=0,1,0) as BrDeckRehab,
 iif(sum(SmBridge*VertDown)>0 or sum(BigSpan*VertDown)>0 or sum(VertDown)>max(CntCrit)
  or sum(SpanLen*VertDown)>max(LenCrit),1,0) as BrVertDown,
 iif(BrRepl+BrSuperRepl+BrSuperRehab+BrSubRehab+BrDeckRepl+BrPaintProj+BrDeckRehab+BrVertDown=0
  and sum(iif(Good=0,1,0)>0),1,0) as BrGenRepair,
 iif(sum(SmBridge*WearingSfc)>0 or sum(BigSpan*WearingSfc)>0 or sum(WearingSfc)>max(CntCrit)
  or sum(SpanLen*WearingSfc)>max(LenCrit),1,0) as BrWearingSfc,
 iif(sum(SmBridge*ZonePaint)>0 or sum(BigSpan*ZonePaint)>0 or sum(ZonePaint)>max(CntCrit)
  or sum(SpanLen*ZonePaint)>max(LenCrit),1,0) as BrZonePaint,
 iif(sum(SmBridge*BearingRepl)>0 or sum(BigSpan*BearingRepl)>0 or sum(BearingRepl)>max(CntCrit)
  or sum(SpanLen*BearingRepl)>max(LenCrit),1,0) as BrBearingRepl
FROM Stage_1B0
GROUP BY BIN
```

The four criteria are as follows:

- If bridge deck area is less than 100,000 sq.ft. (denoted by SmBridge=1), the triggered span work type is considered for the bridge as a whole.
- If any span for which the span work type was triggered has a length greater than 199 ft (denoted by BigSpan=1), the triggered span work type is considered for the bridge as a whole.
- If the number of spans for which the span work type is triggered is at least 5% of the total number of spans on the bridge (denoted by CntCrit), the triggered span work type is considered for the bridge as a whole.
- If the span work type is triggered for spans whose length sums to at least 5% of the total of all span lengths on the bridge (denoted by LenCrit), the triggered span work type is considered for the bridge as a whole.

The expression for each result set column produced by this query checks all four of these criteria and returns the value of 1 if any one or more criteria are met, or 0 otherwise.

K.2.06 Stage 1B, Step 2 – Apply Stage 1 Project Selection Logic

This query combines the separate bridge work types considered as a result of Step 1, to produce a single project type for each bridge. Conceptually this logic is one long 2-level CASE statement, although it is divided up to comply with Microsoft Access limitations on statement complexity. A more powerful database engine used in enterprise applications could implement this logic more efficiently and avoid producing the intermediate variables of BrProj1 and BrProj2. The project types are represented only by their numeric codes in this query, but would likely need to be presented in a more verbose form in reports. The definitions of these numeric codes* are:

1	Bridge replacement
2-1	Super replacement with Substructure Rehab
2-2	Superstructure Replacement
3-1	Super + substructure rehab & deck replace & paint
3-2	Super + substructure rehab & deck replacement
3-3	Super + substructure rehab & deck rehab & paint
3-4	Super + substructure rehab & deck rehab
3-5	Super + substructure rehab & paint
3-6	Super + substructure rehab
3-7	Super rehab & deck replacement & paint
3-8	Super rehab & deck replacement
3-9	Super rehab & deck rehab & paint
3-10	Super rehab & deck rehab
3-11	Super rehab & paint
3-12	Super rehab
4-1	Substructure rehab & deck replacement & paint
4-2	Substructure rehab & deck replacement
4-3	Substructure rehab & deck rehab & paint
4-4	Substructure rehab & deck rehab
4-5	Substructure rehab & paint
4-6	Substructure rehab
5-1	Deck replacement & paint
5-2	Deck replacement
6	Repaint
7	Deck rehab
8	Vertical down
9	General Repairs
99-1	Wearing surface replacement
99-2	Cyclical zone paint
99-3	Cyclical maintenance
99-4	Supermaintenance

* The project type numbering scheme in the report differs from the numbering used in these queries. 2-1 became 2.1 in the Report, 3-1 became 3.1.1.1, and 3-12 became 3.2.3.2, etc. The numbering scheme wasn't updated in the queries to avoid introducing unexpected inconsistencies.

The 99-4 Supermaintenance category is reserved for extremely large bridges and is only generated by Stage 2, which is discussed next.

