University Transportation Research Center - Region 2

Final Report

Consistency of the New York State Bridge Inspection Program

Performing Organization: City University of New York

September 2013

Sponsor(s):
New York State Department of Transportation (NYSDOT)
University Transportation Research Center - Region 2

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC's three main goals are:

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Consistency of the New York State Bridge Inspection Program

SPR PROJECT # C-07-17
FINAL REPORT

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The New York State Department of Transportation (NYSDOT) maintains an inventory of over 17,000 highway bridges across the state. As per New York State's Uniform Code of Bridge Inspections, all bridges in New York State are inspected biennially, or more often as necessary. Bridge inspectors are required to assign a condition rating for up to 47 structural elements of each bridge, including 25 components of each span of a bridge, in addition to the general components common to all bridges based on visual inspection of these elements. The bridge condition rating scale ranges from 7 to 1, 7 being new and 1 being in failed condition. In addition to this, ratings 8 and 9 are assigned to cases "not applicable" and "condition and/or existence unknown". The objectives of this research have been to (1) conduct a detailed evaluation of the consistency of inspection ratings, and (2) provide recommendations for improvements to bridge inspection procedures and training to improve consistency, whenever possible. A broader outcome of the research has been the development of knowledgebase on factors affecting consistency of bridge ratings. These research objectives have been achieved through a detailed and comprehensive literature review on inspection practices and the NYSDOT bridge inspection program and, development and evaluation of consistency of the bridge inspection ratings through the inspection of 4 selected bridges by 21 inspection teams. Numbers of bridges and inspection teams have been selected to generate statistically sufficient data for the evaluation of consistency of inspection of different bridge elements. A detailed and quantitative evaluation of consistency of inspection ratings of different bridge elements has been carried out through the analysis of inspection data. Results show that the overall consistency of ratings of different elements is more than 90%.</td></tr>
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EXECUTIVE SUMMARY

The New York State Department of Transportation (NYSDOT) maintains an inventory of over 17,000 highway bridges across the state. As per New York State's Uniform Code of Bridge Inspection, all bridges in New York State are inspected biennially, or more often as necessary. Bridge inspectors are required to assign a condition rating for up to 47 structural elements of each bridge, including 25 components of each span of a bridge, in addition to the general components common to all bridges based on visual inspection of these elements. The bridge condition rating scale ranges from 7 to 1, 7 being new and 1 being in failed condition. In addition to this, ratings 8 and 9 are assigned to cases "not applicable" and "condition and/or existence unknown".

The objectives of this research have been to (1) conduct a detailed evaluation of the consistency of inspection ratings, and (2) provide recommendations for improvements to bridge inspection procedures and training to improve consistency, whenever possible. A broader outcome of the research has been the development of a knowledge base on factors affecting consistency of bridge ratings. These research objectives have been achieved through a detailed and comprehensive literature review on inspection practices and the review of the NYSDOT bridge inspection program and development and evaluation of consistency of the bridge inspection ratings through the inspection of 4 selected bridges by 21 inspection teams. Numbers of bridges and inspection teams have been selected to generate statistically sufficient data for the evaluation of consistency of inspection of different bridge elements.

A detailed evaluation of the consistency of inspection ratings of different bridge elements has been carried out through the statistical analysis of inspection data. For bridge elements whose rating is supposed to be between 7 to 1, 96% elements have a consistency of at least 90%. Only seven elements have been identified to have consistency less than 90%. For elements whose rating is supposed to be 8, approximately 97% elements had a consistency of at least 90%, whereas for elements whose rating is supposed to be 9, 91% of the elements were inspected with a consistency of at least 95%. Overall team consistency based on inspection of all elements in the 4 bridges is approximately 98%. These results show that the overall consistency of ratings of different elements is very high.

A qualitative evaluation of all inspection reports has also been carried out to analyze the consistency of report items, such as notes, paragraphs and detection of damages. The results of this analysis indicate that the current quality control procedures being used to review reports for submission allow variation in the content of the reports. However, overall quality of report items, such as notes, photographs, etc., has been found to be very high.

Although overall consistency of the New York State's bridge inspection program is quite high, further improvements in consistency can be achieved by addressing factors contributing to inconsistencies through the modification of the NYSDOT Bridge Inspection Manual and through the training of inspectors during the annual bridge inspector's meeting. Recommendations for improvements in consistency are as follows:

- Some of the inconsistencies are caused because of a few inspectors not being fully familiar with inventory information on the bridge being rated or not rating an element based on overall engineering judgment.

- Addressing the effects of factors such as vegetation, small bearing movements, etc., explicitly in the NYSDOT Bridge Inspection Manual can also be helpful in further improving the consistency of the bridge inspection program.
- A larger variability in NBIS ratings (compared to NYSDOT ratings) can be addressed through (i) more illustrations in the NYSDOT bridge inspection manual on NBIS ratings of selected elements and (ii) increased focus on training of inspectors on NBIS ratings.
- Inconsistencies in elements supposed to be rated 8 or 9 may have been caused because of a few inspectors (i) interpreting the instructions in the bridge inspection manual differently, (ii) not being fully familiar with the bridge inventory information for the bridge being rated or (iii) not following the bridge inspection guidelines as intended. These inconsistencies can be addressed during the annual bridge inspector's meeting through discussions.
- Generally, higher variability has been observed in the inspection of items related to flow conditions or evaluation of scour. Additional training focused on the evaluation of scour may improve consistency in scour assessments, although naturally changing conditions in the field will always present a challenge.
- Clarification in practices and procedures for evaluating and reporting section loss in steel members could also improve the consistency of assessments.
- The consistency of the quality of bridge inspection reports can be improved by clarifying the desired content of inspection reports.

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CHAPTER 1: REVIEW OF BRIDGE INSPECTION PROGRAM

1.1. INTRODUCTION

The New York State Department of Transportation (NYSDOT) maintains an inventory of over 17,000 highway bridges across the state. As per New York State's Uniform Code of Bridge Inspections, all bridges in New York State are inspected biennially, or more often as necessary. Bridge inspectors are required to assign a condition rating for up to 47 structural elements of each bridge, including 25 components of each span of a bridge, in addition to the general components common to all bridges based on visual inspection of these elements. The bridge condition rating scale ranges from 7 to 1, 7 being new and 1 being in failed condition. In addition to this, ratings 8 and 9 are assigned to cases "not applicable" and "condition and/or existence unknown". The objectives of this research have been to (1) conduct a detailed evaluation of the consistency of inspection ratings, and (2) provide recommendations for improvements to bridge inspection procedures and training to improve consistency, whenever possible. A broader outcome of the research has been the development of knowledgebase on factors affecting consistency of bridge ratings. This chapter presents outcome of an extensive literature review that are pertinent to the bridge inspection program of NYSDOT. The focus of the review has been on the bridge inspection practices nationwide, identified gaps and needs in the area of bridge inspection, reliability and consistency concerns with the visual inspection program and quality control (QC) and quality assurance (QA) of bridge inspections nationwide and in European counties.

1.2. NATIONAL BRIDGE INSPECTION STANDARDS

Following the collapse of the Silver Bridge in 1967, the United States Congress passed the Federal Highway Act of 1968, which led to the creation and implementation of the National Bridge Inspection Standards (NBIS). These standards define the Federal requirements for publically owned highway bridge inspections in the Code of Federal Regulations, Title 23, Part 650, Subpart C [CFR (2004)]. These standards establish requirements for inspection procedures, inspection frequency, personnel qualifications, inspection reports, and inventories [FHWA (1988)]. The standards also delineate five different types of inspections: routine, in-depth, interim, damage, and inventory. These different types of inspection are implemented based on the purpose of the inspection and the condition (age, traffic conditions, and known deficiencies) of the bridge [Alampalli and Jalinoos (2009)]. The maximum interval for inspections is typically 24 months. However, under certain circumstances, this interval may be increased to 48 months with FHWA approval [FHWA (1988)]. The first full biennial inspection cycle began in 1973, and continues to the present day.

In 1988, the NBIS were revised to allow states to vary the inspection frequency of their bridges. The frequency of routine inspections was allowed to be extended by individual States from 24 to 48 months for certain bridges meeting FHWA guidelines [FHWA (1988)]. The most recent revisions made to the NBIS were completed in 2004 and implemented in 2005 [FHWA (2004), Alampalli and Jalinoos (2009)]. These revisions clarify that (i) the department of transportation of a state is responsible for ensuring that the inspections are carried out and (ii) inspection frequencies are described in terms of months. These revisions also include requirements for (i) systematic QC and QA to ensure consistency in inspection results, (ii) periodic refresher training for inspectors and (ii) state-wide procedures to ensure that critical findings are addressed in a timely manner. Existing inspection practices in New York, such as QC/QA procedures described in the bridge inspection manual (BIM), annual inspectors' meetings, and the flagging procedure used for critical finding, are consistent with these revisions. Other states have traditionally had less developed practices to meet these requirements, and are currently developing and documenting practices. In response to audits of the FHWA oversight role in the bridge inspection process, the FHWA has developed 23 metrics for ensuring the compliance of current provisions of the NBIS, including the revisions implemented in 2005. These metrics include the assessment of overall inspection organization, qualifications of inspectors and program managers, scheduling of inspections, and documentation of QC/QA practices. Currently, a number of states are developing approaches for the documentation of inspection practices to comply with oversight metrics.

1.2.1. Condition Ratings

There are several different methodologies currently being utilized for describing the condition of bridge and bridge components/elements. Generally, there are two common rating methodologies used for recording the condition of highway bridges; component-level rating approach that records the overall condition of primary components of a bridge, or element-level rating approach that rates individual elements of a bridge. The component-level rating scheme is described in the Recording and Coding Guide whereas the element-level scheme is described in the Commonly-Recognized Bridge Elements (CoRE) Guide and/or the Bridge Element Inspection Manual, developed by the American Association of State and Highway Transportation Officials (AASHTO) [Jensen and Johnson (2010), AASHTO (1997)]. Although each state is required to submit inspection findings to the FHWA according to the Recording and Coding Guide, which prescribes data format and information to be submitted, the use of element level approach has been becoming increasingly common to meet the needs of states in terms of managing their bridge inventories. Among element-level approaches, there is variation between states implementing the methodology.

Under the NBIS system, each major component of the bridge (superstructure, substructure and deck) receives a single rating to describe its overall condition. The ratings are applied on a scale from 0 to 9, with 9 representing a component in "Excellent" condition, 6 representing a component in "Satisfactory" condition with minor damage, 3 representing a component in "Serious" condition for a bridge with significant deterioration or damage, and 0 representing "Failed" condition [FHWA (1995)]. The rating scale is intended to describe the general condition of a component of the bridge in terms of the severity of damage or deterioration on overall condition of the component. Critical findings or damage requiring urgent action are not explicitly addressed as a separate item in the rating system, but may result in a low overall component rating. This can create some inconsistencies in the methodology, since a localized defect in a component in otherwise good condition may result in a rating that does not describe the overall condition of the component as intended, while in other cases, the result may represent the overall condition but not the localized damage, which may be critical.

The AASHTO Commonly-Recognized Bridge Elements (CoRE) Guide specifies typical elements common to highway bridges for use in element rating systems [Jensen and Johnson (2010), AASHTO (1997)]. Originally published in 1994, a new CoRE guide was approved in 2010 for use in element-level inspection approaches and associated bridge management programs. The CoRE Guides are applied in element level inspection approaches in which bridge elements - for example, steel girders - are individually rated using *condition states*. Using such a scheme, inspection documents the type of damage and the extent to which that damage exists on an individual element of a bridge. For example, when rating steel girders, the inspector is required to provide estimates (in linear feet for a girder) of damage, e.g., corrosion, under an element-level inspection approach.

Under the revised CoRE guide, certain elements are identified as National Bridge Elements (NBE) that are intended to capture the condition of primary structural components so that the inspection is consistent from state to state and the condition of bridge elements can be described on a national basis. Bridge Management Elements (BMEs) are used to describe components such as rails, joints, bearings and coating systems that are typically managed by agencies utilizing bridge management programs. The BMEs are general in nature and are intended to be modified to suit the needs of owners or agencies [Jensen and Johnson (2010)]. The condition of elements is described in four general states: good, fair, poor and serious. Defect or Smart flags are used to either break down deteriorated quantities into specific defects that drive the deterioration of an element, or to identify forms of damage, such as fatigue cracks or severe section loss that may require an urgent action.

In contrast to the element rating system, which describes the extent of damage to an element, but not necessarily its overall effect on the safety or performance of that element, New York State rates bridge elements on a 7 point scale, with 1 representing a totally failed condition, 3 representing serious deterioration or not functioning as originally designed, 5 representing minor deterioration but functioning as originally designed, and 7 representing an element in new condition with no deterioration. The even-numbered ratings (i,e., 2, 4, and 6) are used to shade between odd-numbered ratings (i.e., 4 between 3 and 5). Ratings for various elements within each span of the bridge are determined and then an overall rating is given to various elements in each span. Detailed descriptions of the elements to be rated, as well as example photographs of various condition states, are included in the New York State bridge inspection manual [NYSDOT (1997)]. New York State also utilizes Red, Yellow and Safety flags to identify specific elements of a bridge requiring attention or an urgent action. As such, the flagging system utilizes portions of the NBIS rating methodology (in terms of describing the effects of damage or deterioration on the safety condition of the bridge elements) and portions of the element level approach, because these rating are applied on an element span-by-span level as opposed to the single overall rating for the component provided by the NBIS. Similar to the smart flags used in the element-level approach to identify forms of damage that may be critical, the NYSDOT rating system uses colored flags describing the urgency of actions for certain serious conditions. Hence, the NYDOT inspection approach provides a hybrid of attributes of each system, and is unique in this regard relative to the approach adopted by other bridge owners.

On a national level, the direction of condition rating schemes is heading toward element-level inspections utilizing as few as four condition states, as described in the AASHTO Bridge Element Inspection Manual. In the future, the NBIS may be converted to an element-level inspection scheme, and efforts to support this change are currently underway at the FHWA [Everett (2011)].

1.3. WHITE PAPER ON BRIDGE INSPECTIONS AND RATING

In 2008, an ad-hoc group of members of the Structural Engineering Institute (SEI) of ASCE and AASHTO issued a white paper addressing the practices and standards used across the country to ensure the safety of highway bridges [ASCE (SEI)-AASHTO (2009)].The ad-hoc group included individuals from AASHTO member states, consultants and academia, as well as ex-officio members from AASHTO and the Federal Highway Administration (FHWA). This group concluded that, in general, the current NBIS and programs have adequate policies and procedures in place to ensure public safety. The group also identified areas where the current system could be improved, and identified gaps and needs to improve bridge safety and to ensure consistency and reliability in inspection results nationwide. In ASCE (SEI)-AASHTO (2009), the ad-hoc group divided their findings and recommendations into following ten general categories in terms of gaps and needs:

1. A more rational, risk-based approach for determining appropriate inspection intervals for bridges is needed, as opposed to a set twenty-four month cycle for all bridges. This approach would consider factors such as design, details, materials, age, ADT and loading of specific bridges to determine the interval between inspections.
2. New and more assertive types of Quality Control (QC) / Quality Assurance (QA) programs, such as performance testing of inspectors, could be used to enhance the consistency of inspection practices.
3. The consistency and the effectiveness of inspections nationally could be improved if inspector qualifications were matched to the bridge type, condition, and complexity in a more uniform manner.
4. A bridge inspection manual for nationwide use should be developed with expanded use of photographs, illustrations, and detailed drawings indicating specific deterioration conditions and methods of reporting deterioration.
5. There is a need to have close collaboration between those responsible for maintenance and repair of a bridge, and those responsible for bridge inspection.
6. The load ratings process should be reliable, uniform, and consistent across the states.
7. The development and maintenance of a centralized system for documenting critical deterioration in bridges, as experienced by bridge owners, is needed to support the interchange of information and to provide a resource for bridge owners.
8. There is a need to develop standardized procedures for special inspections involving nondestructive evaluation (NDE) of components such as pins to provide more guidance to bridge owners.
9. Terms such as structurally deficient, functionally obsolete, and fracture critical require accurate definitions in the public arena such that public perception of bridge safety is consistent with the facts.
10. A mechanism should be developed such that critical conditions identified during bridge inspections are addressed in a timely manner.

In ASCE (SEI)-AASHTO (2009), the ad-hoc group has addressed gaps and needs in the policies and practices for highway bridge inspection across the United States. Some of these gaps and needs pertain directly to the quality of bridge inspections, while others are more programmatic in nature. The ad-hoc group's recommendation on the need for reliability-based inspection practices is being addressed through research currently being carried out through the NCHRP 12-82 project [Washer et al (2011)]. Gaps related to a centralized system for documenting critical deterioration, uniform load rating process, interaction between inspection and maintenance personnel, and better defining language describing structurally deficient bridges are outside the current research focus.

In terms of the quality of bridge inspections, the current NYSDOT bridge inspection program has some requirements that exceed the minimum requirements of the NBIS, and as a result there are some gaps or needs identified by the panel that may not be applicable to the NYSDOT's bridge inspection program. For example, Finding 4 above indicates that a manual for nationwide use should be developed with an expanded use of photographs, illustrations and detailed drawings indicating specific deterioration conditions and methods of reporting deterioration. Detailed manuals of this type have been found in other countries and are used as part of the quality program for bridge inspection [Everett et al (2008)]. While there is a need on the national basis for such a manual to ensure uniformity across programs receiving federal aid, New York state already has such a manual, complete with photographs and illustrations, diagrams and specific inspection procedures identifying "what to look for" as well as special emphasis areas. Directions on how to report certain deterioration patterns are included in the manual. Several other states have similar manuals, though these manuals are specific to the state and are usually associated with element-based inspection approaches. While these manuals naturally require periodic revision to adjust for developing or new information and an improved knowledge base, the NYSDOT Bridge Inspection Manual is of the type envisioned by the panel to be developed on a national level to improve the consistency of ratings.

In terms of inspector qualifications, it is noted that the requirements for the inspection team leader in New York are more rigorous than the minimum standards required by the NBIS, including the requirement of registration as a professional engineer. In other states, requirements are typically less, which may be sufficient for certain common bridge types. On the other hand, specialized inspection skills may improve the quality of inspection for unique and unusual bridges, though there is currently no national approach to make this process uniform.

Finding 10 above by the ad-hoc committee recommends the development of mechanisms to ensure that the critical conditions are addressed in a timely manner. Critical findings procedures are required under the current NBIS, and a number of states have been developing or improving their practices to address this need. In New York, a flagging procedure has been in use for many years that identifies safety hazards, prioritizes those hazards in terms of their urgency, and includes reporting and action plans. Such a procedure could be a model for other states to follow in terms of critical bridge inspection findings.

Findings by the ad-hoc committee that are relevant for exploration for the NYSDOT include new and more assertive types of QC/QA. The consistency study carried out in this project is one of the types of QC/QA envisioned by the ad-hoc committee. Following this study, over the longer term, such a process could be implemented as an ongoing activity to meet the need for effective QA. Such a process for QA is currently used successfully in Oklahoma. It should also be noted that the NYSDOT bridge inspection manual includes procedures for QC/QA that are more complete than the procedures utilized commonly on a national basis. Improving QC/QA practices nationwide are found in response to the 2004 changes in the NBIS that required systematic procedures in each state. Additional current activities in New York, which are not unique but only implemented in a limited number of other states, include annual bridge inspectors meeting that brings together inspectors to address programmatic challenges, new and emerging technologies and practices, and areas of programmatic focus. Such activities help address the needs identified by the ad-hoc group.

Finding 9 by the ad-hoc group indicates the need to have specialized procedures for NDE technologies for specific applications. The current NYSDOT inspection manual includes procedures for a limited number of traditional NDE technologies, including magnetic particle inspection (MT) and dye penetrant inspection (PT). This is an area where the inspection manual could be improved to recommend the usage of commonly used techniques, such as chain drag, hammer sounding or ultrasonic thickness measurement approaches.

As a part of the gaps and needs summarized above, the ad-hoc group identified a number of longer-term action items for research and development, including developing more effective manuals, guidelines on the use of new technologies such as NDE, improved QC/QA practices such as performance testing of inspectors and use of control bridges, and developing reliability-based inspection practices.

1.4. RELIABILITY OF VISUAL INSPECTION FOR HIGHWAY BRIDGES

This section provides an overview of the 2001 FHWA report entitled "Reliability of Visual Inspection for Highway Bridges" [Moore et al. (2001), Phares et al (2004)]. This study was the first systematic study on the subject of visual inspections of highway bridges since the inception of the NBIS. Its stated objectives were to assess the overall reliability of both routine and in-depth visual inspections, to investigate the key factors affecting the reliability of these inspections, and to explore the ways in which visual inspection procedures differ between individual States DOTs [Moore et al. (2001)]. The study focused on the reliability of visual inspection as a test method for condition assessment of bridges, as implemented across the federal-aid program. The study did not model a specific bridge inspection program at the state level, which typically includes visual inspection as a tool along with other programmatic elements that may contribute to the effectiveness of a program. Load rating programs, bridge-specific procedures developed through engineering analysis and other factors that are specific to an individual states' overall inspection program effectiveness were not the focus of this study.

The report by Moore et al. (2001) describes results of ten inspection tasks performed by qualified state inspectors on seven typical highway bridges. Inspection tasks included seven tasks that modeled routine inspection procedures, and three tasks that modeled in-depth (hands-on) inspection procedures. The tasks to conduct in-depth inspection procedures typically were limited to a portion of a bridge, for example, hands-on inspection of only 1 bay of a multi-girder steel bridge. Seven test bridges that represented bridges of common and ordinary design were used as test specimens in the study.

Forty-nine inspectors from twenty-five states participated in the study, typically working independently to conduct inspections on seven test bridges. Results of inspector testing were double-blind, such that inspectors were anonymous, and inspectors identifications were not retained. In general, the study consisted of inspectors being tasked to complete an inspection meeting the NBIS requirements. Inspection forms were provided for most of the tasks, such that the inspectors completed the inspection and documented results on standard forms. One task included inspectors completing the inspection and utilizing the forms commonly used in their home state to document results. During this particular task, the inspectors worked together as an inspection team.

Inspectors were not provided with historical data, such as prior inspection reports or detailed inspection procedures or prioritization information. They were provided with general information about each structure and instructions for completing each inspection task. In addition, prior to and following each inspection task, a questionnaire was orally administered to each inspector to ascertain key information about how similar the inspection task assigned was to their normal duties, to test the knowledge of the inspector regarding the bridge being inspected, and to determine the effect of influence such as tiredness or distractions during the tasks. An observer was present during the execution of the task to record information regarding the thoroughness of the inspection, duration of the inspection, and to record general observations regarding the conduct of the tasks and environmental variables.

Factors influencing the inspection results were studied, based on the results of the self-reporting questionnaires, task-specific questionnaires and observations of the conduct of each task. Multivariate correlation studies of inspection factors and inspection results were conducted. Inspector factors such as reported fear of traffic, near-visual acuity, color vision and formal bridge training were recurring in the multivariate equations, though strong direct correlations were not found. Frequently recurring inspection factors included light intensity, structure accessibility and inspector rushed level [Moore et al. (2001)]. There were several factors, such as being a registered Professional Engineer (PE), general education level, and bridge inspection experience, that could logically be expected to influence inspection results, but were found to have minimal correlation. Overall, these multivariate correlation studies did not provide conclusive correlations between the factors studied and the quality of inspection results.

There were twenty separate conclusions from this study. A conclusion of significant relevance to the present study in New York is related to a significant variation in the amount of time that inspector's expected to spend and the time actually spent conducting similar inspection tasks. This conclusion indicated that there was significant variability in the inspection procedures and practices among the states participating in the study. It was also found that there was significant variation in the way routine inspections were conducted, resulting in a variation in the condition rating assigned and the documentation of inspection results. For example, out of nine available condition ratings, on average four to five different condition ratings (with a maximum of six) were assigned to each bridge component. Field notes and photographic documentation also varied significantly.

Statistical analysis of the routine inspection results indicated that only 68 % of the inspection results varied within +/-1 of the average rating assigned [Moore et al. (2001)]. A sample of these results is shown in Figure 1-1. As shown in the Figure 1-1, which documents the NBIS component ratings for the deck, superstructure and substructure for the single-span concrete T-Beam bridge, there was significant variation in the component ratings for this

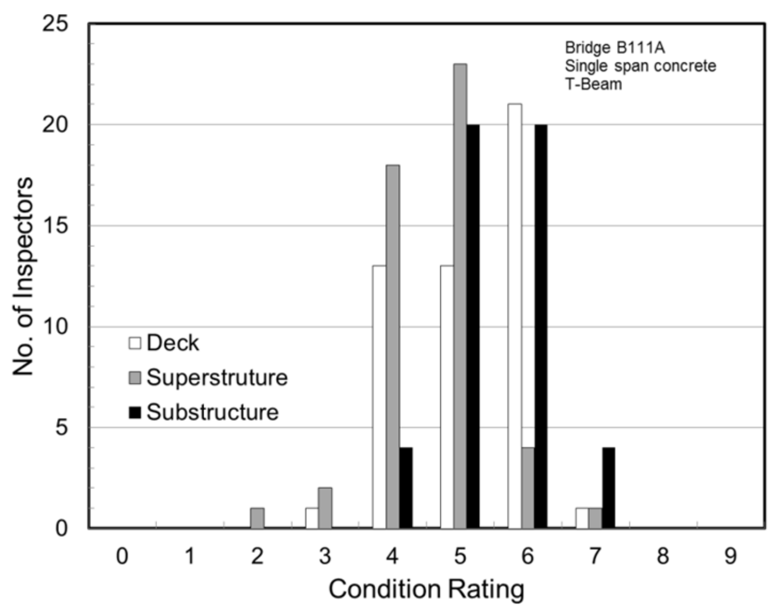


Figure 1-1: Condition Rating Distribution for a Concrete T-Beam Bridge.

simple, common bridge. Rating results varied between 2 (critical) and 7 (good) for the superstructure of the bridge.

Inspection ratings for the test bridges were also compared with those for "control" or reference ratings. The reference ratings were determined by a qualified team of inspectors conducting an in-depth and thorough assessment of the test bridges, and were used for a comparative analysis of inspection results. Conclusion from this analysis indicated that there was a tendency for inspectors to rate components in good condition low (relative to the reference) and rate components in poor condition high. This resulted in a clustering of inspection results in the area of 5 (fair) – 7 (good) on the rating scale.

The study also found that in-depth visual inspections are unlikely to identify defects that the inspections are expected to identify. This includes a number of defects that could be expected to be observed during a thorough in-depth inspection, such as corrosion, missing rivet heads, coating failure and cracks. For one task of the study, which involved hands-on inspection of one bay of a welded plate girder bridge, there were crack indications in the weld at seven locations. Based on the testing results, a detection rate of only 4% was found, with many inspectors not reporting any crack indications in the area inspected. This result is often described as evidence that visual inspection is not capable of detecting cracks in bridges. However, an assessment was done as part of the study to evaluate the thoroughness of the inspections conducted during this study. This evaluation showed that almost all of the cracks reported were found by inspectors conducting a "thorough" in-depth inspection of most or all of the critical areas, as determined from observations of inspector thoroughness. In addition, data from the study indicated that the distance to target, or distance at which the surface is observed by the inspector, was much less for inspectors detecting cracks. Among inspectors correctly identifying cracks, 86% used a flashlight during the inspection, while only 38% of inspectors reporting no crack utilized a flashlight. The crack indications that were included in the study have been photographed, and are included in the report, indicating that these defects were indeed visually observable. In other words, the visual inspection methods were capable of detecting the cracks. However, lack of thoroughness in the inspection procedure, lack of use of lighting (flashlight), and not getting close enough to the surface to observe the crack contributed to missed crack indications. Improved training in crack detection, ensuring adequate access to conduct the inspection, and ensuring correct tools (such as flashlights) may be useful in improving the quality of hands-on inspections.

It was concluded that the NBIS allowed for some significant variation in the results of visual inspections of bridges between states, and that there was both room for and need for improvements in the consistency of visual inspection procedures for bridges. The outcome of this study resulted in modifications to the NBIS – specifically, increased requirements for QA and QC to ensure consistent results across inspection programs in different states, and retraining of inspectors. These modifications were intended to reduce the variation in inspection results across a given bridge inventory, and to increase the training to inspectors with the goal of obtaining more thorough and effective inspection practices.

1.5. RELIABILITY-BASED BRIDGE INSPECTIONS

Recent developments in the bridge inspection area include the development of guidelines for Reliability-based inspections [Washer et al. (2011)]. This research, which addresses finding 1 of the AASHTO ad-hoc group's findings and long-term research needs, has the goal of improving the safety and reliability of bridges by optimizing inspection resources and by focusing resources on the bridges most in the need of inspection. On-going research has developed draft guidelines for implementing this approach to inspection planning. Generally, the intention of the methodology is to identify bridges that have good durability and reliability characteristics, such that the likelihood of the development of damage is low, and inspection needs are less, and bridges where the likelihood of damage progression is high, and therefore inspection needs are greater. The methodology is intended to match the inspection frequency and scope to the needs for the bridge, such that inspection resources are focused where most needed.

The methodology developed is based on well-established approaches in other industries that include risk-based assessments in the planning and execution of inspections [API (2002), ASME (2007), ABS (2003)]. In this approach, the likelihood of certain damage occurrence on a particular bridge and the consequences of that damage are assessed. The likelihood of damage occurrence is assessed through an expert elicitation that considers the bridge design characteristics, environmental and structural loading on the bridge, and its current condition. Information on the deterioration patterns within a given bridge inventory can be used to support the assessment [Agrawal et al. (2008, 2010)]. These data are utilized in developing engineering rationale for determining the likelihood of damage occurrence into one of four categories, ranging from “Remote” to “High.” The consequences of damage occurrence are also assessed through an expert elicitation, considering the criticality of occurrence of different damage modes. This process considers whether a given damage mode occurrence will result is a benign impact on safety and serviceability, or will have more significant impact. The consequence of the damage occurrence is also categorized into one of only four categories, ranging from “Low” to “Severe.” These data are then used to determine an appropriate inspection interval for a given bridge, by simply locating various damage modes that are likely for a bridge within a risk matrix as shown in Figure 1-2. In this matrix, bridges that are likely to have damage and have high consequences in the event of collapse tend to belong in the upper-right corner of the matrix, indicating intense inspections at shorter intervals. However, bridges that are unlikely to have damages and have low consequences in the event of collapse tend to belong in the lower-left corner of the matrix, indicating lesser intense inspections at longer intervals. Under the draft guidelines, typical inspection intervals of 12 to 96 months are envisioned, with maintenance inspections occurring on a 24 month interval for bridges with extended inspection intervals to monitor occurrence of significant or unexpected changes.