```
1   SELECT *,
2    iif(BrRepl=1,'1',
3     iif(BrSuperRepl=1 and BrSubRehab=1, '2-1',
4     iif(BrSuperRepl=1, '2-2',
5     iif(BrSuperRehab=1 and BrSubRehab=1 and BrDeckRepl=1 and BrPaintProj=1,'3-1',
6     iif(BrSuperRehab=1 and BrSubRehab=1 and BrDeckRepl=1,'3-2',
7     iif(BrSuperRehab=1 and BrSubRehab=1 and BrDeckRehab=1 and BrPaintProj=1,'3-3',
8     iif(BrSuperRehab=1 and BrSubRehab=1 and BrDeckRehab=1,'3-4',
9     iif(BrSuperRehab=1 and BrSubRehab=1 and BrPaintProj=1,'3-5',
10    iif(BrSuperRehab=1 and BrSubRehab=1,'3-6',
11    iif(BrSuperRehab=1 and BrDeckRepl=1 and BrPaintProj=1,'3-7','')))))))))) as BrProj1,
12   iif(BrProj1<>'',BrProj1,
13    iif(BrSuperRehab=1 and BrDeckRepl=1,'3-8',
14    iif(BrSuperRehab=1 and BrDeckRehab=1 and BrPaintProj=1,'3-9',
15    iif(BrSuperRehab=1 and BrDeckRehab=1,'3-10',
16    iif(BrSuperRehab=1 and BrPaintProj=1,'3-11',
17    iif(BrSuperRehab=1,'3-12',
18    iif(BrSubRehab=1 and BrDeckRepl=1 and BrPaintProj=1,'4-1',
19    iif(BrSubRehab=1 and BrDeckRepl=1,'4-2',
20    iif(BrSubRehab=1 and BrDeckRehab=1 and BrPaintProj=1,'4-3',
21    iif(BrSubRehab=1 and BrDeckRehab=1,'4-4','')))))))))) as BrProj2,
22   iif(BrProj2<>'',BrProj2,
23    iif(BrSubRehab=1 and BrPaintProj=1,'4-5',
24    iif(BrSubRehab=1,'4-6',
25    iif(BrDeckRepl=1 and BrPaintProj=1,'5-1',
26    iif(BrDeckRepl=1,'5-2',
27    iif(BrPaintProj=1,'6',
28    iif(BrDeckRehab=1,'7',
29    iif(BrVertDown=1,'8',
30    iif(BrGenRepair=1,'9',
31    iif(BrWearingSfc=1, '99-1',
32    iif(BrZonePaint=1, '99-2','99-3'))))))))))) as BrProject
33  INTO Stage_1B_Result
34  FROM Stage_1B1
```

The INTO clause in line 33 outputs the results into a table in the database. This could be helpful for presentations and for dealing with Microsoft Access limitations, but might be omitted in an enterprise application if the results are to be fed directly into Stage 2.

K.2.07 Stage 2A, Step 0 – Prepare Stage 2 project criteria

This query adds columns to the results of Stage 1B, to bring in data from other tables that are required for the Stage 2 logic. Chapter 4 discusses these criteria in detail.

```
SELECT b1.*,
 iif(b2.[scour critical code]>='0' and b2.[scour critical code]<='3',1,0) as ScourCrit,
 iif(b3.[Deck Area (Sq Ft)]>270000,1,0) as BigBridge,
 iif((SELECT count(*) FROM RC21 h WHERE h.BIN=b1.BIN
   and h.[type of work] in ('110', '121', '122', '220', '230', '240', '410', '420')
   and h.year>=2019)>0,1,0) as RecentCapProj,
 iif((SELECT count(*) FROM RC15 s WHERE s.BIN=b1.BIN and s.[design type] in ('12','16'))>0,1,0) as JackArch,
 iif(b4.[GTMS - Type] ='19',1,0) as Culvert
FROM Stage_1B_Result b1, RC05 b2, SUBSETS b3, RC02 b4
WHERE b2.BIN=b1.BIN and b3.BIN=b1.BIN and b4.BIN=b1.bin
```

K.2.08 Stage 2A, Step 1 – Apply Stage 2 project selection logic

This query adds two columns to the results of Step 0. It modifies the bridge project selection to consider additional data not derived from the element level, in the Stage2Proj column (lines 2-9). For any changes that it makes to the project selection, it also generates an alert message in the Stage2Alert column (lines 11-18). It stores the final results in a database table (line 19).

```
1  SELECT *,
2   iif(BrProject in ('2-1','3-1','3-2','4-1','4-2'),'1',
3   iif(BrProject>='2-1' and BrProject<='5-2' and ScourCrit, '1',
4   iif(BigBridge,'99-4',
5   iif(BrProject>='2-1' and BrProject<='5-2' and RecentCapProj,'99-3',
6   iif(((BrProject>='3-1' and BrProject<='4-2') or (BrProject in ('5-1','5-2'))) and JackArch,'1',
7   iif((BrProject in ('2-1','2-2')) and Culvert,'1',
8   iif(BrProject>='3-1' and BrProject<='7' and Culvert,'9',
9   BrProject))))))) as Stage2Proj,
10
11  iif(BrProject in ('4-1','4-2'),'Sub rehab and deck or super replace',
12  iif(BrProject>='2-1' and BrProject<='5-2' and ScourCrit, 'Scour critical',
13  iif(BigBridge,'Big bridge',
14  iif(BrProject>='2-1' and BrProject<='5-2' and RecentCapProj,'Recent capital project',
15  iif(((BrProject>='3-1' and BrProject<='4-2') or (BrProject in ('5-1','5-2'))) and JackArch,'Jack arch',
16  iif((BrProject in ('2-1','2-2')) and Culvert,'Culvert replace',
17  iif(BrProject>='3-1' and BrProject<='7' and Culvert,'Culvert minor rehab',
18  ''))))))) as Stage2Alert
19 INTO Stage_2_Result
20 FROM Stage_2A0
```

K.2.09 Stage 3 – Generate project alerts

This query produces an additional set of alerts to draw attention to bridge features that could affect project scoping decisions, but require more human judgment than the preceding steps. The logic does not make any changes to project selection.

```
SELECT s2.*,
 iif(not (RC06.[Posted VC Under (ft)] is null) and RC06.[Posted VC Under (ft)]<=13
  and left(s2.Stage2Proj,1) in ('4','5'),'Underclearance; ','') +
 iif(not (BSA.[Hydraulic Rating] is null) and BSA.[Hydraulic Rating]<'3'
  and left(s2.Stage2Proj,1) in ('2','3','4','5'),'Hydraulics; ','') +
 iif(RC05.[Fracture Critical]='Y'
  and left(s2.Stage2Proj,1) in ('3','4','5'),'Fracture critical; ','') +
 iif((SELECT max(iif(T3,1,0)) FROM Stage_1A2 WHERE Element in (330,331,332,333,334))=1
  and left(s2.Stage2Proj,1) in ('4','7'),'Railings; ','') +
 iif(RC01.[Year Built]<1941
  and left(s2.Stage2Proj,1) in ('2','3','4','5'),'Bridge age; ','') +
 iif(RC02.[GTMS - Type]='05'
  and left(s2.Stage2Proj,1) in ('3','5'),'Adjacent box beams; ','') +
 iif(RC02.[GTMS - Type] in ('09','10')
  and left(s2.Stage2Proj,1) in ('3','4','5'),'Truss superstructure; ','') +
 iif(RC02.[GTMS - Material]='7'
  and left(s2.Stage2Proj,1) in ('2','3','4','5'),'Timber structure; ','') +
 iif(RC12.[AADT]>75000
  and left(s2.Stage2Proj,1) ='7','AADT; ','') +
 iif(RC02.[Deck area (sq ft)]>75000 and RC02.[Deck area (sq ft)]<270000,'Very large bridge; ','') +
 iif(RC01.[Historical Signficance] in ('1','2','3'),'Historical significance; ','') +
 iif(RC07.[NBI Substruct Condition] in ('0','1','2','3','4')
  and left(s2.Stage2Proj,1) in ('2','3','4','5'),'Substructure condition; ','') +
 iif(RC07.[NBI Superstruct Condition] in ('0','1','2','3','4')
  and left(s2.Stage2Proj,1) in ('3','4','5','7'),'Superstructure condition; ','') +
 iif(RC07.[NBI Deck Condition] in ('0','1','2','3','4')
  and left(s2.Stage2Proj,1) in ('3','4','7','9',),'Substructure condition; ','') +
 iif(RC05.[General recommendation] in ('0','1','2','3')
  and left(s2.Stage2Proj,1) in ('2','3','4','5','7','9'),'Substructure condition; ','') +
 iif(RC07.[NBI Substruct Condition] in ('6','7','8','9')
  and left(s2.Stage2Proj,1)='1','Substructure upper threshold; ','') +
 iif(RC07.[NBI Superstruct Condition] in ('6','7','8','9')
  and left(s2.Stage2Proj,1)='2','Superstructure upper threshold; ','') +
 iif(RC07.[NBI Deck Condition] in ('6','7','8','9')
  and left(s2.Stage2Proj,1)='5','Deck upper threshold; ','') +
 iif(RC05.[General recommendation] in ('5','6','7','8','9')
  and left(s2.Stage2Proj,1) in ('1','2'),'General recommendation upper threshold; ','')
 as Stage3Alert
FROM Stage_2_Result s2, RC01, RC02, RC05, RC06, RC07, RC12, BSA
WHERE s2.BIN=RC01.BIN and s2.BIN=RC02.BIN and s2.BIN=RC05.BIN and s2.BIN=RC06.BIN
 and s2.BIN=RC07.BIN and s2.BIN=RC12.BIN and s2.BIN=BSA.BIN
```

Multiple alerts can be generated on a bridge: they are all concatenated together into one long message string. Developers using SQL platforms other than Microsoft Access will want to change the string concatenation operator “+” to conform to the syntax requirements of the desired database engine.

K.2.10 STAGE 4A – APPLY PROJECT WORK TYPES TO ELEMENTS

The choice of project work type at the bridge level may lead to changes in the treatment level that is selected for individual elements on the bridge. This SQL query consists of a nested set of if..then..else logic that implements the work type treatment logic table presented in Chapter 4. It considers the element and treatment level identified for each element in Stage 1A Step 2, and modifies it according to the category of bridge work selected in Stage 2A Step 1. The Stage4Tmt column produced by this logic can have the values Replace, Rehab, Heavy, Light, or empty string (signifying no treatment).