Data from the assessment are also used to identify inspection needs for a given bridge, based on the likelihood of the occurrence of damage and its consequences. This approach prioritizes bridge inspection needs, and is similar to the special emphasis areas currently used in New York. For example, fatigue cracking is more likely to occur in category E details in steel bridges, and therefore these details require 100% hands on inspection under current NYSDOT procedures. Under a risk-based inspection (RBI) approach, the consequences of development of a fatigue crack is also assessed to determine if the fatigue crack would actually have significant consequences in terms of bridge safety or serviceability. If the bridge is multi-girder, and the girders are closely spaced, the consequences of the fatigue crack may be very insignificant, particularly if the bridge is in a rural environment and traffic volumes are low. As such, the detail may require less focus than a detail in a bridge that has heavy traffic volumes or less redundancy, or where traffic volumes increase the likelihood of crack occurrence and propagation. The risks to the inspector resulting from difficult access challenges during the inspection may not be justified if the cracking is unlikely to occur, or is of little consequences.

On the other hand, if the cracking is likely or the consequences are severe, the assessment may show that more intense inspections and/or nondestructive evaluation (NDE) may be needed. The process improves overall reliability of the inspection by focusing resources where most needed, as determined through an engineering assessment, as opposed to uniform inspection requirements that don't recognize variable risks associated with different bridges based on their design, materials, condition and service levels.

The process developed for the risk-based inspection provides risk-based tools for making such assessments for cracking or other damage modes that affect bridges of any material or design type. The tools developed can be utilized as an inspection planning tool to improve the quality and reliability of inspections, even if the interval between inspections in not changed.

Among the benefits of risk based inspection (RBI) are (i) improved allocations of resources by focusing inspection efforts where most needed, and (ii) reduced inspection requirements where inspections are providing lesser benefits. The quality of inspections can also be improved through the prioritization process, providing further guidance to inspectors to ensure that critical damage modes are assessed in the field more uniformly. The concepts underlying the RBI process can be applied to bridges for the purpose of modifying inspection intervals, or to simply prioritize inspection efforts based on rational process, even if the interval between inspections is not changed.

1.6. QUALITY CONTROL (QC) / QUALITY ASSURANCE (QA) FOR BRIDGE INSPECTION

Revisions to the NBIS in 2004 required all states to implement systematic QC/QA to ensure consistency within bridge inspection and load rating programs. Historically, QC/QA implementation varied across different states, with some states having defined QC/QA programs, such as New York and Pennsylvania, while other states having more informal QC/QA programs within their bridge inspection programs. Currently, systematic QC/QA programs are among 23 metrics being evaluated by the FHWA for compliance with the NBIS, and a number of states are currently working to improve their QC/QA documentation and process to ensure compliance with the requirements.

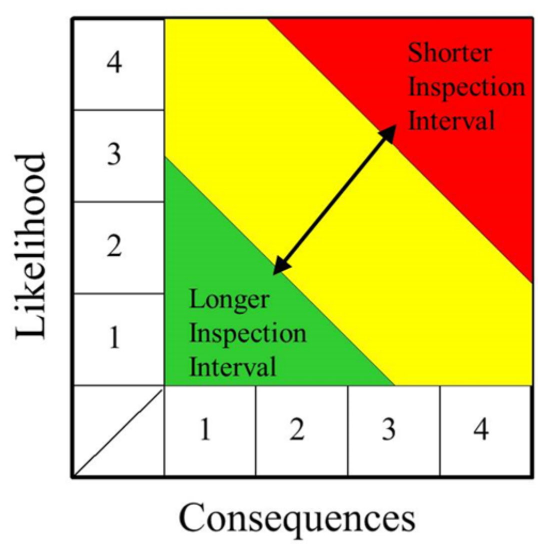


Figure 1-2: Risk Matrix Used to Determine Inspection Interval.

Generally, the goal of QC/QA procedures is to maintain and verify the quality of bridge inspections. These QC/QA procedures ensure that a bridge inspection program meets or exceeds the requirements of the NBIS and additional requirements that exist within a particular jurisdiction. These procedures also ensure that the inspections conducted within the program are consistent. Quality programs ensure consistency in the content of reports and forms, application of procedures, and in inspection results, in terms of condition ratings and other inspection data.

To address the need for improving quality in the bridge inspection process following the NBIS revisions, a scanning tour of selected European countries was conducted in 2007 to develop knowledge about quality processes associated with bridge condition evaluation outside the U.S. [Everett et al. (2008)]. A team including representatives from the FHWA, State and County transportation agencies, and the academic and consulting communities attended a series of meetings with European organizations to discuss quality in bridge inspection programs. Countries reviewed during the scan indicated some formal quality practices that included such activities as annual inspector meetings, comprehensive bridge inspection guidelines, high level qualification of inspectors and peer review of the inspection results [Everett et al. (2008)]. Detailed reference manuals, including extensive descriptions of deterioration and damage, along with photographs and sketches, were common quality tools found during the tour.

In a few cases, specific QC/QA methods were found. For example, the German bridge inspection program stores data in a national database, and software-based QC is performed on the data to find inconsistencies in the bridge inspection data [Everett et al. (2008), Haardt and Holst (2008)]. Annual professional development seminars for bridge inspectors are also held [Everett et al. (2008), Hearn (2007)]. Other European countries, including Denmark, France and Great Britain, include some elements of QC/QA in their bridge inspection and management programs, though these are limited. In Denmark, inspectors are highly trained and are specialized for bridge inspection. In France, engineers perform inspection and establish the inspection interval for the bridge, which can be up to 9 years. France also uses a performance test and written exams to qualify inspectors. Engineers in England use computer data checks to spot-check inspection reports and identify inconsistencies or errors. Generally, quality programs found on the international stage rely on inspector training and very detailed inspection manuals to ensure quality in their bridge inspections. Technical decision-making processes to determine inspection intervals, requirements and qualifications of inspectors were also found in most countries as a means of assuring quality. These are similar to the reliability-based inspection practices discussed previously, though typically less systematic and uniform, relying almost entirely on the expert judgment of the engineer performing the inspection. Review of current literature did not reveal relevant new data on international practices.

The most aggressive form of measuring and ensuring quality within a bridge inspection program is the control bridge inspections used in Finland, which is very similar to the control bridge method used in Oklahoma and process used for the FHWA visual inspection study by Moore et al. (2001). The Finnish model for assuring quality in bridge inspections is discussed later in the chapter.

Following the scanning tour, a guideline document was developed to assist states with implementing QC/QA practices to meet the requirements of the NBIS [Washer and Chang (2009)]. This guideline provides an overview of the requirements and processes for implementing QC/QA for bridge inspection. Some of the primary concepts from these guidelines are reviewed herein to describe general requirements for QC/QA practices for highway bridge inspections.

1.6.1. Quality Control (QC) / Quality Assurance (QA)

QC/QA procedures are required to maintain "quality" in a bridge inspection program. In general, "quality" is typically assessed as being inversely proportional to variability, that is, lesser the variation in the inspection results, higher the quality. Quality dimensions that are assessed are often associated with including all appropriate forms and documentation, and ensuring that the results are consistent with the procedures. Quality dimensions are sometimes associated with the results of bridge inspection in terms of the consistency of condition ratings or assessments. Additional quality dimensions may include measures of consistency with policies and requirements, such as the use of safety devices, appropriate access equipment, timeliness of the inspection, etc. The "quality" of the bridge inspection program can be measured by determining the variability in quality dimensions as compared with established requirements and procedures. Improvements in quality can be achieved by reducing variations from the target values for the quality dimension used.

Procedures used to maintain quality are typically termed as "quality control," (QC) which has the formal definition in the NBIS as follows: "*Procedures that are intended to maintain the quality of a bridge inspection and load rating at or above a specified level*." Programmatic items such as inspector training and qualifications, well-developed procedures and manuals, and other tools intended to maintain the quality of inspections are part of QC. Periodic reviews of the application of procedures and practices, such as reviewing an inspection report to ensure quality, are also part of QC procedures. These reviews are usually conducted within a specific work group, such as a region, for the purpose of correcting and reducing errors, inconsistencies or omissions from specific bridge inspection reports. For example, review of an inspection report at the region level to ensure that the forms are complete and include required elements such as sketches, notes and photographs, is a QC procedure.

Procedures that evaluate the effectiveness of QC and measure the quality across a bridge inspection program are "Quality Assurance," that has the formal definition in the NBIS as "*The use of sampling and other measures to assure the adequacy of quality control procedures in order to verify or measure the quality level of the entire bridge inspection and load rating program.*" Quality assurance activities are usually conducted from outside the work group that conducts inspections, for the purpose of evaluating the quality level of the program overall and determining if QC procedures are effective. This includes assessing the effectiveness of QC in assuring quality of submitted inspection reports, and in identifying deficiencies that may be corrected on a programmatic level, such as changes to procedures or training.

A key element of any QC/QA program is the correction of deficiencies or errors identified through the QC/QA program. "Corrective Action" is a general term used to describe any actions taken to correct an inconsistency or deficiency that is identified during a QC or QA review. Corrective actions may be very specific, such as making changes to a report to correct an error, or changing the description or procedure in an inspection manual. Annual inspector meetings, distribution of quality reports or technical advisories can also serve as corrective actions to improve the quality of a program and address concerns identified in a QA or QC review. Regardless of the form, corrective actions are a critical component of improving the quality of a program, because these actions address quality issues identified through the process and take action to correct them.

1.6.2. Characteristics of Effective Programs

While bridge inspection programs and QC/QA procedure vary across different states, there are some common characteristics of these programs. Characteristics that are common to effective programs are described in the NCHRP report "Guideline for Implementing Quality Control and Quality Assurance for Bridge Inspection" '[Washer and Chang (2009)]. One of these characteristics is the observation that the QC and QA review is independent, such that the individuals performing reviews are independent from the inspectors that developed the report, and this review (assessment) is based on objective measures. Effective programs also have documentation of the quality program that describes the roles and responsibilities of those involved in the quality program to ensure consistency over time. Documentation of the review procedures for both QC and QA and procedures for corrective actions in responding to findings of the quality review are established during such programs. Effective programs also have established schedules for quality evaluation, and provide comprehensive coverage of inspection program. NBIS metrics utilized by the FHWA include field review of inspection teams, refresher training for program managers and team leaders, and independent review of reports.

Generally, these characteristics are represented in the current procedures described in the NYSDOT Bridge Inspection Manual. Reviews of the bridge inspection reports and the field reviews are performed by a party independent of the inspection teams. New York State employs Quality Control Engineers (QCE) to perform independent QC reviews of bridge inspections, including review of bridge inspection reports from each inspection, to carry out field reviews of bridge inspection teams, and to discuss apparent problems with team leaders as the need arises. Procedures are intended to ensure that the documentation for each bridge is complete, inspections achieve a required level of thoroughness, and ratings are consistent with procedures. An optional check-list approach is provided in the bridge inspection manual to assist in the review. Quality assurance is performed by the Bridge Program and Evaluation Services Bureau through a checklist that includes review of a sample of BIN folders and field reviews of the bridge inspection teams. This type of field review of inspection teams is common in several states in either their documented QC/QA procedures or as historical practice.

Innovative procedures for QC/QA are currently utilized in some cases. Characteristics of these procedures are discussed in the following sections. This includes tools for QC that could be implemented, as well as QA process for the evaluation of the effectiveness of QC.

1.7. QUALITY CONTROL PROGRAMS

The purpose of QC is to maintain the quality of the inspection. Hence, QC reviews typically focus on quality as documented in the inspection report or may be observed through review activities. Inspection reports are usually reviewed for consistent and complete data entry. Certain programmatic elements such as procedures and practices also play a role maintaining the quality of bridge inspection, and as such can be part of the QC process. These include organized maintenance of records and files, inspector qualifications, required training or retraining of inspectors and periodic inspector meetings such as those in New York and many other states.

Many states, like New York, utilize some type of quality control engineer for independent review of every inspection report to assess consistency, whereas some states reply on review of a sample of inspection reports. A few states historically have relied on data error checking functions in the NBIS submittal. Still others use peer teams to check inspection results for a sample of bridges. For example, 5% of inspections in Utah are checked by a peer team to ensure consistency.

Several QC tools or procedures leading to improved inspection quality in other states have been identified through literature review. This includes procedures for rotating and performance testing of inspectors, annual calibration meetings that help improve the consistency of condition ratings and an improved, illustrated pocket guide for field use. Two innovative methods of improving quality have been identified as: Improved lighting for inspections, and a method for vision testing of inspectors. Improved lighting and vision testing of inspectors are not currently implemented in any state, but represent state of the art technologies commonly used in other industries to ensure inspection quality.

1.7.1. Calibration Meetings

Several states, including New York, Michigan, Alabama and Illinois, are using annual inspector meetings to "calibrate" inspectors to improve consistency in condition ratings. In a calibration exercise, inspectors may be shown photographs of bridge element in different condition states, and the appropriate rating assigned to the condition shown in the image is discussed, or there is a field review of a typical bridge where appropriate condition ratings are discussed. This "calibration" process helps support a uniform understanding of the inspection ratings, and provides a forum for discussion on factors affecting certain rating. In Alabama, desktop exercises concerning inspection procedures are combined with a group inspection of a bridge in the field, where ratings and procedures are discussed for a sample bridge. In Illinois and Michigan, the calibration is done in the classroom using slides presentations showing bridge elements in various forms of deterioration. The advantage of using a classroom presentation is that a broader diversity of examples and a larger number of inspectors can be engaged in the activity.

An innovation being used in Illinois is the use of an electronic audience input device by bridge inspectors for assigning condition ratings based on photographs of bridge elements in various condition states. This allows simultaneous submission of ratings for an element shown in a photograph during a large meeting of inspectors and comparison of results across the group. Figure 1-3 shows a sample slide from the training workshop. This photograph shows a steel element, an appropriate rating assigned to it and the rating description from the rating manual (when the rating is done, this information is not on the screen). Several slides of an element showing its overall condition may be used in the presentation to imitate the visual condition in the field. Ancillary information describing the extent of the damage, for example, extent of section loss in the members shown (but not shown in the photo), are described during the exercise.

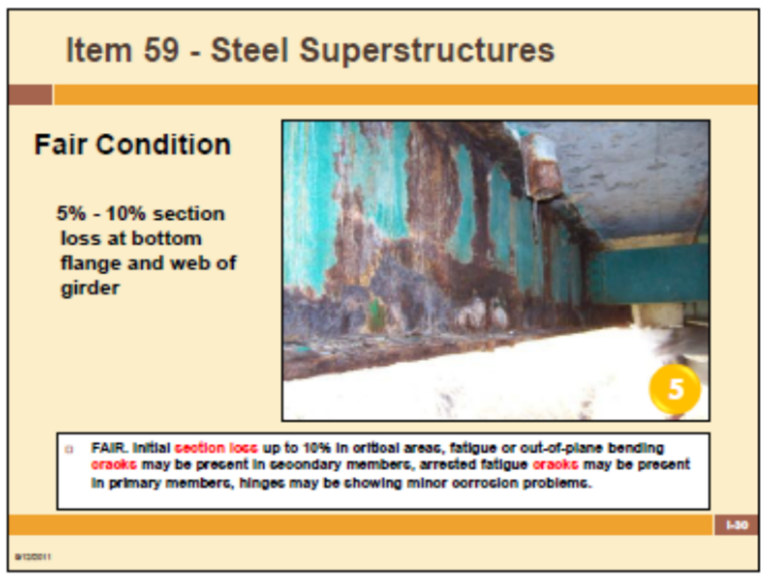
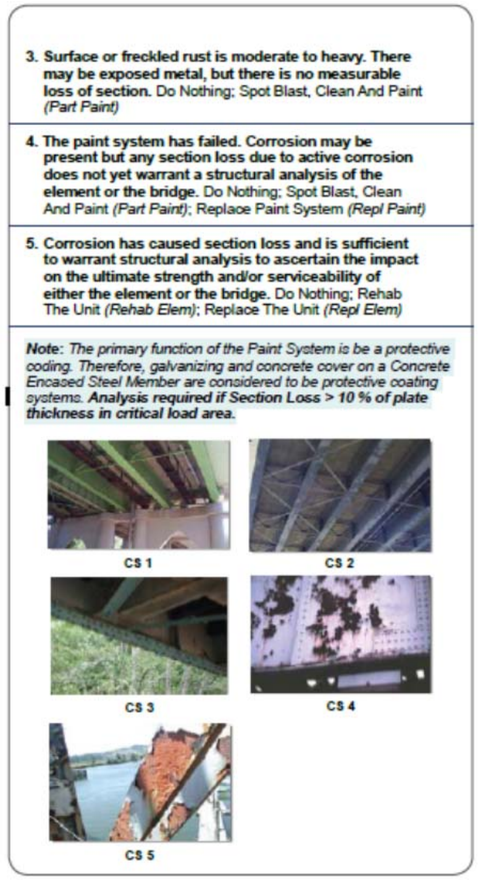


Figure 1-3: Slide from the ILDOT Inspector Calibration Class Showing Steel Superstructure Component.

These inspector calibration meetings are a means of improving the consistency of the subjective condition ratings assigned during inspection. The electronic input capability provides data on the variability of the rating during the exercise. This data could be used to track inspector rating distribution for elements, improvements over time, or measure the quality of the training provided during the meetings.

1.7.2. Bridge Inspection Pocket Coding Guide

Another QC item that is utilized in Oregon is a very detailed pocket coding guide that includes detailed photographs of elements and their ratings, and a description of "business practices," that is, the rules, policies and practices to be followed during bridge inspection. The primary advantage of a "pocket guide" is to make element rating descriptions and example photographs readily accessible in the field, such that these can be utilized during the inspection. This pocket guide includes detailed photographs for different condition states and element identifications to assist inspectors in the field. Policies and practices included in the pocket guide include such items as load posting notification criteria, inspection frequency requirements, etc. A sample of a page of this manual is shown in Figure 1-4. As shown in the sample page, photographs of each condition state for the subject element are provided as a visual example to the inspector that can be used in the field for comparison. During performance testing of inspectors, familiarity with the business practices included in the pocket guide and appropriate condition ratings are evaluated.



3. **Surface or freckled rust is moderate to heavy. There may be exposed metal, but there is no measurable loss of section.** Do Nothing; Spot Blast, Clean And Paint *(Part Paint)*

4. **The paint system has failed. Corrosion may be present but any section loss due to active corrosion does not yet warrant a structural analysis of the element or the bridge.** Do Nothing; Spot Blast, Clean And Paint *(Part Paint)*; Replace Paint System *(Repl Paint)*

5. **Corrosion has caused section loss and is sufficient to warrant structural analysis to ascertain the impact on the ultimate strength and/or serviceability of either the element or the bridge.** Do Nothing; Rehab The Unit *(Rehab Elem)*; Replace The Unit *(Repl Elem)*

Note: *The primary function of the Paint System is be a protective coding. Therefore, galvanizing and concrete cover on a Concrete Encased Steel Member are considered to be protective coating systems.* ***Analysis required if Section Loss > 10 % of plate thickness in critical load area.***

CS 1

CS 2

CS 3

CS 4

CS 5

Figure 1-4: Image of a Page From the ODOT Pocket Coding Guide.

A pocket guide of this type and format makes information on the appropriate rating for elements as well as the appropriate procedures readily available to inspectors in the field. This guide is comprehensive and includes complete listing of elements, rating guidance, and policies affecting the procedures for inspection. Developing manuals of this type was among the recommendations of the AASHTO ad-hoc group, and was also identified by the FHWA scanning tour as a quality tool frequently used in Europe. Such a guide could be developed for use in the field in New York as a revision to the BIM to improve consistency of inspection results. Additional photographic examples of appropriate ratings for elements could be used to make the pocket guide more comprehensive.

1.7.3. Inspector Rotation

A tool for quality control used by some states is to rotate inspectors, such that different teams assess the same bridge either during subsequent inspection cycles, or as a re-inspection for QC review purposes. Under this scheme, inspection teams are rotated to inspect or re-inspect bridges normally inspected by another team, either within their work group (region or district) or in different regions. Using such a rotation can improve the consistency of inspection results between peer inspection teams because the inspectors can compare previous inspection results of a different team with their own. Additionally, putting "fresh eyes" on a bridge, i.e., having a different inspection team assess the bridge, may identify a critical item or feature not identified by during previous cycles. This is utilized in states that use contractors to conduct routine inspections, such as Texas, as well as in state that utilize primarily state forces, such as Maryland and Ohio. This could be implemented in a regional organization by exchanging inspectors between regions for a certain number of inspection annually, or within a region using several inspection teams.

Inspector rotations are sometimes done by simply assigning selected bridges to a different inspection team for the next periodic inspection, such that a different team inspects the bridge at the next regular interval. In other cases, inspector rotations are done as a QC review, where a sample of bridges are re-inspected in the same inspection cycle to provide a QC check on inspection results.

1.7.4. Performance Testing of Inspector

Because the bridge inspection process is generally qualitative and subjective, maintaining consistent training and qualifications for inspectors increases the likelihood of consistent results, and serves as an effective mechanism for the "calibration" of the inspection program. An innovative means of improving the qualification processes for inspectors is to have performance testing. This approach has been adopted in Oregon. The purpose of the testing is to verify that the required training and qualification have been successful in achieving desired results, i.e., an inspector is meeting expectations. Performance testing of inspectors is a typical feature in critical NDT applications, such as the inspection of nuclear power facilities and aerospace structures, and has been used to qualify NDT inspectors in steel bridge fabrication shops.

In a performance test, the subject inspector conducts an inspection and prepares a report for a typical highway bridge. The results of this inspection are compared with a standard inspection, such as the results of an expert team inspecting the bridge, or previous inspection reports. This process evaluates if the inspector has adequate knowledge of the inspection procedures, identifies element correctly, completes forms correctly, and rates elements according the established criteria. In Oregon, inspectors entering the program are subjected to a performance testing on 4 bridges of various design features, and results are compared on the basis of assigned tolerance (of +/-1 for NBI ratings), element condition states, correct identification of elements, and adherence to required procedures. Results are compared to a control inspection result from an expert. An average of 4 inconsistencies or less per bridge are required to qualify as a bridge inspector. This process is also used to maintain the qualification of inspectors for QA, except that a peer team is used to conduct the control inspection. This peer-review process is described in the section of the report describing QA processes. Performance testing of inspectors, which was among the items identified by AASHTO/ASCE ad-hoc group, is also integrated in QA procedures that utilize control inspections.

1.7.5. Quality Control Tools

Two technologies for improving the reliability of typical visual inspections and the quality of inspection results have been identified as (i) improved inspection lighting and (ii) testing visual acuity of inspectors. As noted in the FHWA visual inspection study by Moore et al (2001), inspection lighting was one factor contributing to the likelihood that a given inspector detected a crack. Establishing adequate visual acuity of inspectors is also a means of ensuring quality. In this section, inspection lighting and visual acuity testing for inspectors are discussed. These are presented as relatively simple QC tools that could be utilized to improve the reliability of the inspection process.

1.7.5.1. Inspection Lighting

Highway bridge inspectors obviously rely primarily on visual inspection for the detection and assessment of damage. Ambient lighting conditions below and within the superstructure of a bridge are typically very low, on the order of 5-20 ft-candles. Hence, adequate lighting may not be available to effectively assess damage. Significant differences in lighting below the bridge, as opposed to the environment surrounding the bridge, which may be bright daylight, requires adjustments in vision that may require extra time, further diminishing an inspectors ability to see well below the bridge and within the superstructure elements. Fracture critical and non-redundant bridge members require hands-on inspections that rely on the inspector's ability to visually detect cracks and other critical damages. Research has shown that crack detection rates for bridges can be very low, though the use of flashlights during inspection appears to have a positive influence [Moore et al. (2001)]. The ability to detect cracks and other damages in bridges can be improved with the use of adequate lighting sources to ensure that sufficient lighting is available during inspections [Cella (1994), Cumblidge et al. (2004)].

Ambient light levels of 50 to 100 ft-candles (fc) are generally required for inspection tasks, whereas 100 to 300 fc are suggested for detailed tasks [Kleven and Hyvarinen (1999)]. Standards for NDT such as MT and PT typically require a minimum of 100 ft-candles of illumination on the surface being inspected [ASTM (2008, 2011)]. Presently, there are no known inspection lighting requirements for the visual inspection of bridges.

Use of a suitable flashlight or other lighting source can provide adequate lighting for bridge inspection. However, not all commercial flashlights provide adequate lighting. Figure 1-5 shows the illumination provided by typical flashlights at a distance of 24, 48 and 72 inches. In this figure, flashlight identification numbers 1-4 are lights with LED bulbs, 5-7 are lights with Xenon bulbs, and 8-10 are common, incandescent lights. This figure illustrates wide variations in the surface illumination provided by typical commercially available flashlights, with some flashlights not providing 100 ft-candles of illumination, even at a close distance of 24 inches. Generally, initial testing has shown flashlights utilizing LEDs or Xenon bulbs are more likely to provide sufficient illumination than some traditional incandescent bulb flashlights. However, this depends on the optics in the flashlight; reflector and other light characteristics. Hence, characteristics other than simply the type of bulb need to be considered in selecting appropriate lights.

A simple method for improving the reliability of inspection would be to establish a lighting standard that specifies light characteristics to be used during inspections. Flashlights that meet that standard could be identified and supplied as additional inspection tools. Prices for flashlights meeting a 100 ft-cdl illumination standard in Figure 1-5 range from \$10 to \$100. Hence, this requirement can be

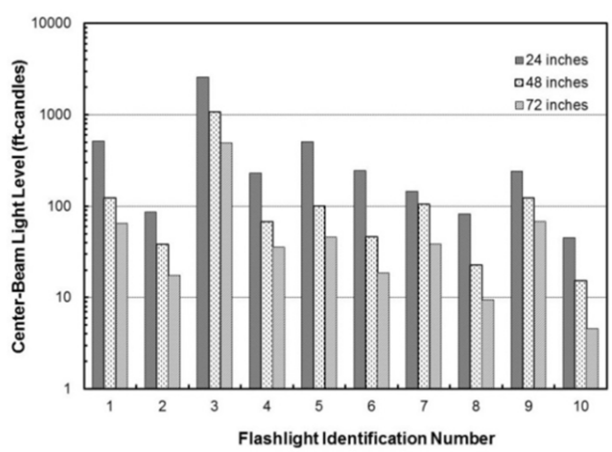


Figure 1-5: Illuminance Provided by Commercially Available Flashlights at Distances of 24, 48 and 72 inches.

imposed immediately. Implementing a lighting standard for bridge inspection would be an innovative and unique element of QC for bridge inspection.

1.7.5.2. Vision Testing

Another tool that could be considered for improving QC is the vision testing of inspectors. Most industrial standards for inspection and NDE include a requirement that the vision of inspectors be tested periodically [Beard et al. (2002)]. Since vision is the primary tool being utilized to detect and analyze damages during an inspection, ensuring that the vision of inspectors meets a suitable standard is essential for improving the reliability of the inspection. Vision in human eyes deteriorates with age because of decrease in the flexibility of the lens and the ability to focus. There is significant loss of focal function at near-distances at the age of 40 and almost complete focal loss at the age 50 because of normal deterioration of eyes. In most cases, these visual deficiencies are corrected by appropriate corrective lenses (glasses). However, since the loss of visual acuity is a deterioration process in the eye, the prescription used must be updated periodically. The reliability of inspection results, particularly the detection of small features such as cracks, may be diminished if prescriptions are not updated periodically, or if an inspector has a visual loss that is unknown to them or is uncorrected.

Visual acuity testing has not been a requirement for bridge inspectors, though a few states require driving certifications that include vision test [Moore et al. (2001)]. In other industries, a simple, on-site visual acuity test is utilized to ensure that inspectors meet a minimum vision standard [Kleven and Hyvarinen (1999)]. This simple-to-implement eye test requires only that an inspector read some lines of the text printed on a card, as shown in Figure 1-6, at a distance of 12 to 14 inches. Typical requirements are to read the J2 line of text, which provides an equivalent of 20/20 near-distance acuity. Test can be conducted annually, simply to ensure that the inspector has vision corrections, if needed. A Jaeger eye test can be completed on-site in less than 1 minute. A laminated Jaeger card costs approximately $7.50.

Figure 1-6: Photograph of Jaeger Visual Acuity Test Card.

1.8. QUALITY ASSURANCE METHODS

Currently, there are several methodologies for QA being implemented in the US. These methods can be generalized into several generic models that describe the process implemented for QA [Washer and Chang (2009)]. The most widely used method for quality assurance is the field verification model (FVM), in which individuals from a central office review inspection teams in the field. These reviews typically include an office review component that assesses the bridge files for contents such as listings of fracture critical bridges and other bridges requiring special inspection, qualification of inspection personnel, and other required components of the bridge file. These reviews also typically include a field review component to verify inspection processes being implemented in the field, and to ensure that the inspection reports provide an accurate representation of the field conditions. The primary difference between this method of QA and other methods is that a re-inspection of the bridge is not conducted; only verification that the inspector condition ratings seem appropriate for the conditions found in the field. As a result, there is less objectivity in the process relative to other methodologies for performing QA reviews. Other processes that are currently implemented, though on a much more limited basis than field verification processes, typically include an independent re-inspection of one or more bridges to provide a measure of variability between the subject inspection and the re-inspection. The following section describes models of these other methods, including independent oversight, peer review and use of the control bridge model.

1.8.1. Independent Oversight Models

The independent oversight model (IOM) is characterized by re-inspection of a sample of bridges by an inspection team that is independent from the team that conducted the subject inspection. The QA inspection team may be an expert group, a QA consultant team or a peer team from another district or region. The re-inspection generates companion inspection results that can be compared to the subject inspection data for the analysis of consistency and accuracy. This process is generally more objective than the field verification process, because the re-inspection is done without the knowledge of the inspection results from the subject inspection team.

Tolerances for specific inspection or inventory items can be established to evaluate the consistency of the inspection results and to track quality improvements over time. For example, for the minimum vertical clearance over a bridge, a tolerance limit of +/- 2/10 foot from QA coding might be used to determine if the results in the inspection report are "consistent" or "not consistent." Other items, such as appropriately identifying the number of joints, might have no tolerance. Although a simple scoring method, this allows for improvements in quality to be tracked over time and to be compared across groups. This approach for quality assurance has been used in Pennsylvania for many years, and is implemented by using a quality assurance contractor to re-inspect bridges across the state to provide individual and system-wide reports on quality on an annual basis [Purvis (1991)]. In this approach, individual inventory items or report elements are identified and assessed for consistency. Hence, this approach has resulted in increased consistency in inspections for both state and local agencies. This approach is also used in Michigan to provide oversight of the inspection program that is distributed among 350 separate bridge owners to provide a QA review on 10% of bridge owners annually.

The results of the QA review are typically summarized in a QA report generated and discussed directly with the subject inspection group, which provides an opportunity for corrective actions at the inspection team level. A summary report is also generated, including the results on reviews of individual work groups to provide data across the program and to identify improvements needed to procedure or practices.

1.8.2. Collaborative Peer Review

Another method of QA is to use a collaborative inspection process as a part of the QA review. This approach is being used in Oregon. Under this approach, the inspection team being evaluated participates in the inspection with a group of peers from other regions or offices, and/or experts from the central office. The group conducts an inspection of a sample of one or more typical bridges to develop a collaborative inspection report. Discussion of appropriate ratings and findings is done regularly during the QA inspection. After the peer team develops its report, the original inspection report is reviewed and differences are discussed in detail among the team members. The consistency of inspection results are evaluated by comparing the results of the peer team inspection report with the original inspection results from the subject team. This provides a means of assessing inconsistencies between the results, and identifying areas where improvements may be needed for the specific inspection teams. The summarization of results from the reviews of multiple teams can assist in identifying programmatic improvements. The peer team may also review the resources available to the inspection teams, such as tools, access equipment, etc., to confirm the qualifications of inspectors, and other common components of an office and field reviews. This approach is also used in Utah and Alabama as a part of their annual training for inspectors.

An advantage of the CPR approach is that the interaction of the peer group during the inspection provides on-site training for inspectors during the inspection, both for the subject inspection team and the member of the peer team. The process also helps to “calibrate” the inspection process across the participating peer group. Through the calibration, more uniform understanding of the appropriate ratings for specific elements as well as other inspection items and procedures can be gained.

1.8.3. Control Bridge Model

Another method of quality assurance that is being implemented in Oklahoma is the Control Bridge Model (CBM), which typically includes many inspection teams inspecting the same bridge, to assess inconsistencies between inspections by different teams. These control (or reference) bridges are inspected by all of the inspection teams being evaluated as a part of QA review. Each inspection team conducts a standard, independent inspection of the control bridge and generates a suitable bridge inspection report. An expert group or inspection team also inspects the bridge, and generates the inspection report and rating for comparison with each team’s results.

There are several advantages to this approach over other approaches. First, the process provides for objective and independent review of inspection quality which is the characteristic of an effective quality programs. Second, each inspection team being evaluated observes the same bridge under essentially the same condition. As a result, inspection approach, specific ratings for elements, tools used, time required, and other supporting information should match across the inspector population and with the expert team. Inconsistencies in the inspection process or results can be clearly identified for specific situations. This reduces the uncertainty in the results compared with the evaluation of teams inspecting different bridges, which is done in other approaches discussed earlier. Additionally, since there are multiple results to compare, it can be easier to identify if a particular inconsistency is specific to a single team, or is more widespread, perhaps resulting from a need for improvement in the inspection manual or procedures being used, or a need for further emphasis on a particular inspection item. An additional benefit of such a model is that the review of the inspection results supports “calibration” for inspector ratings, as each inspection team can compare their results and rating with the ratings and results of other teams and the control (reference) team.

An alternative implementation of the CBM is used in Maine as a part of annual inspector training. In this case, inspectors conduct independent inspections on 2-3 bridges as a part of the annual inspectors meeting, and the results are then compared during a discussion session held as part of the meeting. Although less formal and quantitative than the method used in Oklahoma, this approach is simple to implement and assists with calibration of inspector ratings across the group.

In the Oklahoma model, results of the inspections and comparison with the control inspection are presented during inspector's meeting. In addition to summarizing the overall results of the inspection, individual teams are provided with scoring of their results compared with the control inspection results. This provides individual teams with information on how their inspection results compare with the control and other teams. As a result, quality functions such as calibration of rating and performance testing of inspectors is achieved through the process. A similar process has been used in Finland for ensuring and improving the quality of bridge inspections.

1.8.4. Finnish Control Bridge Model

Finland has a comprehensive system for QC/QA of bridge inspections that is similar to the CBM described previously. This program is conducted within different regions of the country for QC/QA of contractors performing inspections, for annual training of inspectors at workshops, and for the qualifications of inspectors [Everett et al. (2008), Dietrich et al. (2005), Söderqvist et al. (1998)]. Bridges in each of the regions are selected each year by the Finnish Road Administration (FINNRA) and two control inspections are performed, along with the one standard inspection [Dietrich (2007)]. Control inspections are performed by private companies supervised by FINNRA officials, and the data from the control inspections are evaluated against the data from the standard inspections to identify and measure inconsistencies in the inspection results.

The assessment of quality is conducted by evaluating the inspector deviation from the control inspection. Finland rates bridge conditions according to accumulated damage points for elements according to the following formula:

$$VPS = \Sigma(\text{Weighting coefficient of the structural part * condition points of the structural part * repair urgency points * damage class points})$$

Where *VPS* is the "damage point sum" of the individual elements of a bridge, and is typically a number in the hundreds. Condition points describe the condition of the element on a scale from "New or like new" to "Poor", and damage class points describe the damage present on a scale from "Mild" to "Very serious." Repair urgency is rated on a scale "No repair" to "Immediate Repair." Thus, in Finland, numerically higher scores for bridge ratings indicate worse conditions and greater urgency for repair. Unlike the rating scales typically used in the US, which are characterized by a discrete scales consisting of whole numbers (1 through 9, 1 through 7, etc.), elements of bridges in Finland are rated using a continuous scale that is comprised of the product of several individual assessments, such as condition of the element, severity of the damage, and the urgency of repair.

Deviation figures are calculated which provide a quantitative assessment of the amount by which the ratings generated by a standard inspection deviate from the expected real values. For example, Finland calculates a factor called the "Deviation (PL)" which is based on the damage points assigned to each element of the bridge [Dietrich (2007)]. This is used to measure an inspector's deviation from the control value established for an individual element of the bridge.

This figure is computed as PL = $|VP - S_{MEAN}|/S_{MEAN}$, where VP is the damage points assigned for a particular element by an inspector and S_{MEAN} is an average value based on a combination of the inspector and control inspection results. The calculated factor PL describes the entext to which the subject inspecton deviates from the expected real value. A factor called the Relative Deviation (SP) is similarly calculated for the overall bridge rating, i.e. the sum of the damage points of all of the elements of a bridge (VPS). An irregularity report is required if any inspectors' damage point or relative deviation in the quality report exceeds allowable values. These factors are also be calculated to measure inspectors' deviations from benchmark cost estimates for repairs [Dietrich et al. (2005)]. The quality score of an inspector is used to qualify bridge inspectors for tasks as part of the FINNRA procurement process, to identify areas where significant deviations from control values exist and to develop refresher training based on these deviations [Everett et al. (2008)]. The use of the CBM in Finland has been reported to significantly improve the quality and consistency of bridge inspections over time. Since FINNRA adopted this approach in 2002, data indicate that bridge inspection quality and consistency have improved each year [Dietrich et al. (2005), Dietrich (2007)]. FINNRA also holds required inspection workshops annually that include field inspections using the same approach to help train inspectors, and uses this process as a performance testing to qualify new inspectors.

1.9. COMPARISON/ANALYSIS OF QA METHODS

While there are several approaches for QA review of bridge inspections, they share the common goal of improving the consistency of inspection results. Positive results from Oklahoma's adoption of the CBM in 2002 have been documented, including increased emphasis on the importance of bridge inspections, improved consistency in bridge ratings, and boosted morale amongst inspectors and their teams [Washer and Chang (2009), Karper and Peters (2008)]. The bridge inspection workshops, in which inspectors and the oversight teams performing the control inspections meet and discuss/review the comparison between control and routine inspection reports, are a key element of the process that allows for each team to compare their results to the control inspections results. These meetings enable those performing the control inspections to discuss directly any deviations and irregularities in reports with those who actually wrote the reports and to help standardize and make consistent the practices used by inspectors in order to generate consistent results.

The first round of bridge inspections under the CBM in Oklahoma in 2003 resulted in the identification of problems leading to high variability in the ratings given to the same element by different inspectors. One problem identified at that year's workshop was that Oklahoma's BIM contained nearly 200 bridge elements, many of which were obscure or poorly defined, such that individual inspectors could not agree on how to identify or rate certain elements. As a result of this finding, Oklahoma removed nearly 50 of these elements from the inspection manual. Additionally, condition rating descriptions in the manual were improved and photographs of condition states were provided based on inspector feedback.

Identification of systematic issues, such as inadequate descriptions in the manual, is more difficult by other methods, e.g., peer review or independent reviews, because of review on a different bridge for each team assessed. Using the CPR, Oregon compares inspection reports developed by the peer team against previous inspection reports for different bridges. Hence, a direct comparison of performance between different teams is difficult. Uniform calibration of condition ratings and other inspection data is also more difficult because there is only one inspection conducted for comparison for each team. Although this process has been used for several years, improvement in inspection quality are difficult to document.

In Pennsylvania and other states utilizing the IOM, although the re-inspection of bridges provides independent and objective results, it doesn't provide the consistent reference – each re-inspection is performed on a different bridge, so one-to-one comparison between teams isn't possible. There is less emphasis on the calibration of inspection results through this process. Hence, systematic variations may also be more difficult to identify using this approach.

In contrast, CBM provides a way to assess inspection reports against a known constant threshold (the control bridge reports) when all inspectors conduct inspections on the same bridge. Deviations from this constant can be analyzed for all bridge inspection teams. Variations from the control results for each inspector can be quantified, and a weighting system can be used to provide individual inspectors with a quality score bases on the assessment of this data. Additionally, inspection teams can compare their results with the control and with those of other inspection teams. Because of the high number of results for each element, the average ratings and distributions are more statistically meaningful as compared to results from just one inspection verses another. The CBM provides a means to document this variation, and this can be discussed in the annual bridge inspection workshops to determine the cause of the variation and discuss ways to improve the consistency of ratings for this and other similar elements. The process also provides a means of performance testing of inspectors by comparing inspection results against the control team and with inspection results from other inspection teams.

In summary, the CBM integrates key elements of QA that have been identified by AASHTO ad-hoc group, e.g., guidelines for QC/QA for bridge inspection, quality metrics identified by the FHWA, and unique quality tools currently being implemented in other states, into a single process for QA review. These include independent and objective review of inspection results, field review and performance testing of inspection teams, calibration of ratings, and retraining though the results of the testing and associated inspector meetings.

CHAPTER 2: APPROACH FOR THE EVALUATION OF CONSISTENCY

2.1. INTRODUCTION

Similar to the evaluation of the consistency in the FHWA study on the reliability of the visual inspection [Moore et al. (2001)], the evaluation of the consistency of the bridge inspection program of the New York State has been carried out through the planned inspection of selected bridges representative of the bridge population in the state by several inspection teams. Each of the selected teams was assigned to inspect all selected bridges. Hence, important considerations during the planning of the consistency study were to determine: (i) number and characteristics of the bridges, (ii) number and characteristics of the inspection teams, (iii) planning of logistics and inspection and (iv) detailed approach for the evaluation of consistency of the inspection program. Each of these issues is described in detail in the following sections of this chapter.

2.2. SELECTION OF BRIDGES AND INSPECTION TEAMS

Since the evaluation of consistency of the inspection program is carried out through the statistical analysis of a sample of inspection data, the size of the sample of the inspection data for a particular type of bridge element should realistically represent statistical characteristics of the larger population of bridges inspected regularly by New York State. For example, if n_b bridges are inspected by n_i number of inspection teams, then there will be $n = n_b.n_i$ inspection data for elements that are common to all bridges, such as deck, abutments, etc. The size of the sample, n, should be determined such that the sample mean is within certain acceptable deviation (e.g., ±0.01) to the population mean. Statistically, the size of inspection data, n, for a particular element type can be selected to have its mean within ±B of its population mean with 95% confidence through the following equation [Devore and Peck (1997)],

$$n = \left[\frac{1.96\sigma}{B}\right]^2 \quad (2\text{-}1)$$

where σ is the standard deviation of the sample. Here, Eq. (2-1) implies that the mean value for 95% of the samples of size n will be within ±B of the population mean value. Generally, the standard deviation σ can be estimated from available inspection data. However, if such data aren't available, then it can be estimated as σ = (Range of data)/4, where the range of data represents difference between maximum and minimum values of ratings within a sample of inspection data.

If the standard deviation is unknown, we can assume the range of ratings to be 2 (i.e., ratings varying between 4 and 6 for a mean rating of 5), which gives the estimated σ = range of ratings/4 = 0.5. Then, as per Eq.(2-1), 95% of samples of size n = 384 are likely to have their sample mean within B = ±0.05 of the mean rating of a similar element during regular bridge inspections. In this case, if the mean of an element during regular inspections is 5.25, then the mean values of 95% of the samples of size n = 384 are likely to be in the interval of (5.20, 5.30).

Based on the FHWA study [Moore et al. (2001)], the values of standard deviation for decks of different bridges inspected have been found to vary from 0.53 to 0.94, with an average value of approximately 0.81. Although the standard deviation in the present study is likely to be lower, we can assume σ = 0.94 (worst case for the FHWA study) for the planning of inspections. Note that a higher value of σ will result in a larger number of samples as per Eq.(2-1). Hence, assuming a value of σ = 0.94 in the Equation (2-1), Table 2-1 below presents number of samples required for values of B from 0.01 to 0.20. It is observed from Table 2-1 that the number of samples will be very high if it is desired to have sample mean within ±0.01 of the population mean.

In order to evaluate the consistency of the bridge inspection ratings, a selected bridge will need to be inspected by certain number of inspectors to generate statistically sufficient data. This statistical sufficiency doesn't require very accurate representation of the population mean by the sample mean. Rather, the population mean needs to be represented in the sample mean sufficiently. For example, if the mean rating of bridge decks is 4.8, a sample of bridge deck inspections with mean in the range of 4.6 to 5.0 will still represent the population sufficiently, since the sample will represent bridges decks with ratings in the range of 4 to 6, similar to bridge decks in the population with an average rating of 4.8. Hence, it may be sufficient to assume B = ±0.20, i.e., sample mean within ±0.20 of the population mean. This will imply 85 data (see last row of Table 2-1) for elements that are common among bridges selected for inspections. However, it should be noted that the population mean represents average rating of a particular type of element (e.g., structural deck) in different bridges rated by different inspectors. Similar process will be represented in this study since a particular type of element in selected bridges will be inspected by a sample of bridge inspectors. Nevertheless, the variation is likely to be less since the same bridge will be inspected by the whole sample of inspectors. Note that the number of samples required by assuming a lower standard deviation of $\sigma = 0.53$ (the lower limit during the FHWA study) is only 27. Hence, we can assume 80-100 inspection data per element type to evaluate consistency statistically within 95% confidence interval such that the average rating for the sample is between 0.15 to 0.20 of the population mean.

Table 2-1: Size of Samples of Inspection Data for Different Deviations Between Sample and Population Means in a Sample.

B	N
±0.01	33,946
±0.05	1358
±0.1	339
±0.15	150
±0.20	85

2.2.1. Number of Inspectors

Similar to the selection of the size of statistically significant inspection data, the determination of the number of inspectors will depend on the representation of the population behavior by the sample. The size of sample for this case can also be determined by Eq.(2-1). For this, we need to identify the target standard deviation for the sample. For a bridge deck with a reference rating of 4, if 90% of the inspectors rate it at 4 and 10% rate it at 5, the average rating will be 4.1. Similarly, if 90% rate it 4 and 10% rate it 3, the average rating will be 3.9. Table 2-2 below shows the distribution of control rating (as assumed to be actual rating) and distribution of ratings by the sample of inspectors during the FHWA study. The distribution in Table 2-2 shows that more inspectors tend to rate bridge decks with ratings 4 or 5 as 6 or higher. Note that the data in the Table 2-2 are for the FHWA scale of 9 to 1. For example, Row 1 of the table shows a reference rating of 5. This item is rated below 3 by 1, rated 4 by 1, rated 5 by 12, rated 6 by 27 and rated 7 by 8 inspectors. Hence, the mean rating in this case is higher than the reference rating and the standard deviation is 0.87.

Table 2-2: Distribution of Ratings with Respect to the Control Rating during the FHWA Study.

Control Rating (Reference Rating)	**Rated ≤ 3**	**Rated 4**	**Rated 5**	**Rated 6**	**Rated ≥ 7**	**Average**
5	1	1	12	27	8	5.8
4	1	16	20	9	2	4.9
4	1	13	13	21	1	5.2
5	3	14	19	12	0	4.8
4	4	17	24	3	0	4.5
7	0	0	0	5	44	7.1

For New York State, it is assumed that the target difference of average rating by a sample of inspectors as compared to total population of inspectors can be taken between 0.2 and 0.25, which is similar to B = ±0.2 taken for the selection of statistically significant size of the sample. Figure 2-1 shows the plot of allowable deviation (B) between the sample and population means versus the number of inspectors as per Eq.(2-1) for standard deviations $\sigma = 0.53$ and $\sigma = 0.94$. This curve is based on the FHWA study [Moore et al. (2001)]. It is observed from Fig. 2-1 that the number of inspectors corresponding to B = 0.2 and 0.25 for $\sigma = 0.53$ are 24 and 15, respectively. In this study, we are assuming a standard deviation of 0.53 for the selection of inspectors (lower limit for the FHWA study) because of more uniformity in inspection practice in New York State. Hence, we can consider a sample of 21 inspectors to achieve an average rating within 0.2-0.25 of the population mean. Since the consistency of New York State inspection program is expected to be better than that based on the FHWA study, statistically reliable results may also be achieved with slightly lesser number of inspectors (number of inspectors will be smaller for smaller standard deviation as per Eq.2-1).

2.2.2. Number and Characteristics of Bridges

Having selected the size of the sample of inspection data and number of inspectors, the number of bridges can be determined on the basis of this information. Since the number of statistically sufficient inspection data is estimated to be in the range of 85 to 100 and the number of inspectors is expected to be around 21, we will need to select 4-5 bridges of representative characteristics. Assuming that the consistency of NYSDOT study is likely to be better than that in the FHWA study by Moore et al. (2001), 4 bridges have been considered to generate statistically sufficient data for the study. NYSDOT TWG also concurred with this recommendation.

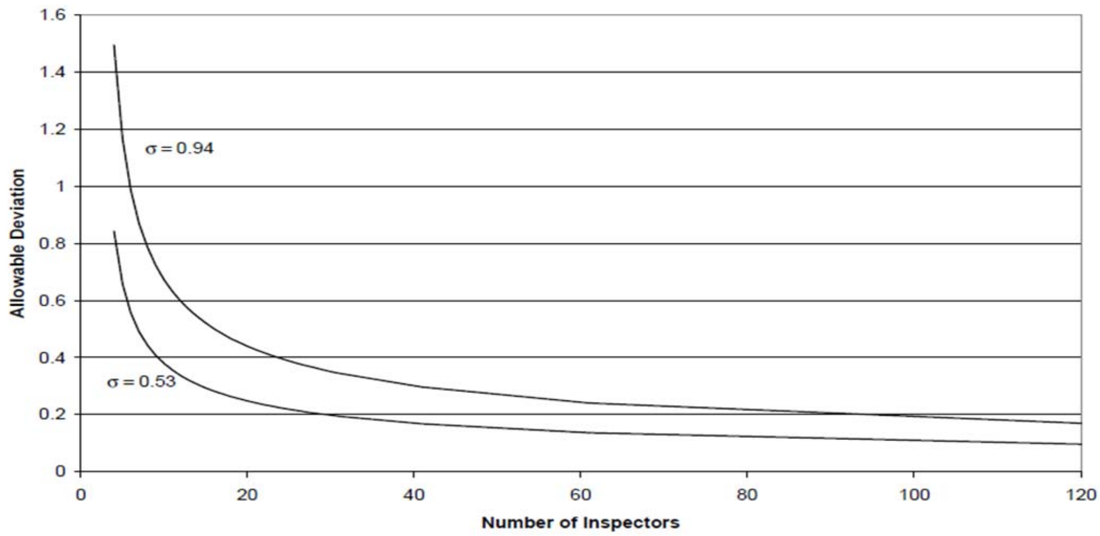


Figure 2-1: Allowable Deviation versus Number of Inspectors as per Equation (1) [Fig. 61 from FHWA Study, Moore et al. (2001)].

It should be noted that these 4 bridges should represent the general characteristics of normal bridges in New York State, since complex bridges are subject to more rigorous and special inspection requirements. Based on the review of bridge types and their ratings in New York State, selected bridges were recommended to possess the following characteristics:

- Representative of overall population
- ADT
- Avoid unusual settings, materials, structural systems
- Known conditions
- Previous inspection reports available
- Flags present
- Select bridges with overall condition rating between 4.5 and 5.5. Such bridges will also have some elements in relatively poor condition.
- Select bridges near the end of 2-year cycle where the crew hasn't received the instructions to fix flags.
- Bridges with elements having shaded ratings (e.g., 4, 2, etc.) should be selected since the inspection of such elements requires subjective judgment.
- Among 4 bridges, 2 bridges with computed condition rating between 5 to 5.5 and other 2 with computer condition rating between 4.5 to 5 should be selected to realistically represent the population of normal bridges.
- Further analysis of NYSDOT bridge inventory and inspection database shows that typical bridges in New York State are steel stringer bridges with concrete deck and are of 1 to 3-spans.
- Selection of specific bridges should also be based on continuity and material types.

Selection by Continuity Type: Figure 2-2 below shows the distribution of bridges by continuity and material types. It is observed that, among normal bridges in New York State, 63% are single span simply supported, 26% are multi-span simply supported and 11% are multi-span continuous bridges. Hence, the following types of bridges can be selected based on continuity:

- Single span simply supported: 2 bridges
- Multi-span simply supported: 1 bridge
- Continuous: 1 bridge

Selection by Material Type: In New York State, bridges are primarily made of steel, concrete and pre-stressed concrete. For the convenience of observation, bridges belonging to each of the continuity types in Figure 2-2 are further classified according to the three material types. It is observed from Figure 2-2 that a majority of bridges are steel bridges, followed by concrete bridges. Pre-stressed bridges are primarily single span and multi-span simply supported types. Hence, based on Figure 2-2, following types of bridges were recommended to be selected:

- Single span simply supported Bridges : 1 Steel, 1 Concrete (Prestressed or Concrete)
- Multi-span simply supported Bridges: 1 Steel
- Continuous Bridges: 1 Steel

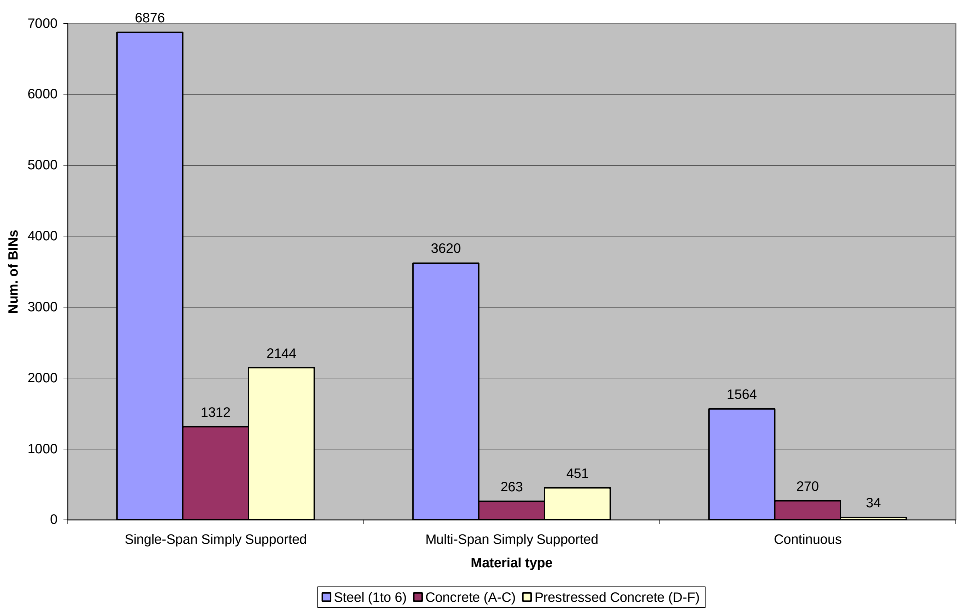


Figure 2-2: Distribution of Bridges in New York State by Continuity Type.

It should be mentioned that the geographical location of bridges and traffic volume on these bridges are also considered to be important factors in the selection of 4 bridges. All bridges should be located within driving distance from each other so that a bridge inspector could move from one bridge site to another without too much travel time. This was considered to be an important factor from logistics and cost point of view, since 21 inspection teams (or 42 inspectors) are involved in the consistency study.

Traffic volume on selected bridges is also an important consideration. Considering 21 inspectors and 4 bridges, a total of 84 inspections need to be conducted in this study. These inspections are planned during a three month period to minimize variations in ratings because of factors other than inspector's understanding of the NYSDOT bridge inspection manual. Selecting bridges with high traffic volume would require Work Zone Traffic Control (WZTC). Hence, bridges whose inspections don't require WZTC or lane closure should be selected to avoid excessive inconvenience to local communities.

Based on criteria for selection of bridges described above, several candidate bridges were selected in coordination with the members of the TWG at NYSDOT. Following a further detailed review of these bridges and extensive discussions with TWG, following four bridges were selected:

- BIN 1026170: A 3 span P/S concrete bridge in Syracuse, NYSDOT Region 3.
- BIN 2205690: A stringer / multi-beam girder single span steel bridge in Utica, NYSDOT Region 2
- BIN 3308970: A stringer / multi-beam girder single span steel bridge in Utica, NYSDOT Region 2
- BIN 3350660: A 3-span Continuous Steel Bridge in Binghamton, NYSDOT Region 9

Tables 2-3 and 2-4 show layout and other geometrical characteristics of these four bridges. Figures 2-3 to 2-6 show photographs of these 4 bridges. It is observed from Table 2-3 that "General Recommendation" ratings for these bridges are in the range targeted in the desired characteristics outlined earlier. Figure 2-7 shows locations of these bridges on the Google Map.

Table 2-3: Details of Bridges.

BIN	Region	Material	Year Built	ADT/Year	Span	Computer Condition Rating (General Recommendation)	Flags	Structural Deck	Primary Members	Sec. Members	Wearing Surface	Worst Rating
3350660	Binghamton (9)	Steel	1983	207/1999	3	5.44(5)	1	5	6	6	5	3 (Erosion or Scour)
2205690	Utica (2)	Steel	1940	8/2008	1	4.83(5)	2	5	4	6	5	2 (Paint)
1026170	Syracuse (3)	Concrete	1982	14346/2007	3	5.28(5)	0	8	5	8	5	4 (Guide Railings, Pedestals, Joint with Deck)
3308970	Utica (2)	Steel	1934	332/2008	1	5.12 (5)	0	6	6	6	3	3 (Wearing Surface)

Table 2-4: Layout and Other Geometrical Information.

BIN	**Region**	**County**	**Bridge Type**	**Material Type**	**Bridge Length**	**#Spans**	**Feature Carried**	**Feature Crossed**
3350660	Binghamton (9)	Chenango	Stringer/Multi Beam	Steel Continuous	42 Ft.	3	Joe Hoben Rd	Mill Brook
2205690	Utica (2)	Onieda	Stringer/Multi Beam	Steel	32 Ft.	1	Kincaid Rd	Little Woodhull Creek
1026170	Syracuse (3)	Oswego	Box Beam / Box Girders	P/S Concrete	173 Ft.	3	Rt. 49	Little Bay Creek
3308970	Utica (2)	Hamilton	Stringer/Multi-Beam or Girder	Steel	45 Ft	1	CR38 (Haslauer Road)	Oneida Creek

Figure 2-3: Elevation Views of BIN 1026170.

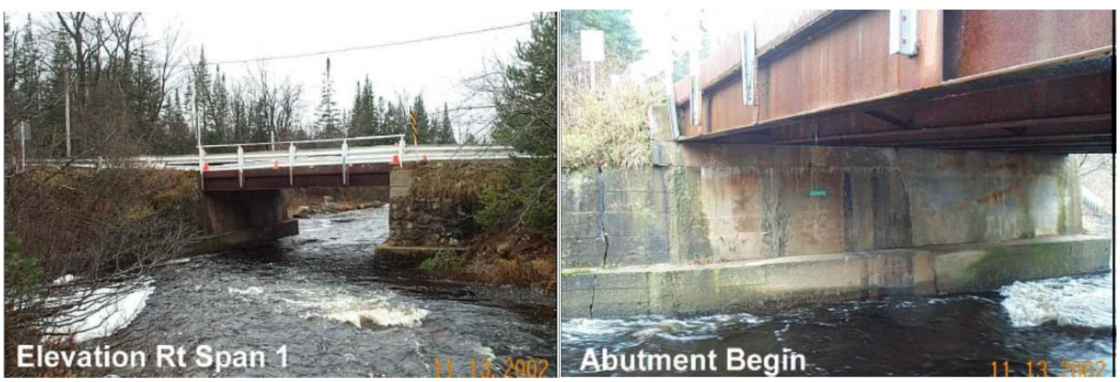


Figure 2-4: Elevation Views of BIN 2205690.