```
SELECT e.BIN,e.Span,e.Element,e.ElmSuffix,e.Parent,e.ParSuffix,e.Pct1,e.Pct2,e.Pct3,e.Pct4,
 e.TmtLevel,e.TmtGroup,b.Stage2Proj,b.BrBearingRepl,
 iif(left(b.Stage2Proj,2)='99',99,cint(left(b.Stage2Proj,1))) as Cat,
 iif(Cat=1,'Replace',
 iif(e.Element>=12 and e.Element<100,
   iif(Cat in (2,5) or b.Stage2Proj in ('3-1','3-2','3-5','3-6','4-1','4-2'), 'Replace',
  iif(Cat=7 or b.Stage2Proj in ('3-3','3-4','3-9','3-10','4-3','4-4'), 'Rehab',
  iif(Cat=9,e.TmtLevel,''))),
 iif(e.element>=300 and e.Element<310,
  iif(Cat in (2,5,7,8) or b.Stage2Proj in ('3-1','3-2','3-7','3-8','3-9','3-10','4-1','4-2','4-3','4-4'),'Replace',
  iif(b.Stage2Proj in ('3-5','3-6','3-11','3-12','4-5','4-6','9','99-1'),e.TmtLevel)),
 iif(e.element=510,
  iif(Cat in (2,5,7) or b.Stage2Proj in ('3-1','3-2','3-3','3-4','3-7','3-8','3-9','3-10','4-1','4-2','4-3','4-4','99-1'),'Replace',
  iif(Cat=9,e.TmtLevel,'')),
 iif((e.Element>=320 and e.Element<340) or e.Element in (810,811),
  iif(Cat in (2,5) or b.Stage2Proj in ('3-1','3-2','3-7','3-8','4-1','4-2'),'Replace',
  iif(b.Stage2Proj in ('3-3','3-4','3-9','3-10','4-3','4-4','7'),'Rehab',
  iif(Cat=9,e.TmtLevel,''))),
 iif((e.Element>=310 and e.Element<320) or e.Element in (851,852),
  iif(Cat=2 or BrBearingRepl=1,'Replace',
  iif(Cat in (3,4,5,7,8,9),e.TmtLevel,'')),
 iif((e.Element>=100 and e.Element<200) or e.Element=830,
  iif(Cat=2,'Replace',
  iif(Cat=3,'Rehab',
  iif(Cat=9,e.TmtLevel,''))),
 iif(e.Element in (860,831),
  iif(Cat=2,'Replace',
  iif(Cat=3,'Rehab',
  iif(Cat=9,e.TmtLevel,''))),
 '')))))))) AS S4T1,