Figure 2-5: Elevation Views of BIN 3308970.

Figure 2-6: Elevation Views of BIN 3350660.

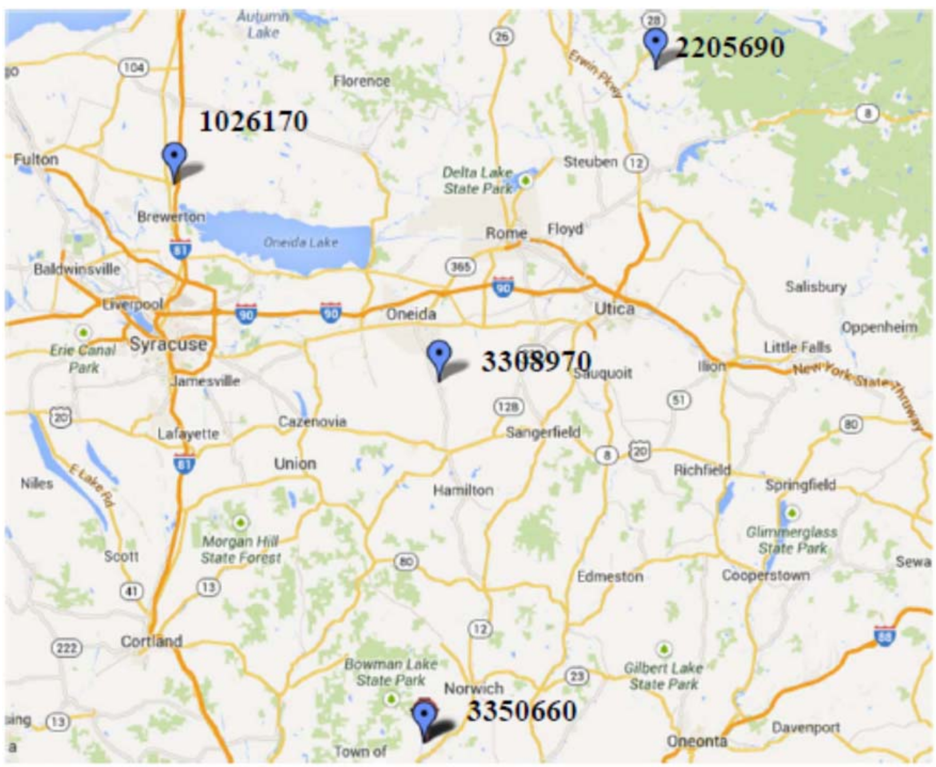


Figure 2-7: Location Map of Four Selected Bridges.

2.3. SELECTION AND ASSIGNMENT OF INSPECTORS

The research team was provided with the names of all inspectors, including state and consultants, for the selection of 21 inspection teams. It has been noted that the proportion of state and consultant bridge inspectors is about 45 to 55. In order to maintain approximately the same ratio among 21 inspection teams, 10 teams were selected from the pool of consulting teams and 11 from the pool of state teams.

In New York State, inspection teams are assigned to each region for regular inspections. In order to ensure statewide representation of bridge inspectors in the study, one state and one consulting inspection team was selected from each of the NYSDOT regions 2, 3, 4, 5, 6, 8, 9. Only state inspection team was selected from regions 7 and 10, whereas two consulting inspection teams were selected from the region 11. This was done because regions 7 and 10 have only one state inspection team whereas region 11 has only consulting inspection teams. From Region 1, 2 state teams and 1 consulting inspection team were selected. From this region, one of the state teams was from the NYSDOT headquarter in Albany. Names of inspection teams have been kept confidential so that the inspectors could carry out the inspections without any bias of being identified later. These 21 inspection teams have been selected out of approximately 80 inspection teams statewide and represent very good sample of the inspection teams used by NYSDOT.

Since there are multiple state and consulting engineering teams in a particular region, selection of inspection teams was done randomly. For example, if a particular region has 5 consulting teams, one of these teams corresponding to a random number between 1 and 5 was selected. This process was repeated for each of the NYSDOT regions till 20 inspection teams were identified. One inspection team was selected from the NYSDOT main office in Albany. Before finalizing inspection teams for the study, all selected inspection teams were contacted for their agreement to participate in the study. A few consulting teams declined to participate because of their disagreement with payment terms and were replaced by other teams in the same region.

Since each of the inspection teams carried out the inspection of each of the 4 bridges, assignment of inspectors mostly involved the logistics and the availability of inspection teams. All inspections were carried out during the period of July 29, 2010 to December 20, 2010. Inspection teams were scheduled such that any one bridge was inspected by only one team on a particular day.

2.4. CONSISTENCY OF BRIDGE INSPECTION PROGRAM AND PROCEDURES

Consistency of the bridge inspection program of NYSDOT has been carried out through the quantitative analysis of the inspection data and qualitative analysis of the components of bridge inspection reports, e.g., photographs, notes, etc. In the FHWA study on the reliability of visual inspection of bridges [Moore et al. (2001)], reliability was evaluated with respect to control inspections (i.e., inspections by a team of selected expert inspectors). Since the inspection ratings by the expert team can also be subjective, the evaluation of consistency of the bridge inspection in this report has been carried out with respect to median ratings, which are less likely to be affected by the inspector subjectivity.

Using median ratings, consistency of ratings of bridge elements has been evaluated for the following 4 cases: (i) Where the ratings of a bridge elements is supposed to be between 7 to 1,

(ii) Where the rating of a bridge element is supposed to be 8 (iii) Where the rating of a bridge element is supposed to be 9 and (iv) Team Consistency. For the first case when ratings are supposed to be between 7 to 1, consistency is evaluated as a percentage of inspectors who rated the element within ±1 of the median ratings. For second and third cases when ratings are supposed to be 8 or 9, consistency is evaluated as a percentage of inspectors who rated the element the same as the median rating. Team consistency has been evaluated to represent the percentage of consistent inspection for three cases described above for all elements of 4 bridges inspected. A more detailed description of the approach for the evaluation of consistency on inspection ratings is presented in the next Chapter.

In addition to the analysis of inspection ratings, the consistency of the bridge inspection program and procedures has also been done through a qualitative analysis of bridge inspection reports. This is based on existing optional Quality Control (QC) procedures available in the bridge inspection manual (BIM), which focuses on a documentation review of the bridge inspection reports. The research team performed analysis of the 80 inspection reports for 4 bridges using a scoring system based on this optional QC checklist. Additional analysis of the quality and consistency of the reports includes the analysis of notes and photographs in the reports, and consistency in reporting key damage modes identified during the inspections.

CHAPTER 3: EVALUATION OF THE CONSISTENCY OF BRIDGE INSPECTION RATINGS

3.1. INTRODUCTION

The main objective of the work done under this task was to implement the plan presented in the Chapter 2 for the inspection of 4 selected bridges by the team of 21 inspectors and to determine the consistency of the bridge inspection program and procedures based on statistical analysis of these inspection data. A detailed description of outcomes of the work is presented in the following.

3.1.1. Execution of the Inspection Program

The study consisted of inspection of 4 selected bridges by 21 inspection teams. Since each of the inspection teams carried out the inspection of all 4 bridges, assignment of inspectors mostly involved the logistics and their availability. All inspections were carried out during the period of July 29, 2010 to December 20, 2010. Bridge Identification Number (BIN) folders for the 4 bridges were obtained from the New York State Department of Transportation (NYSDOT) regional offices managing these bridges. All inspection teams were provided with the previous bridge inspection reports and other relevant information at least 3 weeks prior to their scheduled inspections.

Inspections were scheduled such that any one bridge was inspected by only one team on a particular day. If any of these 4 bridges underwent regular inspection in 2010, then the regular inspection report was used in such cases.

3.2. CONSISTENCY OF BRIDGE INSPECTION RATINGS

Consistency is defined as "the conformity with practices and procedures". The objective of the work carried out in this project has been to evaluate the consistency with which the bridge inspectors in New York State follow mandated inspection practices and procedures. In the FHWA study on the reliability of bridge inspections [Moore et al. (2001)], all inspection ratings were evaluated with respect to a reference inspection carried out by a team of expert inspectors. However, since the rating by a reference team could also be subjective, the consistency has been evaluated in this research with respect to the median ratings to minimize the effect of subjectivity on the consistency analysis, since the median rating represents the opinion of a majority of inspection teams and is less likely to be influenced by the inspector subjectivity. Considering the fact that the inspector subjectivity causing the variation of inspection ratings by ±1 is intrinsic and unavoidable to the inspection program, the following approach has been identified in discussions with the Technical Working Group (TWG) of the project to evaluate consistency of bridge inspection practices in New York State.

NYSDOT rates bridge elements on the scale of 7 to 1, 7 being new and 1 being failed. A rating of 8 is assigned to elements for which ratings 7 to 1 are not applicable, and a rating of 9 is assigned to elements whose condition and/or existence is unknown. Hence, the consistency analysis has been subdivided into 4 parts: (i) Consistency of elements whose ratings are supposed to be between 7 to 1, (ii) Consistency of elements whose ratings are supposed to be 8, and (iii) Consistency of elements whose ratings are supposed to be 9 and (iv) Team Consistency.

3.2.1. Consistency of Elements Whose Ratings are Supposed to be between 7 To 1

Consistency of inspection of elements rated on the scale of 7 to 1 can be evaluated as a percentage of inspectors that rated the bridge element within ±1 of the median rating. This median rating is calculated after removing ratings 8 or 9 that may have been assigned to these elements erroneously by some inspection teams. However, these erroneous ratings are used in the calculation of consistency. For example, if 20 teams rate an element at 6 and one rates it at 8, then the median rating will be based on the ratings by 20 teams and the consistency will be 95.2% (i.e., 20/21=0.952). Table 3-1 below illustrates the approach used for the evaluation of consistency of elements whose ratings are supposed to be between 7 and 1.

Table 3-1: Illustration of Approach for the Calculation of Consistency for Elements Whose Ratings are supposed to be between 7 and 1.

	Element		Median	Inspectors Rating Median		Inspectors Rating Median +1		Inspectors Rating Median -1		Inspectors Rating Median ≥ ±2		Consistency
				Number	%	Number	%	Number	%	Number	%	%
Abutment	Seats and Pedstals	Beg Abut	6	19	90.5	0	0.0	2	9.5	0	0.0%	100.0%
		End Abut	6	20	95.2	0	0.0	1	4.8	0	0.0%	100.0%
	Backwall	Beg Abut	6	20	95.2	0	0.0	1	4.8	0	0.0%	100.0%
		End Abut	6	20	95.2	0	0.0	1	4.8	0	0.0%	100.0%
	Stem(Breast wall)	Beg Abut	5	9	42.9	10	47.6	2	9.5	0	0.0%	100.0%
		End Abut	6	14	66.7	0	0.0	6	28.6	1	4.8%	95.2%
	Erosion or Scour	Beg Abut	5	17	81.0	1	4.8	3	14.3	0	0.0%	100.0%
		End Abut	5	17	81.0	1	4.8	3	14.3	0	0.0%	100.0%
	Footings	Beg Abut	5	21	100.0	0	0.0	0	0.0	0	0.0%	100.0%
		End Abut	5	18	85.7	0	0.0	3	14.3	0	0.0%	100.0%
	Recom.	Beg Abut	5	19	90.5	2	9.5	0	0.0	0	0.0%	100.0%
		End Abut	5	17	81.0	3	14.3	1	4.8	0	0.0%	100.0%

Using the approach illustrated in Table 3-1, the consistency of elements rated between 7 and 1 has been categorized into consistency ranges of 100%, 95-100%, 90-95%, 80-90% and less than 80% for each of the 4 bridges. Table 3-2 shows the percentage of elements rated in each consistency range for the 4 bridges and all bridges combined. For example, 75.44% for BIN 1026170 in Table 3-2 implies that 75.44% of all inspected elements of this bridge have a consistency of 100%. It is observed from the Table 3-2 that overall 72% of all inspected elements have a consistency of 100%, 90% have a consistency of at least 95% and 96% have a consistency of at least 90%. Among 4 bridges, BIN 1026970 has the best consistency, whereas BIN 3308970 has the worst consistency with 94.12% elements having a consistency of at least 90%.

Elements of all 4 bridges in a particular consistency range were merged together after eliminating duplicate elements to identify unique elements in that consistency range. Figure 3-1 shows the resulting bar chart for these 5 consistency ranges. In this figure, for example, elements under 95-100% consistency range were obtained by identifying all unique elements among elements of 4 bridges with a consistency in the range of 95-100%. It is observed from

Figure 3-1 that 39 unique elements have been rated at least once with a consistency of 100%, whereas 26 unique elements have been rated at least once with a consistency in the range of 95-100%, 10 in the range of 90-95%, 4 in the range of 80-90% and 3 below 80%.

Table 3-2: Percentage of Inspected Elements in Different Consistency Ranges For Elements Whose Ratings are supposed to be between 7 to 1.

Consistency Range	Percentages of Elements Rated in the Consistency Range				
	BIN 1026170	BIN 2205690	BIN 3308970	BIN 3350660	Overall for 4 Bridges Combined
100%	75.44%	69.44%	64.71%	74.60%	72.11%
95-100%	19.30%	19.44%	17.65%	15.87%	17.89%
90-95%	1.75%	5.56%	11.76%	7.94%	6.32%
80-90%	1.75%	2.78%	2.94%	1.59%	2.11%
<80%	1.75%	2.78%	2.94%	0.00%	1.58%
At least 95% (Rows 1 +2)	94.74%	88.88%	82.36%	90.47%	90.00%
At least 90% (Rows 1+2+3)	96.49%	94.44%	94.12%	98.41%	96.32%

These results clearly show that the bridge inspection program of New York State follows the bridge inspection guidelines and procedures with a high degree of consistency. Plots in Figure 3-2 show typical distribution of ratings with 100% and 95-100% consistencies. It is noted that the elements with 95% consistency have only one inspector rating the element at greater or less than median ±1 rating or rating other than 7 to 1. It has been observed from statistical analysis of ratings that standard deviation of ratings with 95-100% consistency is in the range of 0.5 to 0.75. This value is significantly below the assumed value of 0.94 used for determining the statistically sufficient sample size. This implies that the bridge inspection data used for consistency analysis is statistically sufficient.

All elements among 4 bridges rated with 95% consistency are presented in the Table A.1 in the Appendix A. This table shows the median rating, the inconsistent rating (i.e., the rating greater or less than median ±1 or rating other than 7 to 1) and the inspection team code assigning inconsistent ratings. It is observed from the Table A.1 that 34 elements had one inconsistent rating. Although 13 distinct teams out of 21 have assigned these inconsistent ratings, team S has assigned 12 out of 34 (approximately 35%) inconsistent ratings.

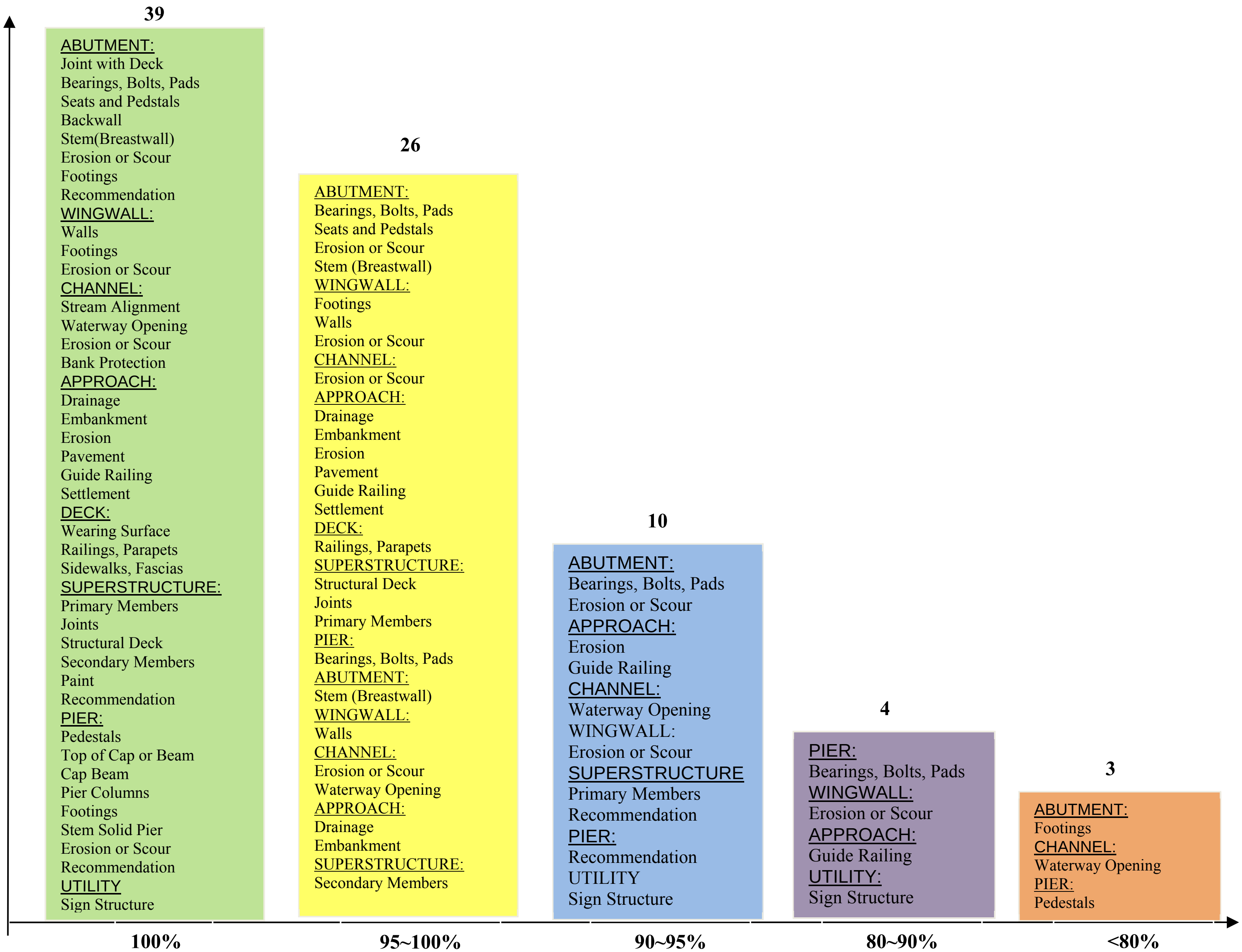


Figure 3-1: Unique Bridge Elements in Different Consistency Ranges for Bridge Elements Whose Ratings are supposed to be between 1and 7.

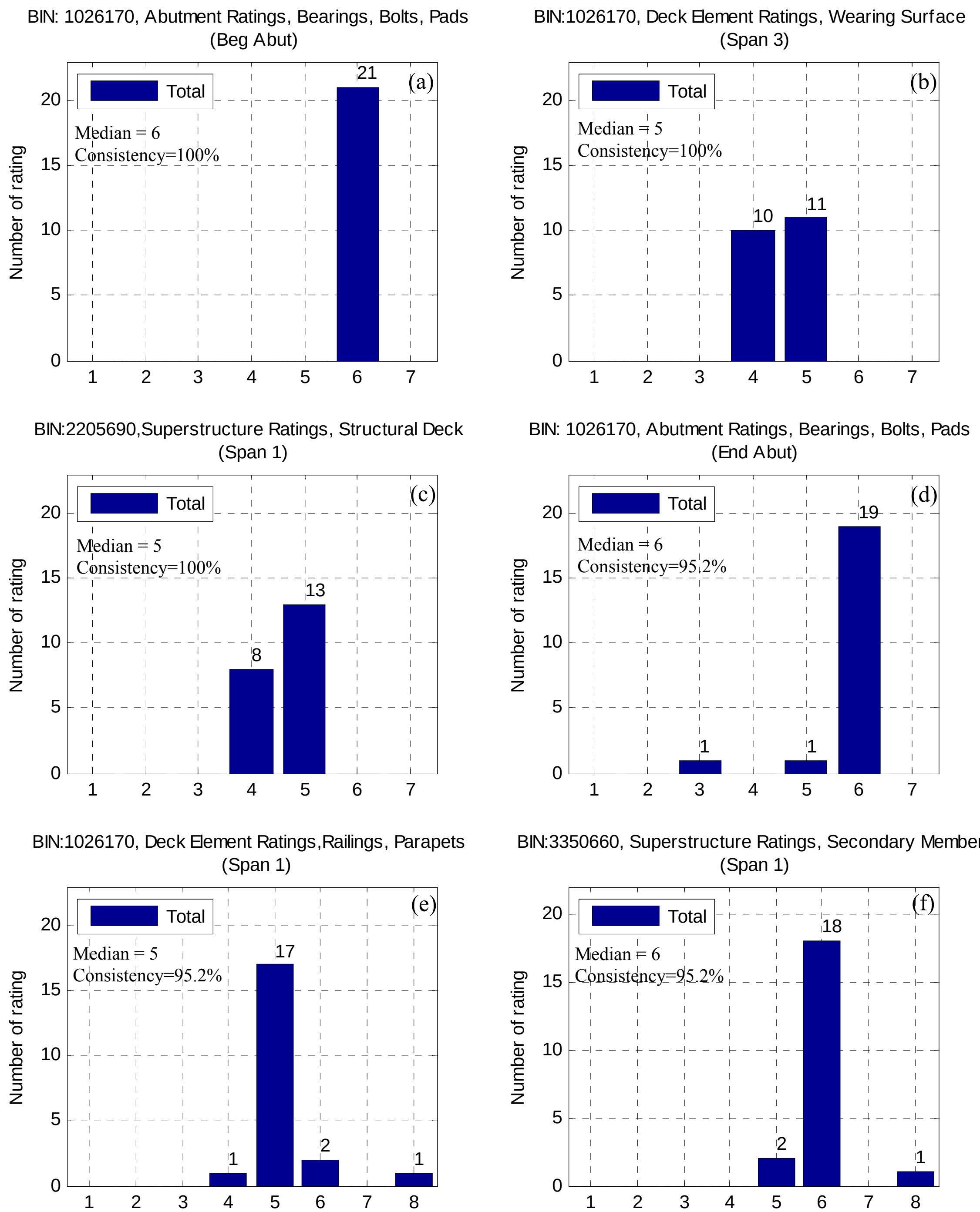


Figure 3-2: Representative Rating Distribution for Elements rated between 7 and 1 with 100% and 95-100% Consistency Ranges.

Several important observations can be made from the data in the Table A.1:

a. There seems to be confusion between Guide Railing (Approach) and Railing, and Parapet (Deck) elements. Team A has rated Guide Railing (approach) element. However, this team has assigned 8 rating to Railing, Parapet (Deck) element for all three spans of the BIN 1026170, although their photographs clearly show railings on all three spans. The same applies to rating of the Railing, and Parapet (Deck) element in the BIN 3308970 by the team K.

b. For BIN 3350660, while 20 inspectors have assigned a rating between 7 and 1 (median = 6) to secondary members, the team S has assigned a rating of 8. According to this team, there are no "Secondary Members" in the bridge. Transverse, diaphragm-like framing in the first interior bay on the left and right sides of the bridge are associated solely with the bridge railing system. This issue should be discussed during the Annual Bridge Inspector's Meeting.

c. Approach elements such as Drainage, Embankment and Erosion may have inconsistent ratings because of some inspectors considering the effects of vegetation in their ratings. These conditions may have changed during the study period. There may be little difference between ratings 5 and 7 for the Embankment element in the presence of vegetation. Bridge inspection manual doesn't discuss the effect of vegetation on ratings. For the Drainage element, one inspector has considered the pattern of flow of water (point flow instead of sheet flow) as a basis for low rating for drainage. This scenario also isn't discussed in the NYSDOT Bridge Inspection Manual, but may affect the rating of similar elements in other bridges during the regular bridge inspection program.

d. Erosion, Scour elements in abutment, wingwall and piers Footings (Wingwall) have inconsistent ratings because of some inspectors considering footings founded on bedrock and erosion caused because of abrasion. There was a concern during the analysis of ratings that these inconsistencies may have been caused because of variations in flow conditions during the study period. Inspection reports don't mention high water flow conditions. In fact, photographs show that inconsistent ratings are during low flow conditions.

e. Bearings, Bolts and Pads elements in the bridge 1026970 have inconsistent ratings because of one inspector identifying lateral distortion of up to 1 inch in bearings, although they note that this doesn't affect the performance. Based on the condition described, this element should have been rated 5 or 6 instead of a rating of 3. Bridge inspectors should be provided additional training on rating on such conditions during the annual bridge inspector's meeting.

f. Various components of Wingwall and Stem (End Abutment) elements in the bridge 3350660 have been rated low because of possible deterioration in wood plank sheathing and opening in wingwalls. Since this condition was observed on September 16, 2010, it is unlikely that the repair was done during the study period.

g. A Primary Element (superstructure) with a median rating of 4 has been rated 6 by the team H because of a crack in the weld between the railing plate and bottom flange of the primary member. Other 20 inspectors have rated this element at 4 because of this crack, even though the crack didn't affect the primary member as a system, as noted by the team H. Rating by 20 inspectors points to their lower risk tolerance (because of the presence of cracks), whereas rating by the team H points to a reasonable engineering decision. Bridge inspection manual should discuss the rating of members when a crack in connecting members doesn't affect the performance of members being rated.

The bar chart in Figure 3-1 shows that only 10 unique types of elements have a consistency in the range of 90-95%. Typical distributions of ratings of elements for this case are shown in plots in Figure 3-3. For elements in this consistency range, while 19 out of 21 inspectors have rated elements within ±1 of the median, only two inspectors have rated at greater or less than the median ±1 or have assigned a rating other than 7 to 1. It has been observed from the statistical analysis of ratings for this case that the standard deviations of ratings of elements in this consistency range vary from 0.64 to 0.85. These values are smaller than the assumed value of 0.94 in determining the number of statistically sufficient inspection data. Hence, inspection data for elements in the consistency range of 90-95% are statistically sufficient to represent the consistency of the state bridge inspection program.

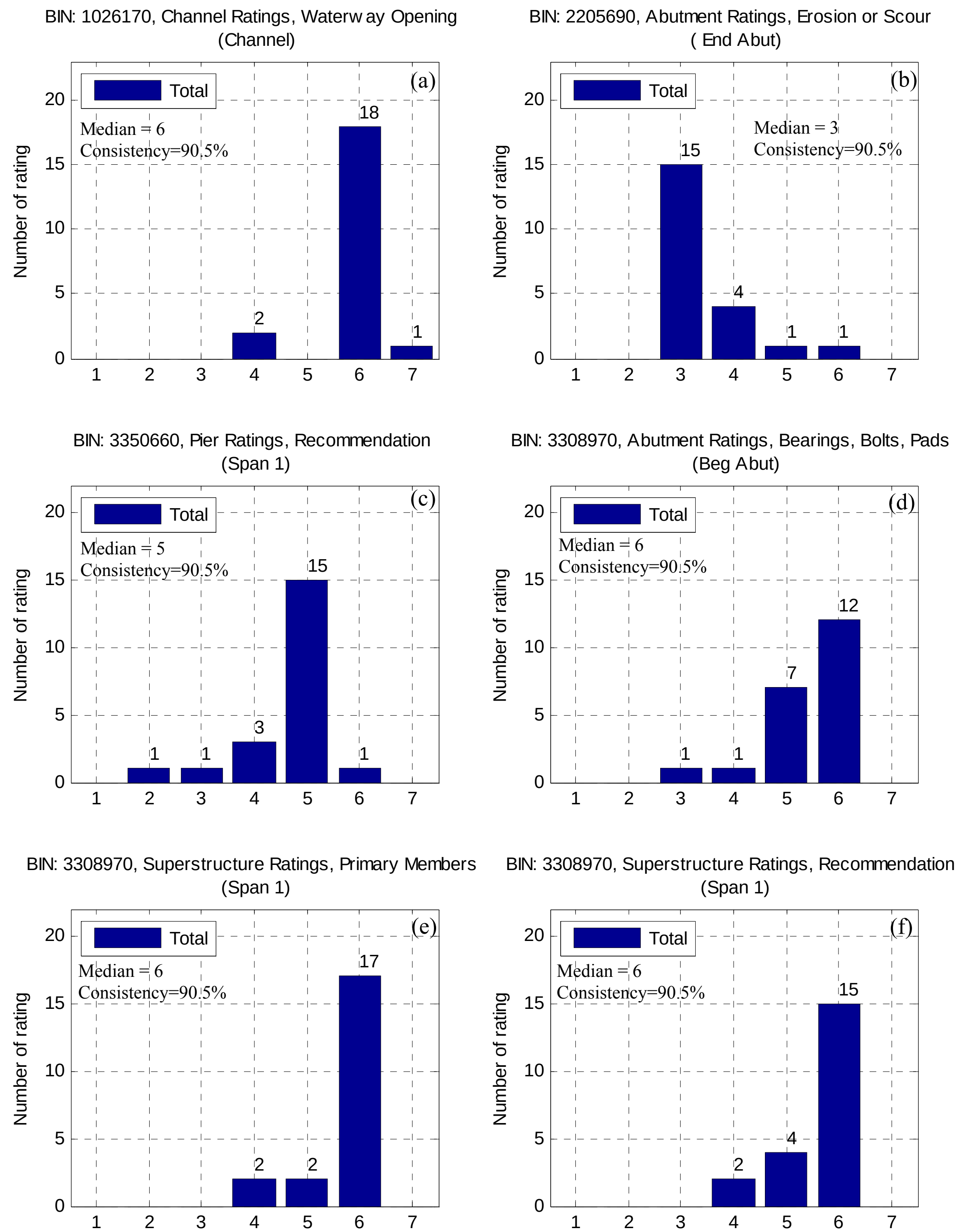


Figure 3-3: Representative Rating Distribution for Elements in the Consistency Range of 90-95%.

Teams assigning multiple numbers of inconsistent ratings are: team S assigning 4 inconsistent ratings, teams W and D each assigning 3 inconsistent ratings and teams G, P C, F, and J each assigning 2 inconsistent ratings. Several important observations can be made from the data in Table A.2:

a. For BIN 2205690, erosion or scour (Abutment, Wingwall) elements have the median rating of 3. These elements have been assigned higher ratings by teams D and G because of the footing being founded on bedrock. None of the inspection reports mention high flow conditions during inspections.
b. For BIN 3308970, Bearings, Bolts, Pads (Abutments) have been rated lower than the median rating of 6 because of conditions such as minor lifting of girders due to differential settlement or pack rust. This condition could have been rated 5, which would have been in the consistent rating category. The NYSDOT Bridge Inspection Manual should include instructions on rating of Bearing elements in such conditions.
c. For BIN 3308970, Primary members (substructure) have been assigned rating of 4 because of a crack in diaphragm (x bracing) even though these cracks haven't propagated into the girders. The ratings for these elements should have been 6, since primary members are in good condition. This issue has also been discussed for the case of 95% consistency previously.
d. For BIN 3308970, Superstructure recommendations have been assigned a rating of 4 without any note.
e. For BIN 3350660, Ratings of 2 or 3 have been assigned for Pier Recommendation without any notes.

It is observed from Figure 3-1 that only 4 types of bridge elements have been rated with the consistency in the range of 80-90%. These elements are: Bearings, Bolts, Pads (Pier), Erosion or Scour (Wingwall), Guide Railing (Approach) and Sign Structure (Utility). Distributions of ratings for these elements are shown in plots in Figure 3-4. A significant variability in the ratings of these elements is observed from these figures. The standard deviations of ratings for this case have been observed to vary from 0.91 to 1.37. However, only two elements have the standard deviation higher than 0.94.

All elements among 4 bridges in the consistency range of 80-90% are categorized in the Table A.3 in the Appendix A. For this case, 4 elements have been assigned inconsistent ratings by 15 teams that include 10 distinct teams. It should be noted that these inconsistent ratings only represent a maximum of 4 out of 21 (or 19%) ratings for each of the 4 elements. Teams assigning multiple numbers of inconsistent ratings are: team H assigning 3 inconsistent ratings, and teams F, J and T each assigning 2 inconsistent ratings. Several important observations can be made from the data in the Table A.3:

a. For BIN 1026970, Bearings, Bolts, Pads (Pier) have a median rating of 6. These elements have been assigned significantly lower ratings by 4 teams because of minor distortion / movement of bearings. Notes and photographs in inspection reports don't justify these ratings. The NYSDOT Bridge Inspection Manual should discuss the effects of bearing movement on ratings.
b. For BIN 3350660, Erosion or Scour (Wingwall, End Abut) elements have been rated lower than the median rating of 5 by teams B, H, S and T because of undermining. Inspection reports don't note high water flow condition during these inspections.

c. For BIN 2205690, the inconsistency in the rating of Sign Structure (Utility) element may be attributed to a repair in the sign structure during the study period.
d. For BIN 3308970, inconsistency in the Guide Railing (Approach) element is because of two teams assigning ratings for conditions not discussed in the NYSDOT Bridge Inspection Manual: (i) Substandard guide rails and (ii) Presence of tall berms of dirt near guide rails. These issues should either be included in the NYSDOT Bridge Inspection Manual or the bridge inspectors should be advised to rate as per the manual and issue maintenance requests for such conditions.

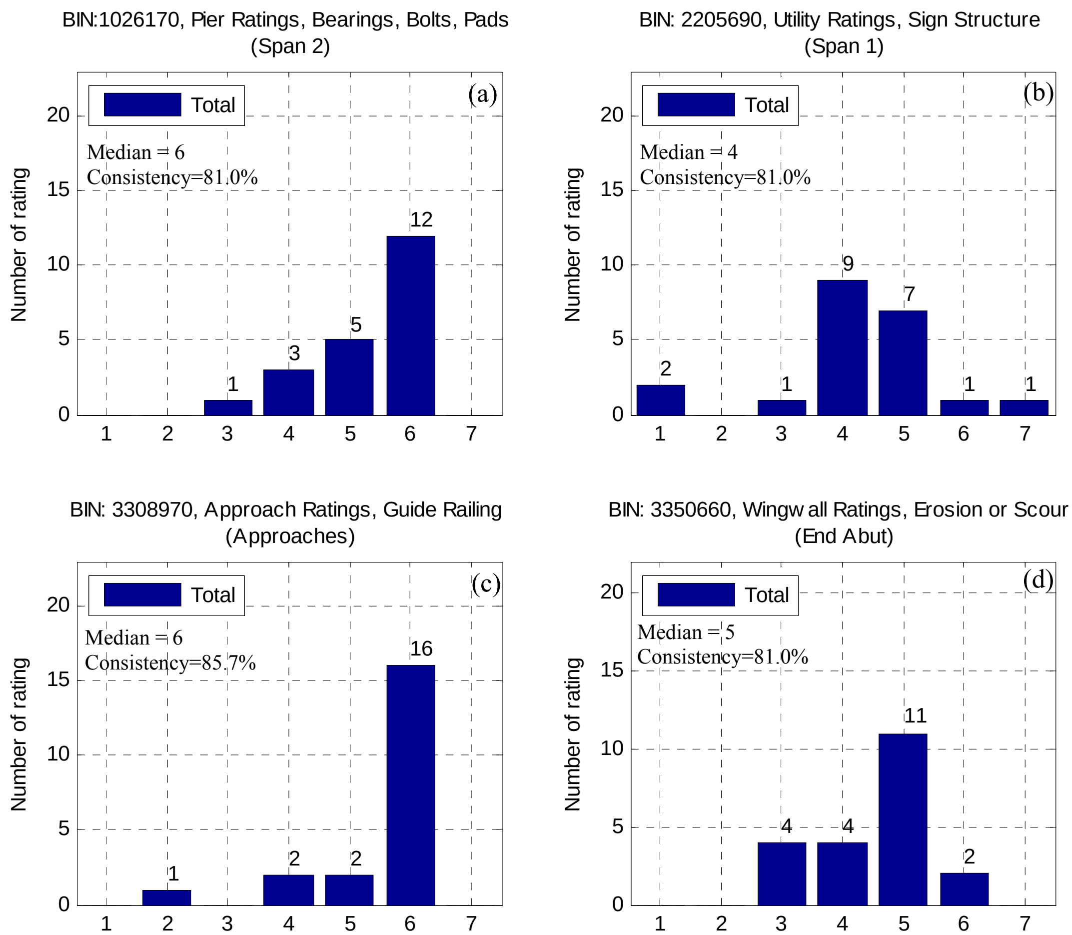


Figure 3-4: Representative Rating Distribution for Elements Rated between 7 to 1 with Consistency of 80-90%.

Only three elements in the Figure 3-1 (Abutment Footings, Waterway Opening and Pier Pedestals) have been rated with a consistency below 80% for bridges 1026170, 2205690 and 3308970, although Abutment Footings and Pier Pedestals have also been rated with a consistency of 100% for bridges 2205690 and 1026170, respectively. Particularly, pier pedestals in span 1 of the bridge 1026170 have been rated with a consistency of 100%, whereas those in span 2 have been rated with a consistency of less than 80%. Figure 3-5(a) shows the distribution of ratings for the pier pedestals in the span 2 of the bridge 1026170. It is observed that median rating for this element is 6, which was rated by 12 inspectors. However, 8 inspectors rated it 4 and 1 inspector rated it 5.

A detailed review of notes and photographs in the bridge inspection reports was carried out to identify the factors responsible for these inconsistencies. It has been noted from inspection reports that all pier pedestals in this bridge underwent FRP wrapping before the study period. Hence, all pedestals in the span 1 were in good condition and were rated 6 by all inspectors. On the other hand, 9 inspectors observed two small and shallow spalls of size 10”×2.5” on the begin face of the pedestal 12 at the pier 2. The right side spall was seen to have developed around a vertical crack that started at the right edge of the bearing. The concrete within the spalls was found to be soft. Several inspectors estimated the spall undermining the bearing by approximately 10%. Figure 3-6 shows the picture of the spalled portion of the pedestal 12 at the pier 2 that was included in their inspection report by the team W. It should be noted that these 9 inspectors also felt that all other pier pedestals in the span 2 could be rated 6. Hence, lower level of consistency is because of 12 inspectors not inspecting all pier pedestals in the span 2 of the bridge to determine the worst rating.

Figure 3-5(b) shows the distribution of ratings for the waterway opening (channel) for the bridge 2205690. It is observed that 15 inspectors rated this element at the median rating of 3. However, 4 inspectors rated it at 5, 1 at 6 and 1 at 7. It has been noted from inspection reports that 15 inspectors rated the waterway opening at 3 because of the following or similar condition for the waterway opening:

> “The upstream channel approaches the bridge at a 45 degree skew towards the begin right wingwall and along the begin stem. The substructures protrude into channel 10 to 12 ft. Constriction scour and alignment has caused erosion along the substructures and banks. There is no significant debris in the channel”.

Figure 3-7 shows photographs representing the above observation. Figure 3-8 shows the sketch of the site illustrating the hydraulic constriction. It has been noted from the inspection report that 6 inspectors rating the waterway opening at 5 or higher rating didn’t document this condition. Rather, they based their rating on the absence of the debris or sufficiency of the opening for the flow. In fact, one inspector upgraded the rating to 7 because the degraded channel bed seems to be allowing for greater hydraulic capacity than was originally designed for. This issue can again be addressed through training during the annual bridge inspector’s meeting since the NYSDOT bridge inspection manual requires considering hydraulic constriction in the rating of waterway opening.

Figure 3-5(c) shows distribution of ratings for Footings (Abutment) for the bridge 3308970. The median rating for this element is 4. It is observed that only 12 inspectors have rated this element at the median. More concerning is the fact that 9 inspectors have rated this element at 9, whereas the median rating is 4. Review of inspection reports shows that the rating of 4 by 12 inspectors was based on a crack in the begin stem which may be an indication of the footing movement, although the footing is buried and not visible for inspection.

This can be further understood from the following typical comment by most of the bridge inspectors rating the footing at 4 and photograph of the crack in the Figure 3-9:

> “The begin stem is cracked through vertically full height below G4. The crack is open to 1/16" @ the base and 1/8" at mid - height, and then branches into multiple cracks near the top. The concrete between the cracks at the top below G4 sounds hollow. The crack may be an indication of footing movement (The footing is buried and not visible for inspection)”.

Remaining 9 inspectors have rated this element at 9 simply because of footing not being visible, although two of them did note the possibility of footing movement because of the stem crack. This kind of variability can be addressed by discussing cases such as this during the annual bridge inspector's meeting. Appropriate modifications in the bridge inspection manual about the rating of footings because of the possibility of footing movement will also be effective in improving the consistency of the regular bridge inspection program.

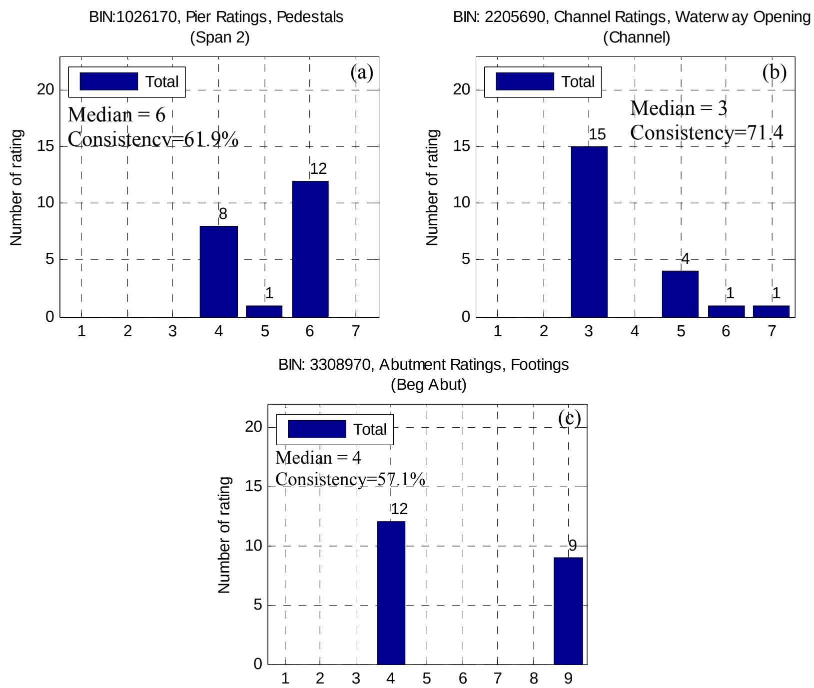


Figure 3-5: Representative Rating Distribution for Elements Rated 7 to 1 with Less than 80% Consistency.

Figure 3-6: Spalled Portion of the Pedestal 12 at the Pier 2 in the Bridge 1026170.

Figure 3-7: Photographs Showing Substructures of Bridge 2205690 Protruding into the Channel.

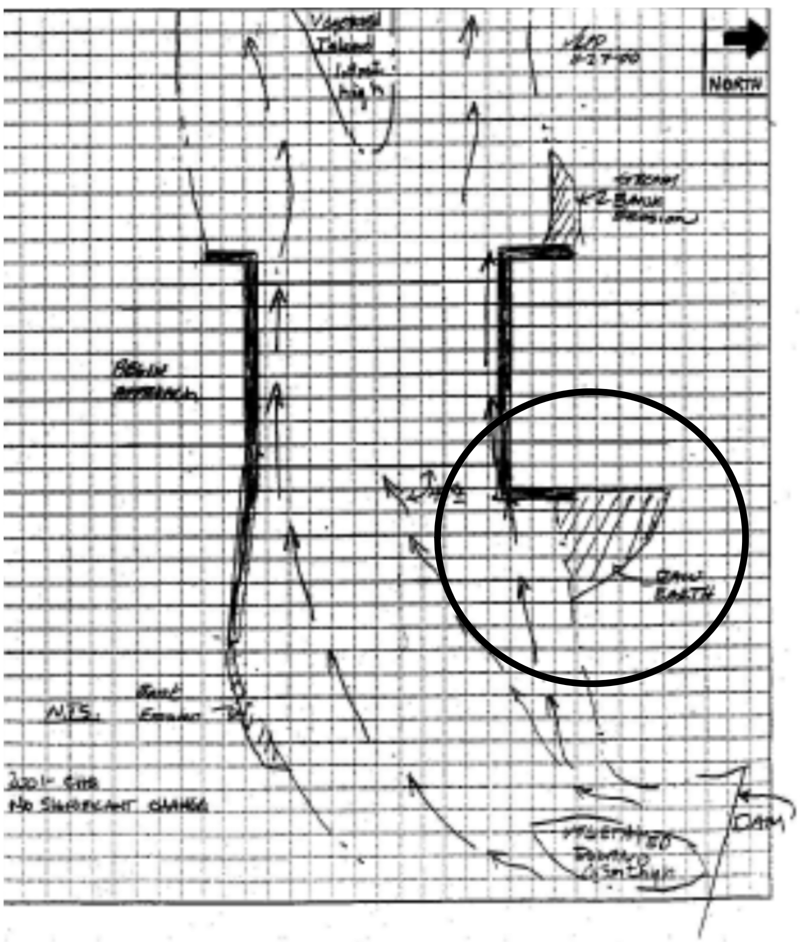


Figure 3-8: Sketch Illustrating Hydraulic Constriction in the Waterway Opening of the Bridge 2205690.

Figure 3-9: Photographs Showing Cracks in the Begin Stem of the Bridge 3308970.

3.2.2. Consistency of Elements Whose Ratings are Supposed to be 8

A rating of 8 is assigned to elements for which ratings 7 to 1 are "not applicable". Consistency of bridge elements whose rating is supposed to be 8 is calculated as a percentage of inspectors who have assigned a rating 8 to such elements. Table 3-3 below illustrates the approach for the calculation of consistency of bridge elements whose rating is supposed to be 8.

It has been observed from the calculation of consistency that the minimum consistency in this case is 85.70%. Hence, a chart similar to that in Figure 3-1 has been created by identifying unique elements in consistency ranges of 100%, 95-100% and 80-90% and is shown in Figure 3-10. It is observed from the chart in Figure 3-10 that while 27 unique elements types have been rated with 100% consistency, only 8 have been rated with 95-100% and only 2 with 80-90% consistency.

Similar to the Table 3-2, Table 3-4 shows percentage of elements rated in each consistency range for each of the 4 bridges and all 4 bridges combined. It is observed that the bridges 1026170, 2205690 and 3308970 have more than 90% elements inspected with a consistency of 100%. Bridge 3350660 has only 76.92% inspected elements with a consistency of 100%. Among all 4 bridges, 87.76% of all inspected elements, whose rating is supposed to be 8, have been inspected with a consistency of 100%. It is further observed from the Table 3-4 that overall 93.20% elements have a consistency of at least 95% and 96.6% elements have a consistency of at least 90%. These results show that the inspection of elements with ratings 8 is also highly consistent.

Figures 3-11 and 3-12 show rating distributions of selected elements for this case in consistency ranges of 100% and 90-100%, respectively. For the cases of 90-100% consistency, it is observed that while 20 inspectors have rated a bridge element 8, only 1 inspector has assigned it a rating of either 9 or a rating between 7 and 1.

Only two elements (mono deck surface and stem solid pier) have a consistency in the range of 80-90%. Distributions of ratings for these two elements are shown in Figure 3-12. It is observed that the lower consistency of 85.7% is caused because of three teams assigning a rating between 7 and 1 to an element that is supposed to be rated 8.

Table 3-3: Illustration of the Approach for the Calculation of Consistency for a Bridge Element Whose Rating is supposed to be 8.

	Element		Median	Inspectors Rating 8		Inspectors Rating 9		Inspectors Rating 7 to 1		Consistency
				Number	%	Number	%	Number	%	%
Abutment	Joint with Deck	Beg Abut	8	21	100.0%	0	0.0%	0	0.0%	100.0%
		End Abut	8	21	100.0%	0	0.0%	0	0.0%	100.0%
	Bearings, Bolts, Pads	Beg Abut	8	20	95.2%	1	4.8%	0	0.0%	95.2%
		End Abut	8	20	95.2%	1	4.8%	0	0.0%	95.2%
	Piles	Beg Abut	8	19	90.5%	1	4.8%	1	4.8%	90.5%
		End Abut	8	19	90.5%	1	4.8%	1	4.8%	90.5%

Table 3-4: Percentage of Inspected Elements in Different Consistency Ranges for Bridge Elements Whose Rating is supposed to be 8.

Consistency Range	Percentages of Elements Rated in the Consistency Range				
	BIN 1026170	BIN 2205690	BIN 3308970	BIN 3350660	Average of 4 Bridges
100%	93.75%	96.00%	90.91%	76.92%	87.76%
95-100%	0.00%	0.00%	9.09%	11.54%	5.44%
90-95%	0.00%	4.00%	0.00%	7.69%	3.40%
80-90%	6.25%	0.00%	0.00%	3.85%	3.40%
At Least 95%	93.75%	96.00%	100%	88.46%	93.20%
At Least 90%	93.75%	100%	100%	96.15%	96.60%

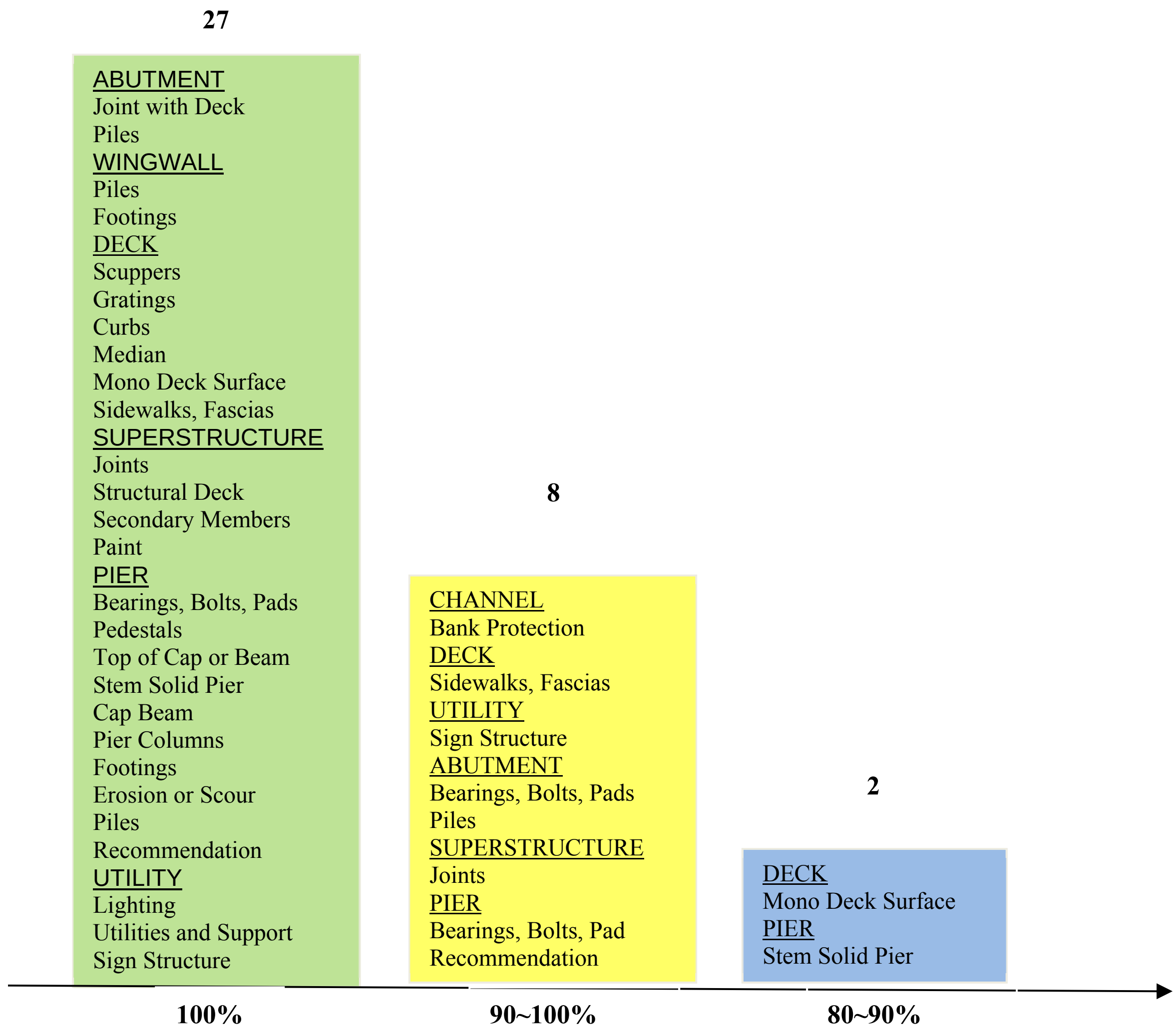


Figure 3-10: Unique Bridge Elements Types in Different Consistency Ranges for Bridge Elements Whose Rating is supposed to be 8.

All elements of 4 bridges with consistency less than 100% are categorized in the Table A.4 in the Appendix A for this case. It is observed that 18 elements (Mono Deck Surface for the bridge 1026970 for three spans have been counted as 3) have been assigned inconsistent ratings by 11 distinct teams out of 21 teams. Teams assigning multiple numbers of inconsistent ratings are: team U assigning 5 inconsistent ratings, team N assigning 4 inconsistent ratings, and teams J, Q and F each assigning 2 inconsistent ratings. Several important observations can be made from the data in the Table A.4. Discussing these observations during the NYSDOT annual bridge inspector's meeting may be effective in improving the consistency during regular inspections.

a. For BIN 1026970, Mono Deck Surface elements for all three spans have a median rating of 8. Teams D, H and N have assigned ratings 4, 6 and 7 to these elements in the three spans.

b. For BIN 2205690, 19 inspectors have considered Bank Protection (Channel) not applicable. However, teams U and W have considered right wingwall scour apron as the Bank Protection (Channel) element. This component of the bridge has been rated as Footing by other inspectors. Based on the photographs and the rating by the W team, 19 inspectors seem to be inconsistent with the NYSDOT Bridge Inspection Manual.

c. For BIN 3308970, sidewalk / Fascias (Deck) has been assigned a rating of 6 by the team K. Photographs show that there is no separate sidewalk. The inspector is rating the deck surface between the railing and the white traffic line as a sidewalk.

d. For BIN 3308970, Team J has rated Sign Structure (Utility) as 1 instead of 8 because of the absence of signs at the point of narrowing of the usable shoulders (see Figure 3-13). The rating in this case should have been 8, i.e., sign structure isn't needed since the narrowing shoulder is clearly visible to the traffic in both directions.

e. For BIN 3350660, Bearings, Bolts, Pads (Pier) have median ratings of 8. Team M has changed the rating for this element from 8 to 6 without any note. Team Q has changed the rating from 8 to 5 based on the rating of the weld between the girder and the cap beam with the following note "Girders were welded to the top of the cap beam at each pier. All bearing welds were in "5" or better condition at each pier".

f. For BIN 3350660, Bearings, Bolts, Pads (Beg & End Abutment) have a median rating of 8. Team Q has assigned a rating of 9 because of end of the girders being encased behind the backwall elements at each abutment, thereby making the bearing areas were not visible for inspection.

g. For BIN 3350660, Piles (Abutment) elements have median ratings of 8. Team B has assigned 9 rating because of plans not being available. Team U has assigned rating 5 based on the condition of timber piles at abutment stem / wingwall corners.

h. The bridge 3350660 is a Steel Continuous - Stringer/Multi-Beam or Girder bridge, although some girders are simply supported. One inspection team has rated Joints (Superstructure, Spans 1, 2) of this bridge as 3 instead of 8 because of a crack in the wearing surface (See Figure 3-14). Since the superstructure is continuous, superstructure joints in spans 1 and 2 should have been rated 8 as per the NYSDOT Bridge Inspection Manual. Another inspection team has rated the joint in the span 3 as Joints (Superstructure). The joint in the span 3 is required to be rated as Joint with Deck (Abutment).

i. For BIN 3350660, Bearings, Bolts and Pads (Pier) elements in spans 1 and 2 with median ratings of 8 have been rated 5 and 6 by two inspection teams. As per the NYSDOT Bridge Inspection Manual, "where stringers frame directly into the web of cap beams without seated connections, rate Bearings, Bolts and Pads 8". One of the inspection teams notes that the girders were welded to the top of the cap beam and still rates it 5.

j. For BIN 3350660, Stem solid pier (pier) has a median rating of 8. However, three teams have assigned ratings between 7 and 1 based on Fig. 4D.5.2 in the Bridge Inspection Manual. This section defines stem solid pier as the section below the pier columns, but above the footing. In this case, the teams have identified a steel beam placed horizontally on the concrete footing as the stem solid pier. If this is correct, then the rating of 8 by 18 teams will be inconsistent. This issue should be clarified during the annual bridge inspector's meeting.

k. For BIN 3350660, a team has assigned Recommendation (Pier, Span 3) a rating of 5, even though all elements of the pier for the span 3 have been rated 8. This element should have been rated 8.

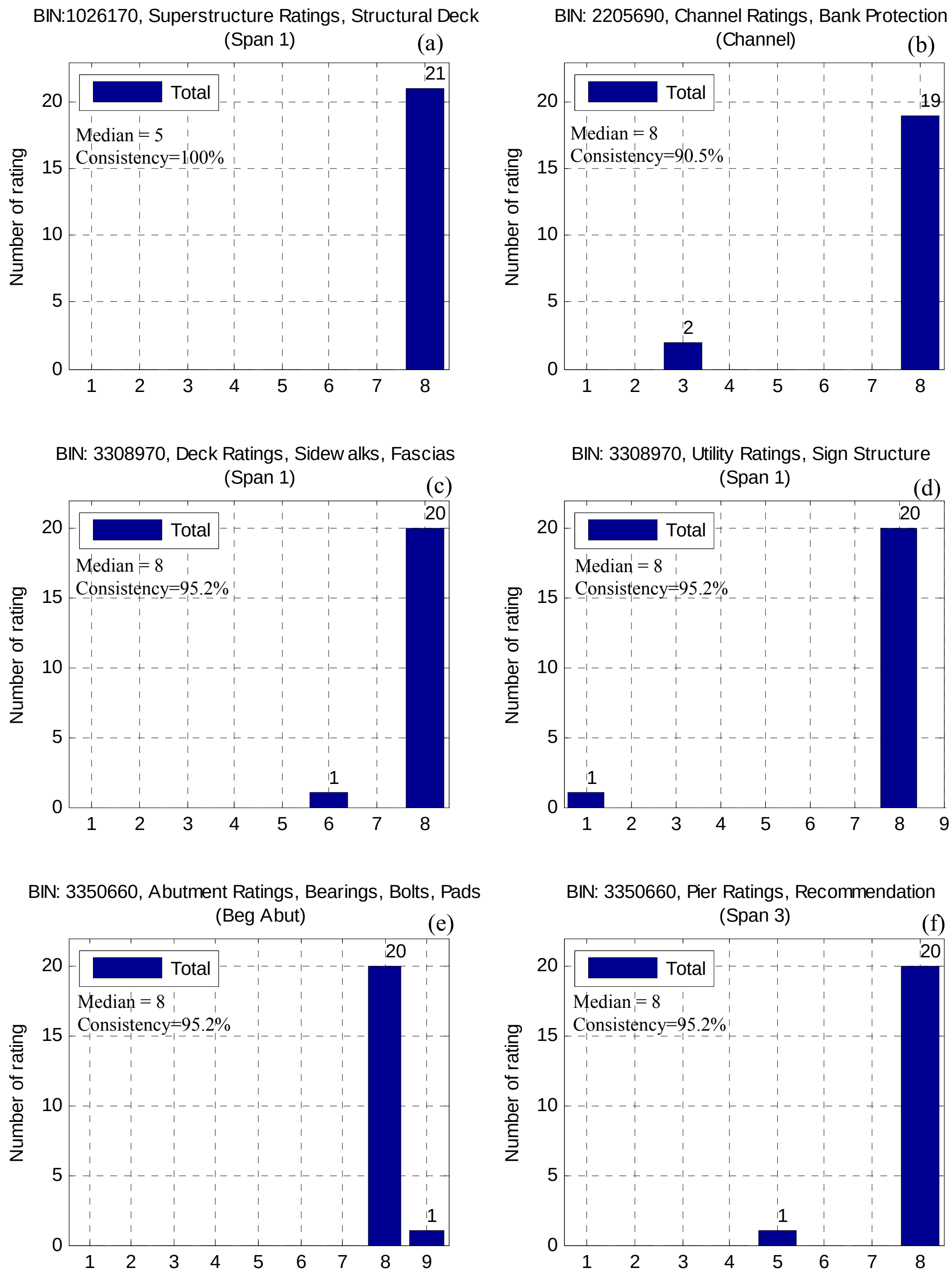


Figure 3-11: Representative Rating Distribution for Elements with 100% and 90-100% Consistency Ranges.