iif(S4T1<>'',S4T1,
 iif((e.Element>=200 and e.Element<240) or e.Element=853 or e.Element=850,
  iif(Cat=4 or b.Stage2Proj in ('3-1','3-2','3-3','3-4','3-5','3-6'),'Rehab',
```

```
35      iif(Cat in (8,9),e.TmtLevel,'')),
36    iif(e.Element>=240 and e.Element<250,
37      iif(Cat=4 or b.Stage2Proj in ('3-1','3-2','3-3','3-4','3-5','3-6'),'Heavy',
38      iif(Cat=9,e.TmtLevel,'')),
39    iif(e.Element=515,
40      iif(Cat=6,'Replace',
41      iif(Cat=9,e.TmtLevel,
42      iif(b.Stage2Proj='99-2','Heavy',''))),
43    iif(e.Element in (520,521),
44      iif(Cat=9,e.TmtLevel,''),
45    iif(e.Element=800,
46      iif(Cat in (2,3,4,9),e.TmtLevel,''),
47    iif(e.Element=801,
48      iif(Cat=9,e.TmtLevel,''),
49    '')))))))) AS Stage4Tmt
50
51  INTO Stage_4_Result
52  FROM Stage_1A2 e, Stage_2_Result b
53  WHERE e.BIN=b.BIN
54  ORDER BY e.BIN,e.Span,e.Element,e.Parent
```

This query is divided into two parts, connected by the intermediate variable S4T1 (lines 29 and 31). This is merely to overcome Microsoft Access limitations on query complexity. The two parts can be rejoined if using a more powerful database engine. In addition to the modified treatment level, this query also carries forward from Stage 1A Step 2 certain columns that are needed for the Stage 5 calculation of predicted conditions after the treatment.

K.2.11 STAGE 4B – APPLY PROTECTIVE ELEMENT WORK TYPES

Elements 515, 520, and 521 are coating elements whose work type depends in part on the work type assigned to their corresponding substrate elements. Stage 4A handles the substrate, and Stage 4B updates this result for the protective elements. An alternative approach might be to suppress these elements in stage 4A and then insert them in stage 4B. Microsoft Access requires the three statements in this Stage 4B query to be executed separately, but other database engines would combine them into a script. In Access these will run faster if Stage_4_Result is indexed on BIN,Span, Element, ElmSuffix, Parent, ParSuffix, and Stage4Tmt.

```
UPDATE Stage_4_Result as Coating
 SET Stage4Tmt='Replace'
 WHERE Coating.Stage4Tmt='' and Coating.Element=515 and Coating.Cat=2 and exists(
  SELECT * FROM Stage_4_Result Substrate
   WHERE Substrate.BIN=Coating.BIN and Substrate.Span=Coating.Span
    and Substrate.Element=Coating.Parent and Substrate.ElmSuffix=Coating.ParSuffix
    and Substrate.Stage4Tmt='Replace');

UPDATE Stage_4_Result as Coating
 SET Stage4Tmt='Heavy'
 WHERE Coating.Stage4Tmt='' and Coating.Element=515 and Coating.Cat in (3,4) and exists(
  SELECT * FROM Stage_4_Result Substrate
   WHERE Substrate.BIN=Coating.BIN and Substrate.Span=Coating.Span
    and Substrate.Element=Coating.Parent and Substrate.ElmSuffix=Coating.ParSuffix
    and Substrate.Stage4Tmt='Heavy');