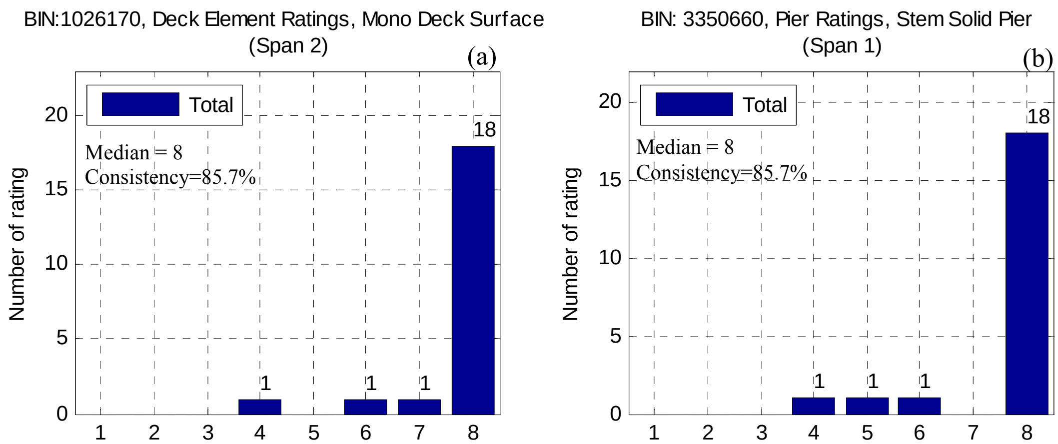


Figure 3-12: Representative Rating Distribution for Elements with 80-90% Consistency.

Figure 3-13: Narrowing of Usable Shoulders in the Bridge 3308970.

Figure 3-14: Crack in the Wearing Surface of the Bridge 3350660.

Some of the issues identified above cause inconsistent rating by only one inspector. However, these issues may be affecting the inspection of large number of bridges during the regular inspection cycle. Hence, pro-active actions on these issues through clarification in the NYSDOT Bridge Inspection Manual and through discussions during the annual bridge inspector's meeting will be effective in improving the consistency of elements that are supposed to be rated 8.

3.2.3. Consistency of Elements Whose Ratings are Supposed to be 9

A rating of 9 is assigned to elements whose "condition and/or existence is unknown". The consistency of bridge elements whose rating is supposed to be 9 is calculated as a percentage of inspectors who have assigned a rating of 9 to such elements. Table 3-5 below illustrates the approach for the calculation of consistency of elements whose rating is supposed to be 9.

Table 3-6 shows percentages of inspected elements of 4 bridges in different consistency ranges. It is observed that all the elements of bridges 1026170, 2205690 and 3308970 have a consistency of at least 95%. On the other hand, all elements of the bridge 3350660 have consistency in the range of 80-90%.

Table 3-5: Illustration of the Approach for the Calculation of Consistency for a Bridge element Whose Rating is supposed to be 9.

	Element		Median	Inspectors Rating 9		Inspectors Rating 8		Inspectors Rating 1 through 7		Consistency
				Number	%	Number	%	Number	%	%
Abutment	Footings	Beg Abut	9	21	100.0%	0	0.0%	0	0.0%	100.0%
		End Abut	9	21	100.0%	0	0.0%	0	0.0%	100.0%
	Piles	Beg Abut	9	21	100.0%	0	0.0%	0	0.0%	100.0%
		End Abut	9	20	95.2%	1	4.8%	0	0.0%	95.2%

Table 3-6: Percentage of Inspected Elements in Different Consistency Ranges for Bridge Elements Whose Rating is supposed to be 9.

Consistency Range	Percentages of Elements Rated in the Consistency Range				
	BIN 1026170	BIN 2205690	BIN 3308970	BIN 3350660	Overall for 4 Bridges
100%	91.67%	100.00%	42.86%	0.00%	69.57%
95-100%	8.33%	0.00%	57.14%	0.00%	21.73%
90-95%	0.00%	0.00%	0.00%	0.00%	0.00%
80-90%	0.00%	0.00%	0.00%	100.00%	8.70%
At Least 95% (Rows 1 +2)	100.00%	100.00%	100.00%	0.00%	91.30%
At Least 90% (Rows 1+2+3)	---	----	----	0.00%	91.30%

Figure 3-15 shows the chart of unique bridge elements in different consistency ranges when the rating is supposed to be 9. It is observed from the chart in Figure 3-15 that seven elements have been rated with a consistency of 100%, whereas two have been rated with a consistency in the range of 90-100% and one in the range of 80-90%. Elements rated with less than 100% consistency are Piles (Abutment) and Piles (Wingwalls). Figure 3-16 shows rating distributions for bridge elements in different consistency ranges. It is observed that the loss of consistency in this case is caused by inspectors rating an element 8 ("Not Applicable") instead of 9.

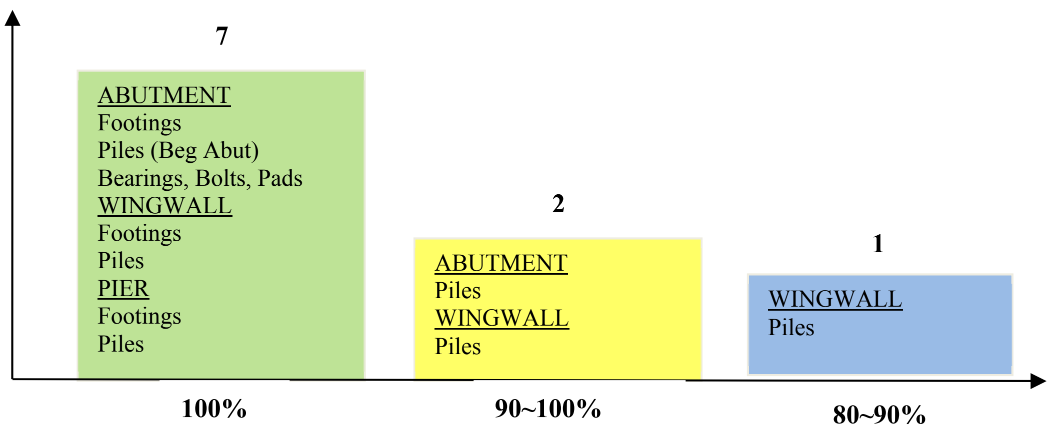


Figure 3-15: Elements in Different Consistency Ranges When they are supposed to be Rated 9.

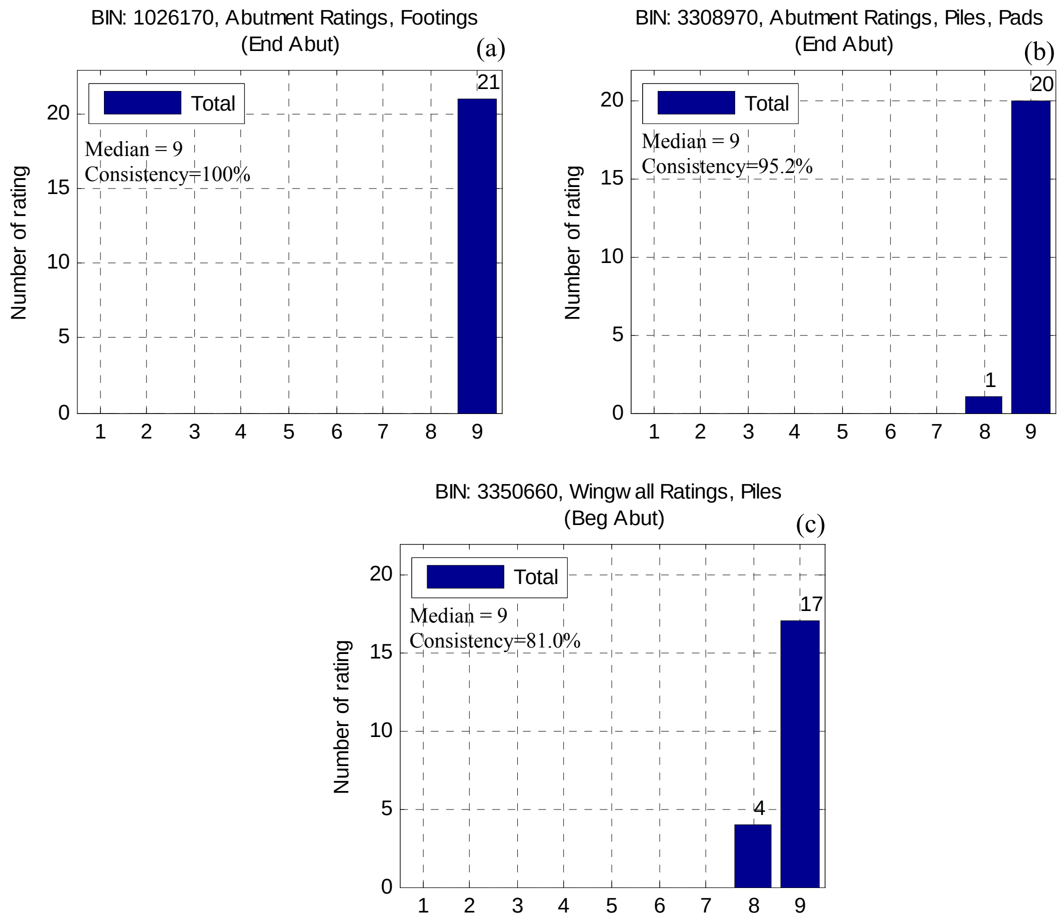


Figure 3-16: Representative Rating Distribution for Elements with 100%, 90-100% and 80-90% Consistency Ranges Whose Rating is supposed to be 9.

All elements of 4 bridges with a consistency less than 100% for elements are categorized in the Table A.5 in the Appendix A for this case. It is observed that 7 elements (Beg and End abutment elements have been counted as 2) have been assigned inconsistent ratings by 12 teams, including 6 distinct teams. Teams assigning multiple numbers of inconsistent ratings are: teams L, B, H and W assigning 2 inconsistent ratings each.

It is observed from the data in the Table A.5 that Piles (Wingwall) and Piles (Abutment) elements in bridges 3308970 and 3350660 have a median rating of 9. These elements have been assigned a rating of 8 by many teams, including the team W. According to inventory, there are no piles. Emphasis on the review of the bridge inventory data before the inspection should be emphasized during the annual bridge inspector's meeting.

3.2.4. Team Consistency

The consistency of a particular inspection team is evaluated as percentage of inspections of all elements where the rating assigned by a team is within ±1 of the median rating when the rating is supposed to be 7 to 1, or 8 or 9 when the rating is supposed to be 8 or 9. Bar plot in Figure 3-17 shows histogram of consistency of inspection teams A to W for 4 bridges. Average consistency is calculated as the average of team consistencies for 4 bridges. Figure 3-18 shows average consistency for the 4 bridges in this study. For bridges 1026170, 2205690, 3308970 and

3350660, minimum values of team consistency are approximately 95%, 90%, 94% and 93%, respectively. Hence, all inspection teams have an average consistency higher than 90%. Overall, average team consistency for 21 inspection teams is approximately 98%. Further improvements in the team consistency can be achieved by addressing issues identified previously with the inspection of various bridge elements.

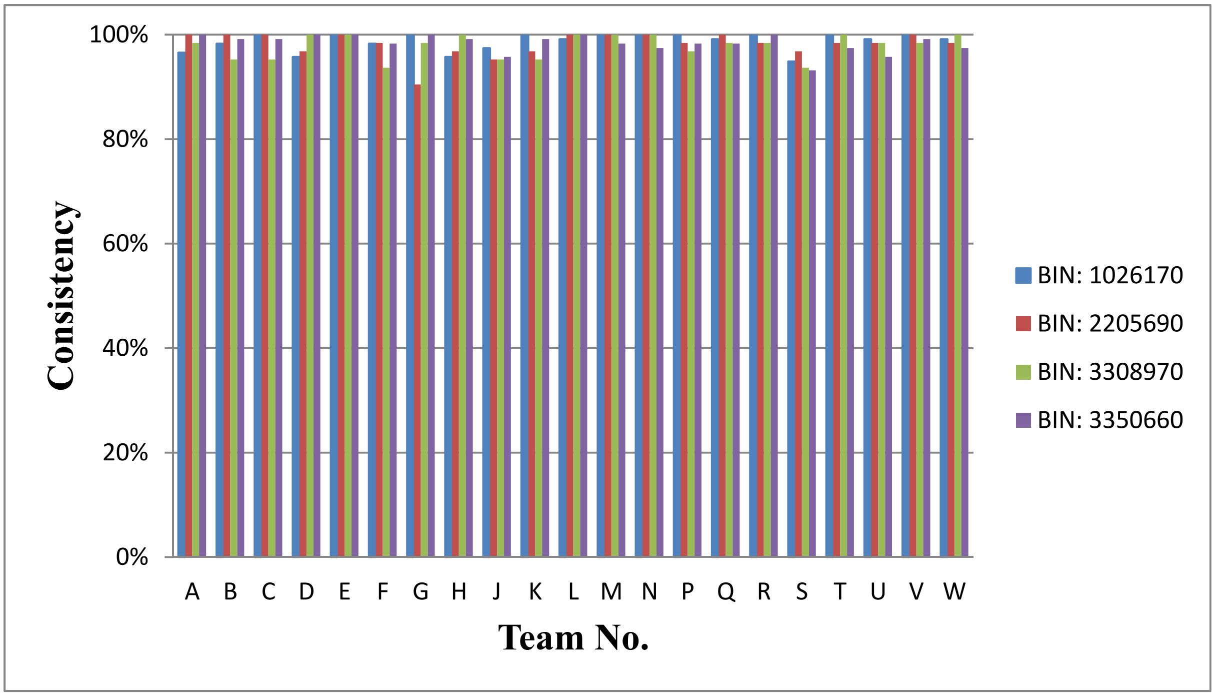


Figure 3-17: Team Consistency of Inspection Teams during the Inspection of 4 Bridges.

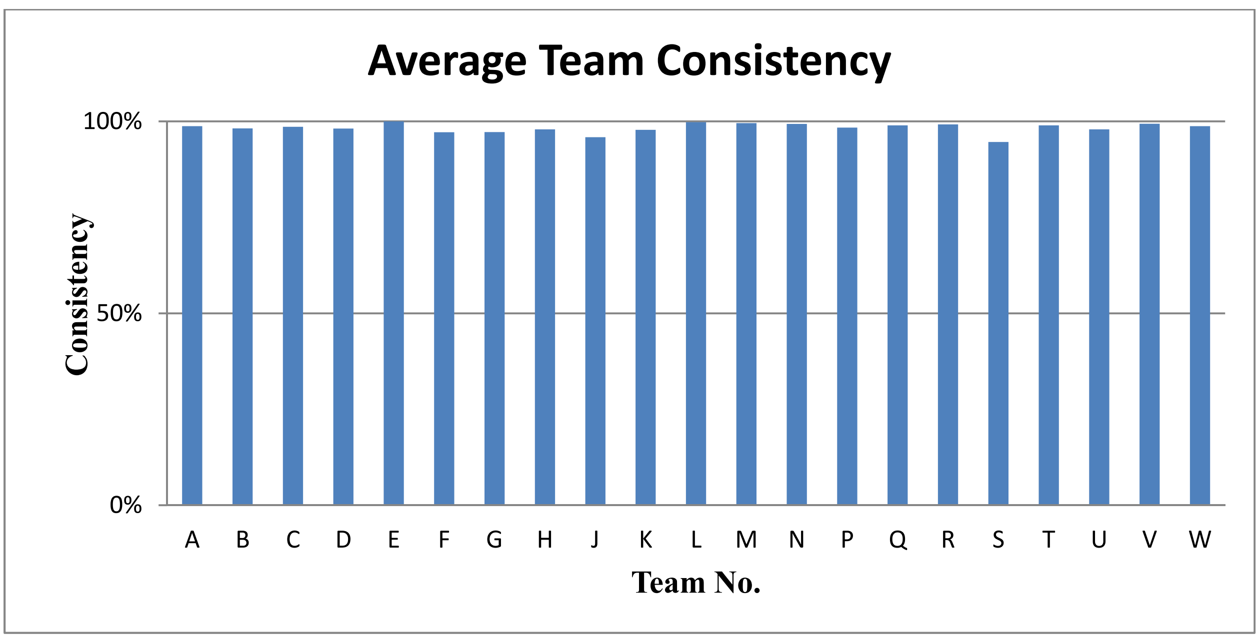


Figure 3-18: Average Team Consistency of Inspection Teams Based in the Inspection of 4 Bridges.

3.2.5. NBIS Ratings

NYSDOT is required to provide data on the condition rating of bridges under the NBIS scale 9 to 0, 9 for elements in an excellent condition and 0 for elements in a failed condition. The elements required to be rated on the NBIS scale are: Deck Condition, Superstructure Condition, Substructure Condition, Channel Condition and Culvert Condition. Table 3-7 shows the calculation of consistency of these 5 elements rated on the NBIS scale. Among total 16 elements in 4 bridges assigned NBIS ratings, 7 (43.75%) have been rated with a consistency of 100%, 5(31.25%) with a consistency in the range of 90-100%, 2 (12.5%) with a consistency in the range of 80-90% and 2 (12.5%) with consistency less than 80%. Overall, 75% elements have been rated with at least 90% consistency while remaining 25% with a lesser consistency.

Figure 3-19 shows distributions of typical elements rated below 100% consistency. It is observed that the variability in ratings of elements with less than 100% consistency is much higher for the NBIS scale than that for the New York State scale. This can be addressed through focused training on NBIS rating during annual bridge inspector's meeting organized by the NYSDOT. Based on the discussions of the consultants with NYSDOT, this issue has already been addressed by the NYSDOT during their annual bridge inspectors meeting held during March 2011.

Table 3-7: Consistency of Element Rated on the Basis of NBIS Scale.

Element	Median Rating	Inspectors Rating Median		Inspectors Rating Median +1		Inspectors Rating Median -1		Inspectors Rating Median ≥ ±2		Consistency
		Number	%	Number	%	Number	%	Number	%	%
BIN: 1026170										
Deck Condition	7	11	52.4%	0	0.0%	5	23.8%	5	23.8%	76.2%
Superstructure Condition	6	13	61.9%	3	14.3%	5	23.8%	0	0.0%	100.0%
Substructure Condition	7	16	76.2%	0	0.0%	5	23.8%	0	0.0%	100.0%
Channel Condition	8	18	85.7%	1	4.8%	2	9.5%	8	18	85.7%
Culvert Condition	N	N	N	N	N	N	N	N	N	N
BIN: 2205690										
Deck Condition	6	13	61.9%	0	0.0%	8	38.1%	0	0.0%	100.0%
Superstructure Condition	5	15	71.4%	5	23.8%	0	0.0%	1	1.0%	95.2%
Substructure Condition	5	17	81.0%	0	0.0%	4	19.1%	0	0.0%	100.0%
Channel Condition	5	17	81.0%	3	14.3%	0	0.0%	1	1.0%	95.2%
Culvert Condition	N	N	N	N	N	N	N	N	N	N
BIN: 3308970										
Deck Condition	6	15	71.4%	3	14.3%	3	14.3%	0	0.0%	100.0%
Superstructure Condition	7	14	66.7%	0	0.0%	3	14.3%	4	4.0%	81.0%
Substructure Condition	5	20	95.2%	1	4.8%	0	0.0%	0	0.0%	100.0%
Channel Condition	7	17	81.0%	3	14.3%	1	4.8%	0	0.0%	100.0%
Culvert Condition	N	N	N	N	N	N	N	N	N	N
BIN: 3350660										
Deck Condition	6	8	38.1%	10	47.6%	2	9.5%	1	1.0%	95.2%
Superstructure Condition	7	14	66.7%	0	0.0%	5	23.8%	2	2.0%	90.5%
Substructure Condition	6	9	42.9%	4	19.1%	3	14.3%	5	5.0%	76.2%
Channel Condition	4	13	61.9%	5	23.8%	1	4.8%	2	2.0%	90.5%
Culvert Condition	N	N	N	N	N	N	N	N	N	N

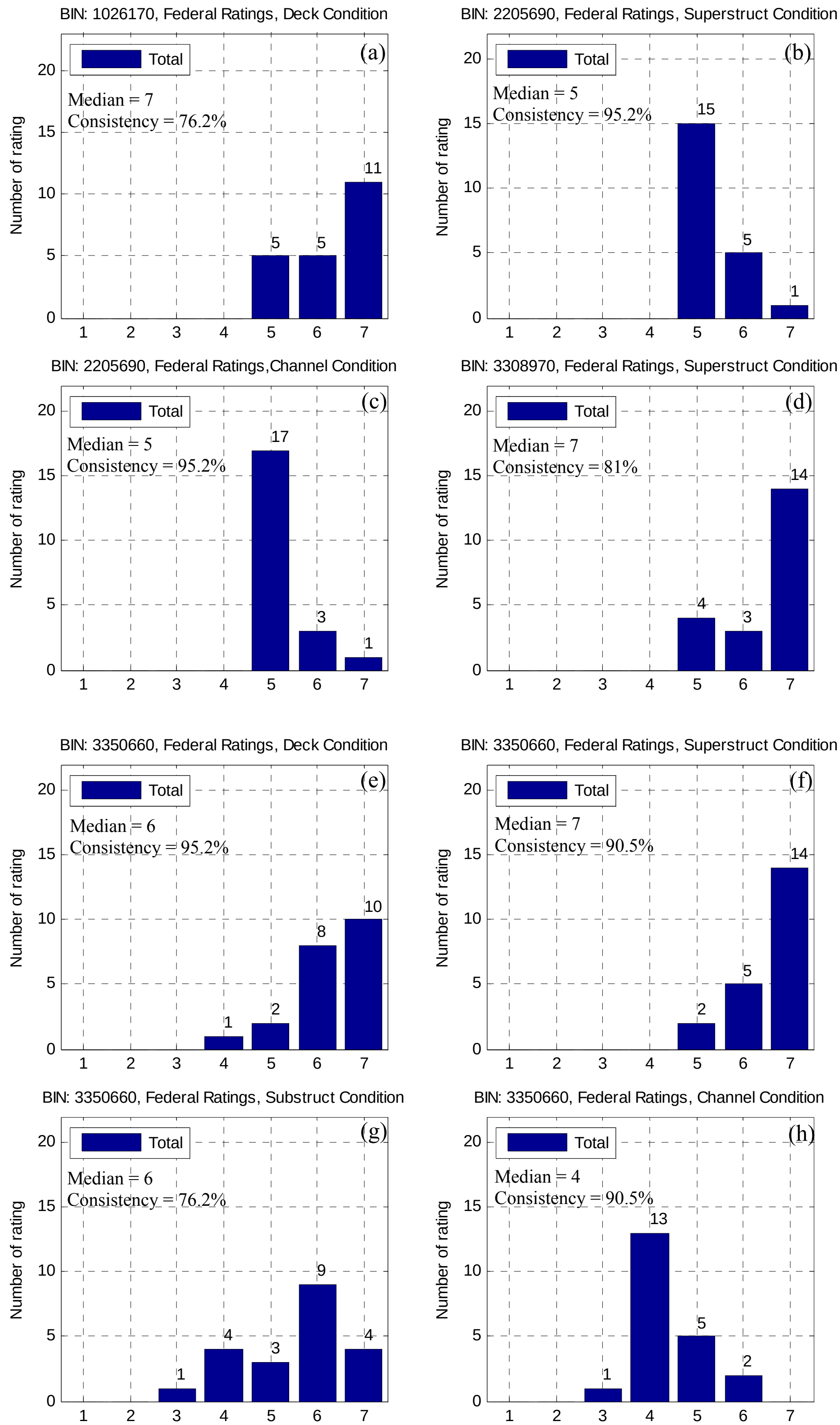


Figure 3-19: Representative Rating Distribution for Elements Rated on the NBIS Scale.

CHAPTER 4: EVALUATION OF THE CONSISTENCY OF BRIDGE INSPECTION QUALITY

4.1. INTRODUCTION

Analysis of consistency of bridge inspection ratings has been presented in the companion report entitled "Evaluation of the Consistency of Bridge Inspection Ratings". The consistency of the bridge inspection program and procedures can also be done through a qualitative analysis of bridge inspection reports. Hence, the evaluation of the quality characteristics of the inspection results from 20 inspection teams has been carried. Several parts of the assessment are based on existing Quality Control (QC) procedures available in the bridge inspection manual (BIM), which focuses on a documentation review of the bridge inspection reports. The research team performed analysis of the 80 inspection reports for 4 bridges using a scoring system based on this optional QC checklist. The inspection reports by the team W, which consisted of members from the central office in Albany, have not been included in the analysis and have been used as reference for comparison in some cases. Additional analysis of the quality and consistency of the reports includes the analysis of notes and photographs in the reports, and consistency in reporting key damage modes identified during the inspections.

4.2. QUALITY SCORING OF BRIDGE INSPECTION REPORTS

Scoring methodologies were developed as tools to provide a general assessment of the quality of inspection reports generated during the research. Generally, the good quality of an entity means that its quality dimensions have little or no variation from its target values. For the case of bridge inspection, quality dimensions are usually various aspects of a report such as notes and sketches, documentation that procedures have been followed, and consistent reporting of conditions. Target values are primarily based on the report including key items that are anticipated as part of the report, and consistent application of the NYSDOT Bridge Inspection Manual (BIM) procedures and requirements. The quality control checklist in chapter 11 of the BIM is a tool to evaluate the quality of a bridge inspection report that addresses these elements through a series of questions regarding the content of a subject report. The research team used this checklist as the guideline for creating a system to score bridge inspection reports for quality. The objective of the assessment was to uniformly evaluate the consistency and quality of the inspection reports in terms of typical quality characteristics or dimensions.

The evaluation also included an assessment of the quality of notes and photographs that documented the inspection results. A general assessment of the quality of notes and photographs was done on the basis of a qualitative scale. In addition, the consistency in the reporting of certain key damage modes, such as cracking, section loss, and scour, has been assessed based on the notes and photographs included in the inspection reports. The consistency in the time utilized by different inspection teams to inspect bridges (inspection time) has also been assessed. The following sections describe the methodology used for the quality assessment of inspection reports.

4.2.1. Quality Control Checklist

The QC checklist is designed to enable a QC engineer to quickly assess a given bridge inspection report. For this study, a modified form of the checklist was prepared in the form of a series of questions based on the items indicated in the quality control checklist. In certain cases, modifications were necessary because the electronic version of the bridge inspection reports doesn't contain all reported elements in the same manner as envisioned when QC checklist was developed. In the modified form of the checklist, relevant elements of the QC checklist in the NYSDOT Bridge Inspection Manual have been included, largely intact and unchanged, although some modifications have been made to put the items on the checklist into a series of 31 yes/no questions that can be used to provide a quality score for a bridge inspection report. One additional item was added to the checklist to assess if drop-line readings were consistent with the reference inspection values (from the inspection reports of the team W). Such a comparison would not normally be possible during a typical QC review. The checklist with 32 questions that was used for the qualitative assessment of the bridge inspection reports is included in the Table B.1 in the Appendix B.

Questions in the QC checklist include such things as if sketches for special emphasis details are present in the report, if the correct number of spans were inspected, and if documentation of photographs included in the report is complete, etc. These 32 questions are intended to provide a measure of the consistency (rather than accuracy) of the reports. For example, one question asks "Scour - Is the extent of scour clearly documented by sketches, if scour is a notable issue?" Such a question is assessed based on inspector's notes – did the inspector feel scour was a notable issue, and if so, did the inspector include a sketch. If the inspector did not indicate scour as a concern in the notes, then this question is N/A (Not Applicable). For example, if the inspector identified the bridge as being founded on bedrock, than scour measurements may not be necessary. Another inspector may not identify the bridge as being founded on bedrock and note scour as a concerns, and as such would include a scour sketch.

Each question was worded in a binary format, wherein the answer was "yes" or "no." For each question, an answer of "yes" was the desired result. An answer of "no" indicated the item either not being included in the report or incorrect. Each report was scored according to the number of questions answered "yes" versus the total number of applicable questions. This scoring methodology is intended to uniformly evaluate the consistency of the reports in terms of their content and provide a score, based on a percentage scale, relative to the items identified in the QC checklist.

4.2.1.1. Photographs and Notes

Bridge inspections generate numeric ratings on the condition of various elements of the bridge. These subjective ratings summarize the conditions of the bridge element concisely. The ratings are typically supplemented by notes and photographs intended to provide additional information on the specific conditions on which the ratings have been based. Notes provide the text descriptions of the specific conditions that support a certain rating. Photographs provide visual data to document the condition at the time of the inspection. Notes are typically cross-referenced to one or more photographs.

Important information on existing conditions of inspected bridge elements are included in the inspector's notes and the photographs that are referenced to these notes. Therefore, the quality of these items has also been assessed. The quality of the notes and photographs has been assessed qualitatively using a 4-level scale. All photographs and notes have been checked individually for the quality. The following sections describe the methodology used to evaluate notes and photographs on a qualitative scale.

Photographs

The quality of photographs included in the inspection reports has been assessed based on the characteristics of the photographs such as if the photograph supported related notes in the report, if the photograph clearly conveyed the point of interest, and if the photograph had sufficient lighting and focus to be clear. A four-level rating system was developed to assess the photographs. This subjective rating scale is intended to characterize the quality of the photographs and their relevance to the supporting notes. The criteria for the qualitative ratings of photographs are as follows:

- **Very Good (VG)** – no further explanation needed beyond notes in the inspection report; clear, understandable, and immediately identifiable support of the referencing note. Subject of photograph is clear and supports associated notes; lighting and focus appropriate.
- **Good (G)** – Some explanation may be required for a lay person, but the photograph is generally clear and shows intended subject with little to no ambiguity, generally supports associated notes, and has adequate lighting and focus.
- **Fair (F)** – Subject of photograph can be identified only with further explanation, even to a professional in the field; photograph may have visual flaws such as low light or poor distance, but subject can still be determined.
- **Poor (P)** – Even with explanation, subject of photograph remains unclear, cannot be determined to relate to the referencing note without difficulty; visual flaws such as low light, blurriness, or poor distance render subject of photograph difficult to understand.

Figure 4-1 shows an example of a very good up-close photograph. The photograph clearly displays extent and severity of spalling at the end of a fascia girder. The photograph is clear, with good lighting, and is referenced in the accompanying note, which describes the condition shown in the photograph. Figure 4-2 shows another example of a very good photograph showing the elevation view of the fascia girder with vertical cracking clearly observable in the image. Figure 4-3 shows an example of a poor photograph. The photograph is blurry. It is very difficult to see the subject of the photo. Details of the bridge condition cannot be determined from the photograph, and the angle of the photograph makes it difficult to discern the point of interest. Each photograph in every report was assessed based on this simple rating scale to determine the quality of photographs in the inspection reports.

Figure 4-1: Example of a Very Good Photograph.

Figure 4-2: Example of a Very Good Photograph.

Figure 4-3: Example of a Poor Photograph.

Notes

The notes in the bridge inspection report describe the inspector's assessment of damage or conditions at the bridge. The notes provide first-hand observations of the damage, and support and expand upon the information contained in the assigned numeric condition ratings. These notes often communicate the extent, location, and severity of damage, urgency of repair needs, and document the current status of the damage for future assessments.

Notes were also evaluated based on a qualitative scoring methodology similar to the one used to assess the photographs in the reports. In developing a standard for the quality assessment, several characteristics of notes were considered, such as if the note was thorough and clear, appropriately focused, included objective or quantitative data, and how well the note related to supporting photographs. The qualitative rating scale used to assess the notes included the following categories:

- **Very Good (VG)** – Note is clear and the subject of the note is easily understood and identifiable; photographic support is good; no further explanation required; includes quantitative data.
- **Good (G)** – Note is generally clear, though some further explanation may be required for a layman; photographic support is generally good; some quantitative data may be provided.

- **Fair (F)** – Note may be unclear in parts or unfocused, or too short to be thorough, though general idea of the note can still be understood; photographic support may be lacking; data is not quantitative.
- **Poor (P)** – Note is unclear; may be completely unfocused or too ambiguous to derive a clear meaning from it; photographic support may be inadequate; note does not contribute to the report in any substantial way.

For example, the following note is an example of a "very good" note. The note is clear and contains information regarding the location of damage, reference to a photograph, and includes some quantitative data on the extent and location of a crack:

> Referenced Photos: "14"
> Span 1 - Right fascia beam 0.8' from bottom a longitudinal splitting crack found. The crack starts at the mid span and stops at the 3/4 span length. No dampness or efflorescence found around the crack. Primary member system for span 1 would rate "5".

Examples of poor notes would include very brief notes that provide little information, such as "condition of end wing walls were unchanged" or "section loss present." The qualitative scale described above has been used to assess each of the notes included in 80 inspection reports. Specific items included in the notes, such as specific damage modes have also been assessed separately for the evaluation of the consistency of inspections.

4.2.2. Results and Analysis

The results of the quality analysis of the bridge inspection reports and trends observed from the data are presented and discussed. First, the results of the overall quality assessment are presented, and specific items that contributed to the quality scores are discussed. The overall quality of photographs and notes, assessed according to the qualitative scale presented earlier, is also discussed. Specific damage modes identified in inspector's notes are assessed in terms of consistency of their reporting and the inspection time (time utilized to finish the inspection).

4.2.2.1. Quality Assurance Analysis

Each bridge inspection report was reviewed according to the checklist developed from the optional QC checklist in the NYSDOT bridge inspection manual in Appendix B. This checklist included 32 questions formatted as a yes/no question (or not applicable). The results of this analysis are summarized in Table 4-1. As shown in the Table 4-1, the average score for the inspections is 84%, indicating that the data in the inspection report generally met the expected data from the QC checklist. However, there were teams that scored as low as 55% on the quality score. Such low scores are generally because of failing to include expected elements in the report, such as a photograph location sketch, access requirements for the bridge, and special emphasis details. The photograph location sketch, in particular, is addressed in a number of items in the quality control checklist. Since the photograph location sketch is a standard inspection report item, the absence of this item was unanticipated. Two teams (C and G) did not include a photograph location sketch in any of their four reports. Their scores were consistently low because of not including this element as well as other expected elements in their reports.

There were a number of areas where there were variations between the QC checklist items and the content of the reports. For example, there was a variation in the inclusion of electrical hazard surveys, and sketches of special emphasis details. The following sections address the items with significant variations between the reports of different inspection teams.

Table 4-1: Results of Quality Analysis for Bridge Inspections.

Inspector	QA Analysis Scores For Each Bridge				
	1026170	2205690	3308970	3350660	Average
A	95%	86%	84%	79%	86%
B	86%	75%	88%	86%	84%
C	70%	62%	65%	57%	64%
D	95%	81%	80%	74%	83%
E	90%	97%	96%	82%	91%
F	95%	79%	88%	78%	85%
G	70%	69%	77%	82%	75%
H	95%	85%	77%	86%	86%
J	81%	86%	80%	71%	80%
K	90%	89%	88%	81%	87%
L	90%	86%	88%	82%	87%
M	95%	97%	92%	81%	91%
N	100%	100%	100%	81%	95%
P	95%	75%	85%	82%	84%
Q	90%	93%	100%	100%	96%
R	95%	93%	100%	93%	95%
S	95%	76%	88%	82%	85%
T	95%	86%	88%	86%	89%
U	95%	93%	92%	86%	91%
V	95%	93%	92%	93%	93%
Average.	91%	85%	87%	82%	86%
Minimum	70%	62%	65%	57%	64%
Maximum	100%	100%	100%	100%	96%
Std. Dev.	8%	10%	9%	8%	7%

Photograph Documentation

Inclusion of required photographs and related documentation has been identified as a factor contributing to low quality scores. All of the photographs taken by the inspectors are required to be documented on a photo location sketch. The QA review included several questions regarding this photo location sketch and elements included in the sketch. The questions from the QC checklist relating to the sketch are included in Table 4-2, including the number of “yes” and “no” answers.

Table 4-2: Quality Analysis Results for Photographs.

Question	Yes	No[1]
Photos - Are all photos located in the photo location sketch?	71	9
Photos - Are all photo locations depicted in the sketch accurate?	70	10
North Arrow - is the North arrow present in the photo diagram?	72	8
Flow - Is the stream flow direction shown on the photo location sketch for bridges over water?	70	10
Photos - are above- and below-deck photographs differentiated on the photo diagram?	72	8

[1] Two teams submitted no sketches (8 total sketches missing)

Photograph Location Sketch

The QA review found that eight reports did not include the photo location sketch. In these cases, all other questions relating to information found on the sketch were answered "No," because the photo location sketch is a standard part of the report. These eight cases of missing location sketches were confined to only two inspectors (i.e., two teams inspecting eight bridges). Because a number of questions in the review focused on the photo location sketch, reports not including a sketch had the lowest average quality scores. In a single case, an inspector did not include one of the photographs in the sketch. In all cases, the reports including the photo location sketch included the north arrow and almost all sketches showed the direction of stream flow. Photo location sketches also accurately showed the location of the photographs in almost all cases.

Electrical Proximity Sketches

There was significant variation in the inclusion of the Electrical Hazard Surveys in inspection reports. Overall, there were 26 reports that included the Electrical Hazard Surveys. There were at least five reports for each of the four bridges that included the Electrical Hazard Surveys. For the bridge 2205690, which had an overhead electrical line, the survey appeared in only seven out of 20 reports. Overall, there were 11 teams that included no surveys in any of their reports and 3 teams that included surveys in reports for all four bridges. These data illustrate variations in the application of the requirements for including these Surveys in the inspection reports across the group of inspectors. This issue could be resolved by a clarification of the desired practice during the annual bridge inspector's meeting.

Special Emphasis Details

One area where inconsistencies were noted was in the documentation of special emphasis details, particularly for Non-Redundant/Fracture Critical Members (NR-FCMs). The NYSDOT Bridge Inspection Manual requires all fracture-critical members and welds of categories D, E and E' to undergo 100% hands-on inspection. Hence, inspection reports should include notes documenting 100% hands-on inspections of special emphasis details. These notes should describe the nature of these special emphasis details (fracture-critical, welds, etc.). Sketches illustrating special emphasis details should be included in the sketches section of the inspection report. However, the QA review found inconsistencies in the inspection and documentation of special emphasis details. Table 4-3 shows relevant questions in the QC checklist and the number of inspectors who included or didn't include proper documentation. The table also shows instances when special emphasis details were not applicable (N/A).

Table 4-3: Special Emphasis Details QA Scoring.

Questions	Yes	No	N/A
Special Emphasis - Does the special emphasis section in the report indicate non-redundant, fracture-critical, pins and hangers, fatigue-prone details, etc.?	55	5	20
100% Hands-On - is this noted as being completed for fracture-critical members and/or special emphasis details?	50	10	20
100% Hands-on - is the 100% hands-on inspection completed or waived for weld categories D, E, and/or E' welds?	33	27	20
Welds Located - Were D, E, and E' category welds located on sketches in the Special Emphasis section of the report?	21	39	20
NR-FCM Drawing - Does the Special Emphasis section have sketches identifying all non-redundant and fracture-critical members/details?	5	15	60

As shown in the Table 4-3, fifty-five out of sixty applicable inspection reports properly indicated special emphasis details. Ten out of sixty reports did not document (in the notes of the report) 100% hands-on inspection of special emphasis details. Where category D, E, and E' details were present, 100% hands-on inspection specifically identifying these details was noted in only thirty-three out of sixty applicable cases. In many of the remaining cases, although inspectors did document completing 100% hands-on inspection, they simply didn't note the category of the detail inspected.

Other area where there were inconsistencies in inspection reports was the inclusion of the sketches showing fatigue-sensitive details or NR-FCMs. Twenty-one out of 60 reports included the detailed sketches in the special emphasis section of the report. These sketches were file sketches. Many inspectors may not have included the sketches in the actual reports because the reports were in the file. Consistency in the reports could be improved by clearly specifying desired contents of reports.

To examine this issue in more detail, the bridge number 3350660 has been assessed in detail to evaluate the consistency of reporting and including sketches for the special emphasis details. This bridge has members identified as NR-FCM and fatigue-prone details (FPD). The sketch for the FC-NRM member was included in only five out of twenty reports, in this case a sketch dated in 1994. Three reports referred to the sketch in the file. Among the inspectors who either included a sketch or referenced the sketch in the file, 100% also reported conducting hands-on inspection of both the fatigue-prone details and the NR-FCM. Among 12 inspectors who did not include a sketch or referenced to the sketch in the file, 5 out of 12 (40%) did not report hands-on inspection of either the NR-FCM or the FPD, as shown in Table 4-4. Among five reports that did not indicate hands-on inspection, two of the reports included no reference in the text to NR-FCM or FPDs, one referenced only FPDs in the special emphasis section, and two indicated the presence of both the FPD and the NR-FCM in the special emphasis section, but did not report hands-on inspections.

It has been observed from the review of reports that there were three teams that did not report the FC-NRM present in the bridge, and two teams that did not report FPDs in the special emphasis area of the report. One team made no reference to the FPDs or the NR-FCM in the text of their report, did not report hands-on inspection of these special emphasis items, but did include photographs of the NRM-FC member in the standard photographs section of the their report. These photographs were titled "Special Emphasis Details."

Table 4-4: Data on the Recording of Visual Inspection and Sketches in the Inspection Reports for the Bridge 3350660.

Special Emphasis Sketch included	No.	Special Emphasis Sketch missing	No.
Sketch or reference to file appears in the report	8	Sketch or reference to file missing	12
Hands-on inspection reported	8	Hands-on inspection reported	7
Hands-on inspection **not** reported	0	Hands-on inspection **not** reported	5

It was apparent from the data for this bridge that the inclusion of the sketch in the inspection report corresponded to some degree with reporting of hands-on inspection. Including the bridges 2205690 and 3308970, which each had FPDs, along with 3350660, 77% of the reports that did not include a sketch had a note indicating the completion of hands-on inspection for the FPD. When a sketch was included, hands-on inspection was reported in 95% of the instances. Therefore, it is somewhat more likely that the hands-on inspection was reported if the sketch was included in the report, though in many cases, the hands on inspection was reported when no sketch was included in the report.

Documentation of the 100% hands-on inspection for fatigue sensitive details has often been found to be inconsistent, appearing in different locations within the report. For example, again looking across the three bridges that include FPDs, for reports that indicated 100% hands-on inspection, fatigue sensible details were noted under a "General Notes" section in approximately 42% of the reports; noted under the "Special Emphasis" area of the report in approximately 58% of the reports, and located among the superstructure notes in approximately 10% of the reports (the notes appear in two locations in about 10% of the reports). These data indicate that the reporting of hands-on inspection and recording of special emphasis inspection needs within the reports has a significant amount of variability. This doesn't necessarily indicate whether the hands-on inspection were or were not performed, but in terms of quality, more consistent reporting of these features in reports could improve the overall quality and consistency of reports.

Dropline Readings

Dropline measurements are typically taken along both fascias of a bridge over water to monitor changes in the stream profile. The results of the dropline readings are included in the inspection report under the "sketches" section. The dropline readings are performed at pre-determined points along the bridge, measured in terms of the stationing from one of the abutments towards the other abutment. The relevant questions from the QC checklist, including the number of answers "yes," "no," and "N/A," are included in Table 4-5.

The QA review found that the dropline readings were performed as required in most of the cases. Seventy-four out of eighty inspection reports included the proper dropline reading documentation. During the QA review, the reported dropline readings were compared against the dropline readings from the report of the team W to measure the consistency of dropline readings within +/- 1.0 ft. of that by the team W. In 19 out of 60 cases, at least one dropline reading fell outside of +/- 1.0 ft. of that by the team W. However, variations were typically small and isolated, for example, one or two measurements varying by more than 1 but less than 2 ft. Generally, dropline readings were very consistent. Given that the measurements were taken at different times over the course of the summer and into the fall, variations in the actual measurements over that time period may have occurred because of changing weather conditions. Overall, the drop line readings were consistent with those by the team W.

In some cases, the stationing used by the inspectors did not match the stationing used by the team W, such that the data could not be compared. In these cases, N/A was used, since it was not possible to compare results that were not at the same stations.

Table 4-5: Recorded drop Line Readings and Readings Within +/-1 ft. of Control Readings.

Question	Yes	No	N/A
Droplines -Were dropline readings taken along both fascias for bridges over water, and if not, is there a valid reason why not?	74	6	0
Droplines - are the readings within a tolerance of +/-1.0 ft from the control inspection readings?	41	19	20

4.2.2.2. Summary of Photograph Quality Assessment

The conditions of photographs in the bridge inspection reports were evaluated on a qualitative scale of VG to P described previously. The results of this analysis, presented in Table 4-6, show that the quality of photograph was very good in general, indicating that the photographs in the inspection reports generally provided detailed information, were clear, had a clear subject and supported associated notes. The average score for the photograph rating was 3.3, indicating that the photos were rated good to very good on average. There were 1,367 photographs included in 80 bridge inspection reports. Overall, 90% of the photographs were rated “Good” or “Very Good” on a qualitative score. Table 4-6 also shows the quality of photographs for each inspection team. It is observed that the team E had the minimum photograph assessment rating of 2.6 with only 60% of the photographs being rated as good or very good.

The 4th column of the table indicates the average number of photographs taken by each inspection team during the inspection of 4 bridges. A substantial variation, from a minimum average of 10 to a maximum average of 31, is observed in the number of photographs taken by different inspectors. While there is likely no correct number of condition photographs that should be taken, such variation may indicate a different intensity of inspection, or at least the documentation of that inspection. The range of photographs taken by an inspector for a particular bridge varies from a minimum of four to a maximum of 36. Such variation suggests a different level of detail in the inspection, with one inspector finding four photographs sufficient to document conditions at the bridge, while another one finding thirty-six photographs necessary for the same bridge.

Table 4-6: Data on Photograph Quality Assessment.

Inspector	Average Photo Rating	Avg. % Very Good or Good	Avg. No. of Condition Photos
A	3.3	86%	16
B	3.1	83%	27
C	3.2	85%	10
D	3.4	95%	11
E	2.6	60%	11
F	3.4	90%	24
G	3.5	94%	17
H	3.5	90%	25
J	3.1	79%	31
K	3.0	77%	12
L	3.4	98%	18
M	3.2	88%	12
N	3.1	89%	13
P	2.9	80%	12
Q	3.2	96%	24
R	3.1	99%	16
S	3.3	97%	25
T	3.2	98%	13
U	3.2	95%	19
V	3.2	91%	12
Average	3.2	89%	17
Min.	2.6	60%	10
Max.	3.5	99%	31
Std. Dev.	0.2	9%	6

4.2.2.3. Summary of Notes Quality Assessment

A similar qualitative assessment was performed for the notes included in the inspection reports. Similar to the number of photographs, the number of notes varied significantly. However, the content of a particular note varies between inspectors, with some inspectors including much more detail or more extensive data within a single note. The qualitative scoring methodology described previously has been used to assess the quality of the notes. The assessment didn't focus on the length of a note or notes. Rather, the focus was on assessing whether the note itself was explanatory or not. Although this assessment is necessarily subjective, overall results indicate that the quality of notes was good. Table 4-7 shows the results of average notes assessment results for each inspection team.

Table 4-7: Inspector Note Quality Assessment.

Inspector	Average Note Rating	% Very Good or Good	Average # of Notes Taken
A	3.3	84%	12
B	3.1	86%	27
C	3	89%	11
D	3.5	96%	11
E	2.8	74%	13
F	3.3	90%	17
G	3.4	100%	10
H	3.7	95%	16
J	3.1	81%	23
K	3	82%	14
L	3.4	98%	12
M	3.3	90%	13
N	3.1	85%	12
P	3	84%	13
Q	3.2	99%	17
R	3.3	95%	13
S	3.3	97%	17
T	3.1	100%	12
U	3.1	92%	16
V	3	86%	14
Average	3.2	90%	15
Min.	2.8	74%	10
Max.	3.7	100%	27
Std. Dev	0.2	7%	4

It has been observed from assessment results that there is a correlation between the number of notes and the number of photographs taken by an inspector. Generally, the larger the number of notes, the larger was the number of photographs. For example, among the inspectors that had an average (14) notes or fewer, the average number of condition photographs taken was thirteen; for those with greater than the average number of notes, the average number of photographs was 22. Overall, there were 1,161 notes included in the 80 bridge inspection reports. Almost 90% of these notes were rated as “Good” or “Very Good” on a qualitative scale. Generally, the quality of both notes and photographs was very high, providing good explanation of conditions at the bridge and documenting inspection findings thoroughly.

4.2.2.4. Identification of Specific Damage Modes

Flagging data, in combination with notes and photographs, can also be used to investigate the consistency of identifying specific damage modes. Hence, specific damage modes found in the note sections of the reports and in referenced photographs were assessed for the consistency between inspection teams. Specific items assessed include cracking in concrete and steel primary members, section loss and reporting of scour conditions. Assessment of specific damage modes has been done on the basis of 20 inspection reports (i.e., excluding the expert inspection report).It should be noted that the objective of analyzing the consistency of identification of specific damage modes is to develop several examples that can be used during annual bridge inspector's meeting, since the identification of these damage modes depends on subjectivity and risk tolerance of bridge inspectors.

4.2.2.4.1. Concrete Cracking in Bridge BIN 1026970

To analyze the consistency of the notes in the inspection reports for identifying specific damage modes, notes for the bridge 1026970 were assessed for three specific damage modes in the superstructure of the adjacent box girders. These include (i) a splitting crack along the fascia girder of span 1 shown in Figure 4-4(a), which runs along the length of the girder approximately 9 to 12 inches from the soffit, (ii) vertical/diagonal cracks in span 3 of the bridge, shown in Figure 4-4(b) and (iii) a large spall in the corner of the box girder, which has exposed 2-3 inches of the embedded strands, as shown in Figure 4-4(c). The identification of these common damage modes was assessed through the inspector's notes, photographs and flags, in cases where the inspectors identified a flagging need. For the longitudinal cracking in span 1, inspectors that reported a longitudinal crack in the primary member notes along some or all of beam 13, or span 1 right side, were counted as having reported this damage mode. For vertical cracking in the Span 3, inspectors that noted vertical cracks, vertical shrinkage cracks, hairline crack or shear cracks, etc., located in span 3 right side, were counted as having reported the damage. For the spalling at the corner of the fascia beam in the span 2 (Figure 4-4c), inspectors that noted spalling at this location with exposed strand or bar, or with rust staining, were counted as having recorded the damage mode. To assess the photographs, the photographs referenced in the notes were identified in the report.

The results of the assessment are shown in Table 4-8 below. As shown in the table, the concrete cracking in spans 1 and 3 were noted by more than half of the inspectors, with one inspector indicating that a yellow flag was warranted for the vertical cracking. For the spalling with exposed rebar or strand, only 15% (3/20) reported this damage mode with exposed strand; one inspector indicated that the condition required a yellow flag until the effect of the damage on the load carrying capacity could be evaluated. There were 6 inspectors who did not note any of the three damages in the notes section of the report. These data may illustrate some variation in the level of detail in the inspection reports, or differences in the perspectives of inspectors regarding the importance of these damage modes. It should be noted that two inspectors found that there was reason to issue a flag in response to one of these conditions. These flags were for different damage modes (spalling with exposed steel and vertical cracking in span 3) and were issued by different inspectors. This can be used for training inspectors about the importance of notes in inspection reports for conditions that don't warrant flag. It is observed from the pictures in Figure 4-4 that the cracks and damages are obvious and must have been seen by the inspectors. It seems likely that many inspectors didn't report these damages in their reports either because these damages were already mentioned in previous reports or didn't consider them affecting the safety of the bridge.

Table 4-8: Assessment of Notes Regarding Specific Damage Modes for Bridge 1026970.

	Longitudinal Cracking	Vertical Cracking	Spalling w/ Exposed Strand
Recorded Note (%)	55%	70%	15%
Photograph (%)	55%	70%	15%
Flag indicated (Yellow), No.	0	1	1

Figure 4-4: Three Damage Areas Assessed Using Notes and Photographs.

4.2.2.4.2. Crack at Rail in BIN 2205690

An existing yellow flag for a large crack at a railing to flange connection was assessed to determine the consistency in reporting for the damage mode. Overall, 19 of 20 inspection teams noted this damage mode on the bridge and continued an existing yellow flag regarding this condition. One team recommended that the yellow flag be removed, because the weld had been repaired as noted in their report:

> ***Note ID: N210800002V0013**: Date: September 9, 2010: The previously reported 4" long crack in the weld that connects right railing post #2 to the bottom flange has been grinded and welded back (Photo16). Yellow flag 2Z090056 has been removed…...*

This appears to be an error in the condition of the member, since teams that reported this damage both before and after the team that removed the yellow flag indicated that the continuation of the flag was appropriate. Figure 4-5 below illustrates the condition at the connection as photographed by the team recommending the removal of the flag, and a team that inspected the same area on September 20, 2010, 11 days later. The note associated with the September 20, 2010 inspection is as follows:

> ***Note ID: 9X10800002T0011** Date September 20, 2010: There is a crack in the weld connecting right railing post 2 to the bottom flange of the right fascia girder. The crack occurs at approximately the 1/4 span point. The crack is approximately 6 in, long (photo 14). The crack may have grown since the 2009 Interim Inspection but it is still in the weld metal only, and has not propagated into the base metal of the girder flange. A Yellow Structural Flag has been continued.*

It is also noted from the photographs (Figure 4-5) that the rough weld surface was left as-welded, although dye penetrant was applied as a means of assessing the crack. However, most procedures, including that included in the BIM, require surface preparation including grinding when applying dye penetrant, to ensure that irregularities in the surface do not mask results. In this case, it does not appear that this surface preparation was completed, and this may have contributed to the crack being reported as repaired. Overall, the consistency for reporting this condition and recommendation for the continuance of the yellow flag is found to be very consistent, with the exception noted above.

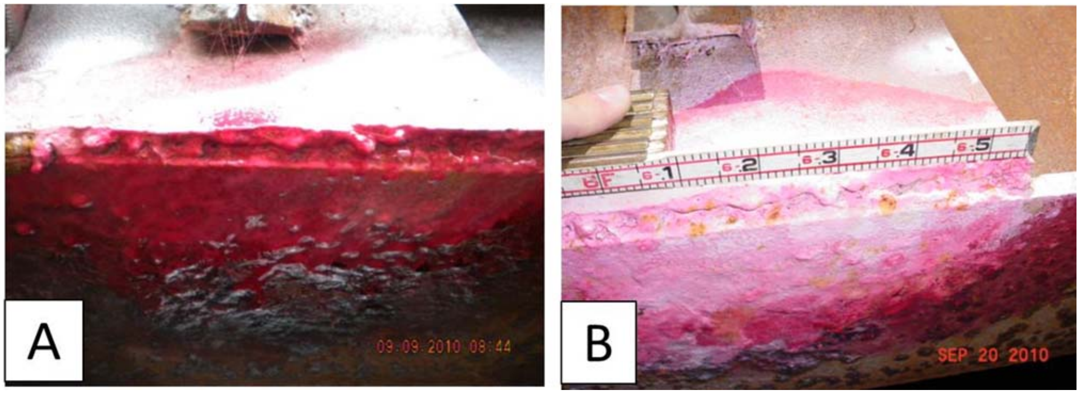


Figure 4-5: Photographs from Inspection Reports Showing A) Photograph from Team Recommending Removal of Flag and B) Photograph from Team Recommending Continuation of the Flag 11 Days Later.

4.2.2.4.3. Detection of Cracks in a Steel Superstructure in BIN 3308970

BIN 3308970 included a cracked secondary member (diaphragm bracing) connection near the top flange, in the compression area of the primary member, as shown in the Figure 4-6. This damage mode was assessed to determine the consistency of reporting among the inspection teams. This detail was adjacent to special emphasis details in the tension zone of the member identified in report sketches.

For the cracked diaphragm bracing connection, 10 out of the 20 inspection teams included this damage in their reports. As discussed previously, under-reporting of this damage mode could be because of varying risk perception of inspectors and their lack of understanding of the impact of damage on the bridge system. Of the team that reported the damage, 70% indicated this as requiring a flag – five indicated a yellow flag and two indicated a red flag. In the opinion of the research team, this condition didn't require issuance of flags.

The results from bridge 3308970 were assessed to determine if the presence of a special emphasis area sketch affected whether or not the damage was detected. Of the eight teams that included a sketch, only three had reported the damage (38%), while for the group of twelve teams that did not include a sketch, seven reported the damage (58%). Therefore, these results show a lack of relationship between the inclusion of the sketch and the detection of the damage. In fact, a larger portion of the teams without the sketch reported the damage than those that included the sketch in the report. Similarly, conducting 100% hands-on inspection did not seem to affect the reporting of the damage. In fact, among the teams reporting 100% hands-on inspection, 9 teams reported the damage and other 9 didn't. Similarly, among the two teams that did not report 100% hands-on inspection, one reported the damage while the other one didn't.

Figure 4-6: Photograph of Cracked Diaphragm Bracing Connection.

There was also a variation in the reporting of cracking in the tension area of the diaphragm connection, where the special emphasis, 100% hands-on inspection was to be conducted. In this area, there was an existing crack along a weld connecting the diaphragm to the flange of the primary member in the tension area. This crack was reported by three out of the 20 teams, and is shown in Figure 4-7. The reported length of the crack is ~1 in., extending from an area where the weld has been ground out ~1.75 in. Three different inspectors reported a crack in an intermittent weld that attached the secondary members, also shown in Figure 4-7b. In total, there were six teams that noted a crack in the special emphasis area. One other team noted in their report that there was no cracking in this special emphasis area, however, the report included a photo of the area shown in Figure 4-7a. The crack shown in Figure 4-7a, which is along a weld connected to the tension flange, is relatively small in size and is likely to be of very little structural significance.