UPDATE Stage_4_Result as Coating
 SET Stage4Tmt='Replace'
 WHERE Coating.Stage4Tmt='' and Coating.Element in (520,521) and Coating.Cat in (2,5) and exists(
  SELECT * FROM Stage_4_Result Substrate
   WHERE Substrate.BIN=Coating.BIN and Substrate.Span=Coating.Span
    and Substrate.Element=Coating.Parent and Substrate.ElmSuffix=Coating.ParSuffix
    and Substrate.Stage4Tmt='Replace');
```

K.2.12 Stage 5 – Estimate effects on element conditions

The final stage of the process forecasts element condition immediately after completion of the project, using the logic and table-driven process discussed in Chapter 4. This calculation starts with a vector of condition states before the work is done, and multiplies it by a transition probability matrix stored in the Elements table (reproduced in Appendix I). The result is a vector of condition states just after the treatment. The naming convention for the transition probability columns is as follows:

- T1 Light treatments
- T2 Heavy treatments
- Effxy Percent of state x that is moved to state y

For example, T1Eff42 is the percent of state 4 that is moved to state 2 if a light treatment is applied. If no treatment is performed, condition remains unchanged. If replacement is performed, 100% of the element is moved to condition state 1. It is assumed that none of the treatments produce a decline in condition, so no columns are provided in the Elements table for transitions where state y is worse than state x.

```
1 SELECT e.BIN,e.Span,e.Element,e.ElmSuffix,e.Parent,e.ParSuffix,
2   e.Pct1,e.Pct2,e.Pct3,e.Pct4,e.TmtLevel,e.Stage4Tmt,
3 IIf(e.Stage4Tmt='Replace' Or (e.Stage4Tmt='Rehab' And e.TmtLevel='Replace'),100,
4   IIf(e.Stage4Tmt='Rehab' Or e.Stage4Tmt='Heavy',e.Pct1+(e.Pct2*ed.T2Eff21+e.Pct3*ed.T2Eff31+e.Pct4*ed.T2Eff41)/100,
5   IIf(e.Stage4Tmt='Light',e.Pct1+(e.Pct2*ed.T1Eff21+e.Pct3*ed.T1Eff31+e.Pct4*ed.T1Eff41)/100,e.Pct1))) AS NewPct1,
6 IIf(e.Stage4Tmt='Replace' Or (e.Stage4Tmt='Rehab' And e.TmtLevel='Replace'),0,
7    IIf(e.Stage4Tmt='Rehab' Or e.Stage4Tmt='Heavy',e.Pct2+(e.Pct3*ed.T2Eff32+ e.Pct4*ed.T2Eff42-e.Pct2*ed.T2Eff21)/100,
8    IIf(e.Stage4Tmt='Light',e.Pct2+(e.Pct3*ed.T1Eff32+e.Pct4*ed.T1Eff42-e.Pct2*ed.T1Eff21 )/100,e.Pct2))) AS NewPct2,
9 IIf(e.Stage4Tmt='Replace' Or (e.Stage4Tmt='Rehab' And e.TmtLevel='Replace'),0,
10     IIf(e.Stage4Tmt='Rehab' Or e.Stage4Tmt='Heavy',e.Pct3+(e.Pct4*ed.T2Eff43-e.Pct3*ed.T2Eff31- e.Pct3*ed.T2Eff32)/100,
11     IIf(e.Stage4Tmt='Light',e.Pct3+(e.Pct4*ed.T1Eff43 - e.Pct3*ed.T1Eff31- e.Pct3*ed.T1Eff32)/100, e.Pct3))) AS NewPct3,
12 IIf(e.Stage4Tmt='Replace' Or (e.Stage4Tmt='Rehab' And e.TmtLevel='Replace'),0,
13    IIf(e.Stage4Tmt='Rehab' Or e.Stage4Tmt='Heavy',e.Pct4-(e.Pct4*ed.T2Eff41+e.Pct4*ed.T2Eff42+e.Pct4*ed.T2Eff43)/100,
14    IIf(e.Stage4Tmt='Light',e.Pct4-(e.Pct4*ed.T1Eff41+e.Pct4*ed.T1Eff42+e.Pct4*ed.T1Eff43)/100,e.Pct4))) AS NewPct4,
15 NewPct1+NewPct2+NewPct3+NewPct4 AS NewTot
16 FROM Stage_4_Result AS e, Elements AS ed
17 WHERE (((e.Element)=[ed].[Element]));
18 WHERE e.Element=ed.Element
```

The NewTot column (line 27) is merely a checksum to assist with query maintenance. It should always have the value 100.0.