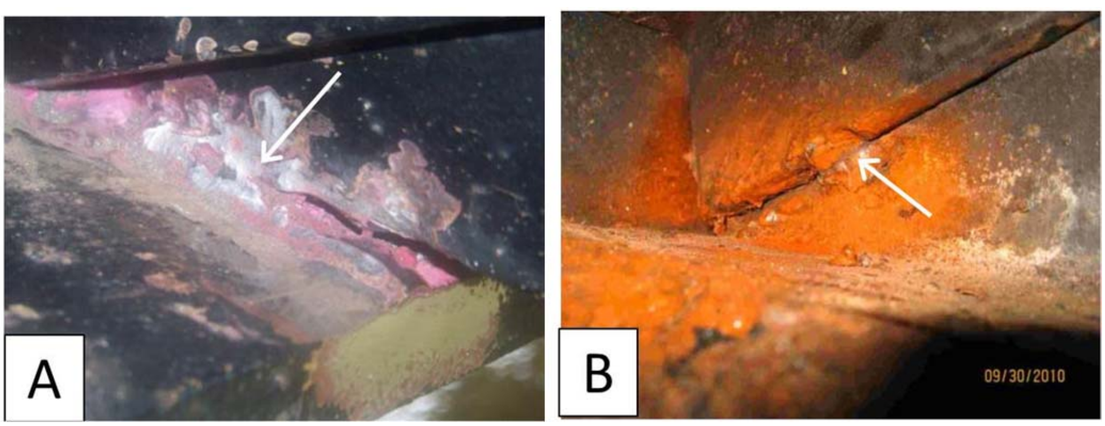


Figure 4-7: Photographs of Cracks in Diaphragm Connection Showing A) Crack in Weld Connecting to Flange, and B) Crack in Secondary Member Weld.

4.2.2.4.4. Section Loss

Bridge 2205690 contained primary members with a failed coating system, section loss and flaking in some areas. Section loss on the primary members was the most significant in the fascia girders, where deck run-off onto the members had caused more significant corrosion than the interior members. These members had surface rusting, but did not appear to have significant section loss. Data from the notes section of the reports indicated that 90% of the reports noted the section loss in at least one of the flanges, and 80% of the reports indicated both web and flange section loss in one or both girders. There was some variation in the level of section loss reported, however, as shown in Figure 4-8, with a maximum section loss of 42% in the flange. Based on visual assessment of the section loss, most of the inspection teams indicated that there was 10% section loss in the flange and 5% in the web. Use of ultrasonic thickness gages was not reported for making the assessment. For the case where 42% section loss was reported, calipers and a ruler appeared in the photograph of the area, suggesting the use of these tools in the assessment. The high section loss value reported may have resulted from measuring the maximum reduction in plate thickness, for example an area with the most severe flaking or pitting, and applying that value as the section loss, as opposed to a nominal or average value over the entire section. On the other hand, inspector's making a visual assessment may have reported the nominal or average value, which would naturally be less.

These results indicate that the teams generally relied on a visual assessment of the section loss in making their evaluations, resulting in variations in the reported section loss. Field measurements in the web area of one girder were made for comparison with the reported values by the research team. These measurements compared the web plate thickness near the abutment, where section loss appeared minimal, to an area of the web where flaking corrosion had occurred. These measurements suggested ~20% loss in the thickness in the flaking area. The results indicate that further guidance for inspectors may be needed of the desired method or methods for estimating section loss.

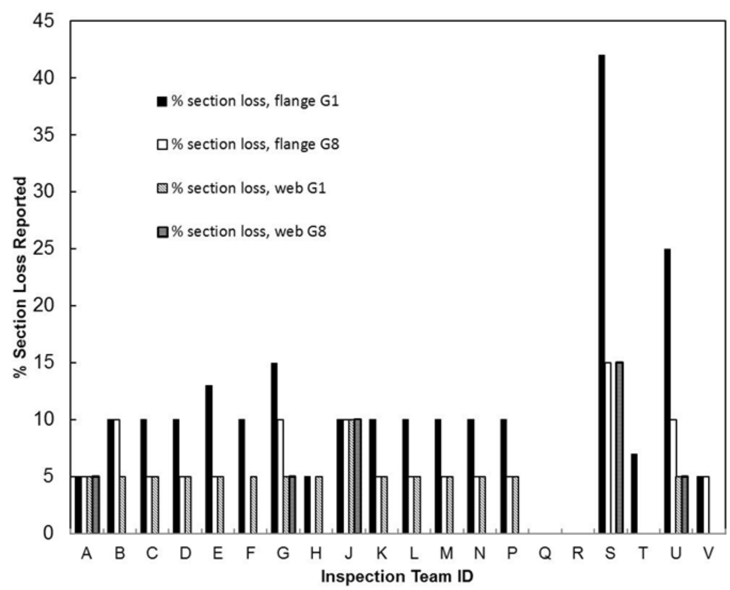


Figure 4-8: Reported Section Loss in Girder Flange and Web Areas.

4.2.2.4.5. Scour Assessment

Assessment of scour reporting was done on the bridge 3350660 that had an existing yellow flag for scour at pier 1 of the three-span bridge shown in Figure 4-9. During the trial inspections conducted as part of the study, local maintenance attempted a repair to address the scour issue, according to the inspector notes collected as part of the study. As a result, some inspections noted the repairs and therefore recommended the removal of the yellow flag, while other inspectors recommended continuation of the yellow flag, even though a repair had been attempted. Some reports didn't note about the attempted repairs at all. Additionally, effects of scour such as undermining of the pier may vary over time due to sediment deposit in the area. These factors complicate the assessment of the consistency of scour assessments, as conditions may be changing somewhat between inspections. Regardless, the consistency in the reporting of scour has been assessed and is reported here.

Figure 4-9: Elevation View of Bridge 3350660 Showing Footings Exposed to Scour.

To assess the consistency of the scour evaluation and the issuance of flags in response to the in-situ scour conditions, a timeline of inspection outcomes was constructed to evaluate if and when repairs had been implemented, and how that might have affected the assessment of the results. Table 4-9 shows the inspection results in chronological order, along with summarized excerpts from the notes for each of the inspection reports, focused on Pier 1. In this Table, the flags are coded as R for a red flag, Y for a yellow flag, N for no flag, and RM for flag removal recommended by the inspector.

As shown in the Table 4-9, there was a significant variation in the assessment of the scour conditions at this pier. Although the on-site conditions may have been changing due to repairs attempted by local maintenance staff and natural variations in scour effects, some inconsistencies other than those that could be explained by such effects are evident in the data. For example, two inspections were conducted on 8/23/10, one indicating that a yellow flag should be issued and the other indicating that the flag should be removed due to gravel in-fill of the scour hole. On 9/9 and 9/15, inspector's assessments indicate a red flag for scour, but on 9/10, between these assessments, the inspector recommends removal of the flag. The day following the red flag on 9/15, on 9/16, the inspector assesses the same conditions as a yellow flag. To illustrate this example, the inspector notes from 9/9 and 9/10 are included in Figure 4-10. The team inspecting on 9/9 recommends a red flag based on their assessment, while the team on 9/10 recommends removing the yellow flag due to placement of stone at the nose of the pier.

Table 4-9: Inspection Notes and Flags for Pier 1 Scour.

Date	FLAG Issued	Pier 1 Scour Notes
8/3/2010	R	Undermined at ends up to 1.7 ft., red flag issued.
8/18/2010	RM	Stones fill placed at pier 1 nose - no undermining found- flag removal recommended.
8/22/2010	N	Reports undermining but no reference to flag.
8/23/2010	Y	Some stones placed in front of pier 1, d=0.5 ft, yellow flag issued
8/23/2010	RM	Undermined area has been filled in with streambed gravel, yellow flag should be removed.
8/25/2010	Y	Severely scoured 27 inches horizontally (d=27 in.), yellow flag
8/26/2010	N	Small amount of undermining noted - no flag mentioned
8/26/2010	Y	Undermined h=10 in. and d= 24 in. at pier 1, yellow flag
9/2/2010	Y	Continue yellow flag, d=0.5 ft
9/7/2010	R	Extensively undermined, average of d=1.5 ft, up to 2.6 ft, red flag recommended.
9/9/2010	R	The extent of undermining has increased significantly up to d=3 ft, with an average of 2.5 ft., gravel moves easily when probed - red flag.
9/10/2010	RM	Stone rip rap in and around undermined area, yellow flag should be removed.
9/15/2010	R	Undermining more severe than during 2009 interim inspection, stones placed by DPW in response to August red flag are now gone- d=1.4 ft. RED FLAG warranted
9/16/2010	Y	Pier 1 undermined h=2.5 in., d=12 in. - additional areas of undermining detected at 7 ft and 12 ft. (h=3.5 in., d=14.5 in.), at 24 and 27 ft., h=3.5 in. and d=8.5 in. - Yellow flag.
9/22/2010	RM	No apparent undermining of the pier; appears previous yellow flag was repaired.
9/23/2010	Y	Scour conditions not repaired, yellow flag continued.
9/27/2010	Y	New native stone rip rap and sandbags have been placed, undermining 1.5 ft deep - yellow flag.
9/29/2010	Y	Rip rap placed at pier 1, undermining could not be verified.
10/19/2010	RM	Scour repaired, grout bags placed, remove yellow flag.
12/15/2010	RM	Stones have been placed, yellow flag should be removed.

(L) 9/9/10 – Red Flag Issued

Span 001 -- Pier: Erosion or Scour -- Rated 2, Was X
Referenced Photos: "17"
2010
The channel along both pier footings exhibits scour since the 2004 inspection. Both footings are exposed almost full height. At pier 1, the end face of the footing is undermined for almost the full length, starting at the left corner for an average height of 3" to 4" high. The footing is approximately 24' long. Over a 9' length, starting 6' from the left corner, the undermining readings indicate a maximum horizontal length of 3' with an average of 2.5'. The footing width is 3' at the base. The extent of the undermining has increased significantly since the previous inspection. There are no cracks in the footing to indicate footing failure due to the undermining. When probing under the footing, gravel material could be easily moved/pushed around.
Due to the extent of the undermining and the increases since the previous inspection, a Red Structural Flag, non-PIA, (No. 1U100046) is issued, superceding the Yellow Structural Flag (No. 9090029) issued in 2009. Please refer to the Pier 1 Channel Profile and Undermining readings for additional information.

(V) 9/10/10 Yellow flag removed
Span 001 -- Pier: Erosion or Scour -- Rated 3, Was X
Referenced Photos: "9", "10", "11"
The channel between the pier 1 and 2 is severely scoured since the 2004 inspection.
The end face of the pier 1 footing is exposed for nearly its full depth for the full length of the face.
The previously reported 3ft long x 10" high x 24" wide undermined area of the footing at left side near left end corner (upstream) now has stone rip rap under and around this location to prevent further scouring. Yellow Flag 9O090029 has been removed ……..

Figure 4-10: Notes on Scour Conditions from Inspection Reports on September 9, 2010 and September 10, 2010.

Repair of the scour conditions with sand bags was included in an inspection report dated 9/27/10. In order to minimize the effects of repair, further analysis of inspections prior to 9/27/10 has been carried out. Hence, among the omitted data (from inspections on or after 09/27/10), there were 2 yellow flags and two flag removals recommended among the four inspection teams that visited the bridge. Among inspection reports during 8/3/10 and 9/23/10, there were four red flags, six yellow flags and four recommendations to remove the flag. Two teams did not indicate if there was an existing flag or if any new flag required. Ratings assigned to the pier 1 erosion and scour were lower for teams recommending a red flag, with two teams rating the element at 2 and two teams rating the element at 3. For teams recommending a yellow flag, five out of six teams rated the element at 3 and one team rated it at 4. Teams recommending the flag removal rated the element at 4 in three out of four cases and 3 in the 4th case. Two teams, that made no flag recommendations, both rated the element at 3. These observations demonstrate the need for increased training on inspection and ratings during varying hydraulic condition near bridge footings.

A key measurement in the assessment of scour is the horizontal measure of the undermining at the pier. Therefore, this item was examined to determine the variability in the undermining among teams that indicated the need for a flag. These horizontal measures are typically recorded as the dimension "d" on an undermining sketch, and are sometimes included in the notes. These measurements may vary somewhat over time due to infill from sediments. The average maximum measurement provided was 1.3 ft. with a maximum of 3 ft and a minimum of 0. Figure 4-11 below shows the maximum measurement provided by teams recommending a flag. In this figure, measurements for teams recommending a red flag are shown by a hatched, gray fill. As this figure indicates, there is significant variation in the measurement of horizontal undermining of the pier. Some of the teams recommending a red flag had the longest horizontal measurements (i.e., longer undermining of the footing).

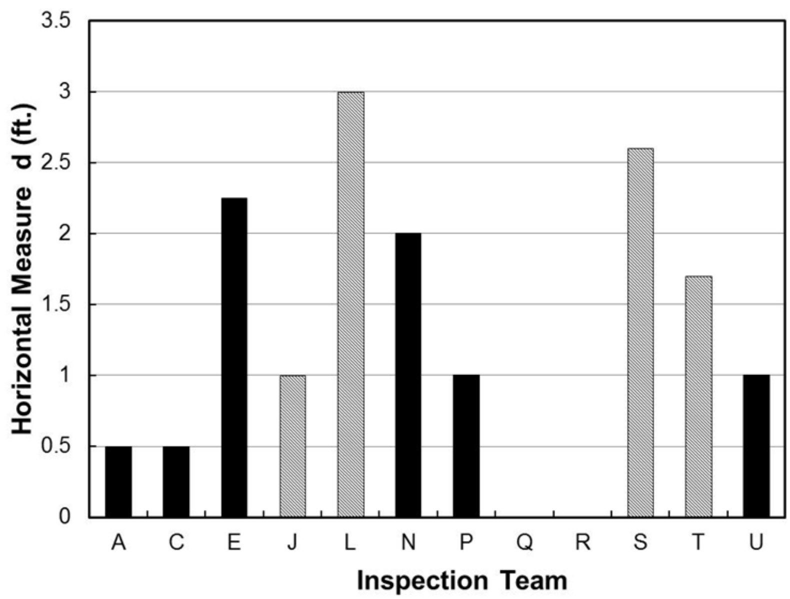


Figure 4-11: Maximum Horizontal Measurements (d) Indicated by Teams Recommending a Red or Yellow Flag for Scour for Bridge 3350660.

These data indicate that there is notable variability in the reported measurements, which may be contributed by changing conditions at the site, inability of the inspectors in distinguishing between conditions posing clear and present danger and those requiring maintenance actions.

4.2.2.5. Damage Mode Detection and Documentation

Given that there was notable variation in the number of photographs and notes taken to describe the condition of bridge in the reports, the relationship between damage detection and number of photographs and notes has been assessed. This has been done by selecting three damage modes that were recorded by at least ½ of the inspection teams. These three damages modes include longitudinal and vertical cracking in the bridge 1026170, and the cracked diaphragm connection in the bridge 3308970. The average number of notes and photographs taken for each of the bridges was compared with whether a given team had recorded none of the damage modes, one, two, or all three of the damage modes. Table 4-11 shows the results of this assessment. It is observed from the Table 4-11 that there is a general relationship between the average numbers of notes photographs with reporting of the damage modes, i.e., teams detecting all three damage modes had the largest number of notes and photographs.

Table 4-10: Number of Damage Modes Reported and Corresponding Average Number of Notes and Photographs.

No. of the Damage Modes Reported	No. of Notes	Std. Dev.	No. of Photos	Std. Dev
All 3	13	4.4	20	8.1
2 of 3	11	2.8	14	6.1
1 of 3	9	3.4	10	4.1
0 of 3	10	3.1	9	3.8

Looking just at the cracking in the bridge 1026170, the number of notes and photographs also corresponded with the reporting of cracks in the adjacent box girder beams, as shown in the Table 4-12. As shown in this table, the average number of notes and photographs is higher for teams that reported both cracks than those that recorded either one or neither of the two cracks. Although similar analysis could be conducted for other two damage modes, these data show that, in general, damage modes are more likely to be reported when the number of notes and photographs taken is high. This is logical, since the number of notes reported by inspectors generally could be expected to correspond with the level of detail and thoroughness of the inspection documentation, and the number of damage modes included in the report.

Table 4-11: Average Number of Notes and Photographs in Report Including Both Cracks, Either Crack or No Crack.

Reported Damage	Avg. Number of Notes	Avg. Number of Photographs
Both Cracks	14	20
Either Crack	13	15
No Cracks	9	9

4.2.2.6. *__Field Inspection Time__*

The field inspection times were also assessed as general indicator of the effort required to conduct the inspections. Figure 4-12 illustrates the field inspection times indicated by the teams in the inspection reports under the heading "Field Notes."

It is observed from the Figure 4-12 that there is a notable variation between teams in terms of inspection times, which is not unanticipated given that there could be differences due to weather, traffic conditions and whether the inspection could all be completed within a single work day, etc. For example, if a team is unable to complete the inspection by the end of the work day, and has to return the following morning, then there will be a natural increase in the inspection time due to the need to mobilize and possibly repeat certain tasks. Additionally, individuals do not share uniform work habits, i.e., some inspectors are likely to be naturally faster than others. Examining the statistical data from this small sample set indicates that the standard deviation for each bridge ranges from a low of 1.3 to a maximum of 1.6 hrs, with an average of 1.45 hrs, as shown in Table 4-13. The difference between the minimum and the maximum inspection times is at least 4.5 hrs., with a maximum of 7 hrs for the bridge 2205690.

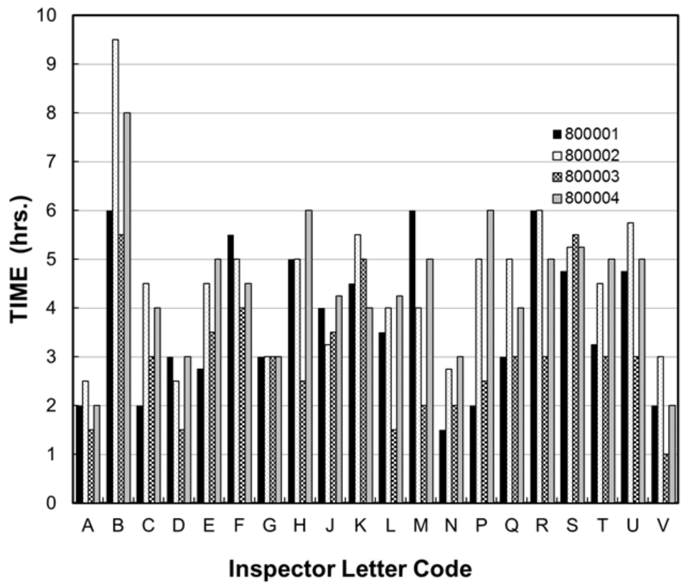


Figure 4-12: Field Inspection Time for the Four Bridges.

Table 4-12: Time Reported for Inspection According to Field Notes.

	1026170	**2205690**	**3308970**	**3350660**
Average Time (hrs.)	3.7	4.5	3.0	4.4
Minimum Time (hrs.)	1.5	2.5	1	2
Maximum Time (hrs)	6	9.5	5.5	8
Standard Deviation	1.5	1.6	1.3	1.4

The average number of notes and photographs also generally corresponded to the average time a team spent on the field inspection. For example, for teams that averaged less than 4 hours for inspections, the average number of notes and photographs was 13 and 15, respectively, while for teams taking on average greater than 4 hours, these averages were 16 and 20, respectively.

Reports also typically include the “Time required to inspect bridge” in the “Miscellaneous” section. The time interval required to inspect the bridge is sometimes significantly longer that the time noted for the field inspection. Eleven of the inspectors entered the same data in this section of the report as in the Field Notes. This indicates that different practices are being used by different teams in terms of what data should be entered in the miscellaneous section of the report, either actual field inspection time, or field inspection time plus other time utilized to complete the inspection of the bridge.

4.2.2.7. Inspection Time vs. Reporting of Damage

The relationship between the reporting of certain key damage modes and the time spent for the field inspection has been assessed for the concrete cracking in the bridge 1026170 and the cracking in the steel girders in the bridge 3308970. Table 4-14 shows the average reported inspection times for bridges 1026170 and 3308970 corresponding to the number of damage modes reported by the inspection teams. These data show that, on average, inspector that reported these damage modes spent more time conducting the field inspection than those that did not report the damage modes.

These results, as well as results indicating the number of notes and photographs, are consistent with varying level of detail during the execution of inspections. Inspection teams that are more thorough identify more damage modes during the inspection. These teams generally take more photographs and notes, and consequently use more time, on average, to conduct the inspection.

Table 4-13: Average Reported Field Inspection Time for Bridges 1026170 and 3308970.

Bridge	1026170		3308970				
Damage	Horizontal and Vertical Cracking		Cracks in Tension Zone		Cracks in Compression Zone		Both
Reported Damage	Both	1 or 0	Crack	No Crack	Crack	No Crack	
Average (hrs)	4.25	3.08	3.67	2.68	3.55	2.40	3.67
Std. Dev. (hrs)	1.43	1.49	1.44	1.14	1.12	1.22	1.44

4.2.2.8. Team Consistency vs. Notes and Photograph Quality Ratings

Team consistency based on ratings on inspected elements of the 4 bridges has been investigated in the companion report entitled "Evaluation of the Consistency of Bridge Inspection Ratings". Using inspection ratings, the consistency of a particular inspection team has been assessed as the percentage of inspections of all elements where the rating assigned by a team is within ±1 of the median rating when the rating is supposed to be 7 to 1, or 8 or 9 when the rating is supposed to be 8 or 9. It has been observed that the minimum average team consistency (considering all 4 bridges) was 95% for the team S. In order the assess the correlation between the team consistency and notes and photograph quality ratings, Figure 4-13 below shows the plot of team consistency based on inspection ratings, and notes and photograph quality ratings for 20 inspection teams. It is observed that both photograph and notes quality ratings for the team E were the minimum among all 20 inspection teams. Overall average QA rating for this team from the Table 4-1 is 90%. However, the average team consistency for this team is 100%. The team with the minimum average consistency of 95% is team S. Percentage of photographs and notes that are very good or good for this team are 97% each, whereas the average QA rating is 86%. Hence, there doesn't seem to be direct correlation between the team consistency based on inspection ratings and inspection report quality ratings. There also doesn't seem to be a direct correlation between team consistency based on inspection ratings and the inspection time. Team A, that spent an average of approximately 2 hours for the inspection of each of the 4 bridges, has a team consistency of 100% whereas team S, that spent the maximum average inspection time of approximately 5.5 hrs, has a team consistency of 95%. It was also noted from the analysis of ratings that team S had contributed significantly to inconsistent ratings. Hence, although there doesn't seem to be a direct correlation between consistency based on ratings and report quality, it is expected that an improvement in report quality will contribute to improvement in the consistency of ratings by encouraging more inspectors carry out hands-on and thorough inspections.

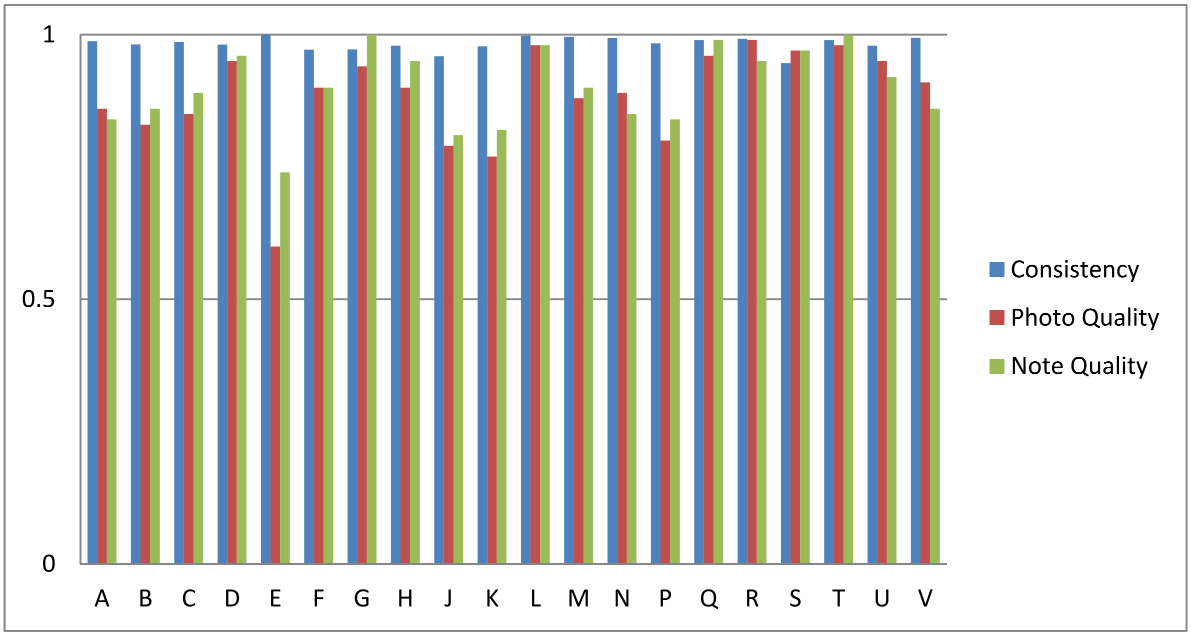


Figure 4-13: Team Consistency Based on Ratings, Photo Quality (% of Photographs Good or Very Good) and Notes Quality (% of Notes Good or Very Good) for 20 Inspection Teams.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

The main objective of the study has been to study the consistency of the New York State Bridge Inspection Program. The consistency study has been carried out both on inspection rating and quality of inspection reports. Following are the conclusions and recommendations on two aspects of the consistency analysis.

5.1. CONCLUSIONS ON INSPECTION RATINGS

The consistency of bridge inspections has been defined as the percentage of bridge inspectors rating a bridge element within ±1 of the median rating, when the rating is supposed to be between 7 and 1. For cases when the rating is supposed to be either 8 or 9, consistency is defined as the percentage of inspectors rating those elements at 8 or 9. The team consistency is defined as the percentage of inspectors rating an element within ±1 of the median rating for elements whose rating is supposed to be between 7 to 1, or 8 or 9 when the rating is supposed to be 8 or 9. Following are main conclusions of this study.

i. For bridge elements whose rating is supposed to be between 7 to 1, 96% elements have a consistency of at least 90%. Only seven elements have been identified to have consistency less than 90%. Overall, consistency of inspections for elements with ratings 7 to 1 is quite high.

ii. For elements whose rating is supposed to be 8, approximately 97% elements had a consistency of at least 90%. Only two elements had a consistency in the range of 80-90%.

iii. For elements whose rating is supposed to be 9, 91% of the elements were inspected with a consistency of at least 95%.

iv. Overall team consistency based on inspection of all elements in the 4 bridges is approximately 98%. This points to the fact that the annual training of inspectors by the NYSDOT is effective. Numerous factors responsible for inspectors assigning inconsistent ratings have been identified. Further improvements in the team consistency can be achieved by addressing these factors through the modification of the NYSDOT Bridge Inspection Manual and through the training of inspectors during the annual bridge inspector's meeting.

v. Compared to NYSDOT ratings, larger variability in NBIS ratings has been found. These data show the need to have more focus on training of inspectors on NBIS ratings.

5.2. CONCLUSIONS ON INSPECTION QUALITY

The results of the QA analysis indicate that the current quality control procedures being used to review reports for submission allow variation in the content of the reports. For example, there is uneven application of the practices regarding the inclusion of photograph location sketches, electrical hazard surveys, dropline readings and access requirements. Many of these items were sometimes missing from the reports. The analysis also showed variation in the area of special emphasis inspections in the reports. Specifically, the inclusion of special emphasis details sketches varied significantly, as did the notes confirming required 100% hands-on inspection. The latter is reported in different areas of the report by different inspectors; in some cases, the 100% hands-on inspection is not noted in the report as required. It appears that the QC reviews currently implemented are not resulting in consistent report contents. Corrective action to address these variations is relatively simple: clarifying the desired content of the report itself, and ensuring that QC reviews include assessing the content of reports. Corrective actions to clarify the desired location and content of notes indicating that 100% hands-on inspection was completed would also improve the consistency of reports.

Analysis of the quality of photos and notes included in the reports indicates that the quality of these report features was very high. Photos are typically clear and the subject of the photograph is easily understood. The quality of notes was also evaluated as being very high, with notes providing clear explanations, with good photographic support and often including quantitative data on the location and extent of damages.

There was variation in the reporting of specific damage modes in the bridges, for both concrete and steel bridges. Because the bridge inspection is a subjective process, there is naturally some variation in the reporting of damage modes existing in a structure. However, for both the concrete and steel bridges examined, there were damage modes where the range of reporting extended from not being reported at all, to being reported as requiring a yellow flag. It would be desirable to have less variation in the reporting of these damage modes. For steel bridges, it appears from the data that cracks in special emphasis areas requiring 100% hands-on inspection were sometimes not reported consistently. Additional training regarding anticipated practices, when using hands-on inspection, may improve the consistency of these results. It was also found that there was some variation in section loss assessment for the steel beams, which may result from different practices in estimating section loss.

There was substantial variation in the assessment of scour conditions for bridge piers. These apparent variations are complicated by the fact that scour conditions may be changing over time due to varying weather conditions, and the fact that interim maintenance and repair by local forces was ongoing during the testing. Regardless, the variation in scour assessments may need investigation and possibly additional training to improve consistency of results.

There is some variation in the number and extent of notes included the report, but generally the notes were of good quality. Similarly, although there is variation in the number of photographs taken, photographs are generally of good quality. There were correlations between the number of notes, number of photographs, time spent on inspections, and reporting of specific damage modes such as cracks in concrete and steel primary members, as would be expected. More detailed reports take longer to develop, include more notes and photographs, and report damage more thoroughly.

5.3. RECOMMENDATIONS ON INSPECTION RATINGS

Although the overall consistency of the bridge inspection program of New York State is quite high, the following recommendations can be helpful in maintaining or improving the consistency of bridge inspections further:

1. All elements rated between 7 to 1 with a consistency less than 100% have been identified. A majority of factors leading to inconsistent ratings of these elements have been identified and discussed. It has been observed that inconsistent ratings are caused because of a few inspectors are:
   (i) not being fully familiar with inventory information on the bridge being rated
   (ii) considering factors such as vegetation, small bearing movements, etc., that aren't explicitly discussed in the NYSDOT Bridge Inspection Manual

(iii) rating based on overall engineering judgment (a majority of inspectors rate on this basis).

However, even with these inconsistencies, overall 96.32% elements have a consistency of at least 90%. Hence, addressing these inconsistencies through the modifications in the NYSDOT Bridge Inspection Manual or through discussions during the annual bridge inspector's meeting will further improve the consistency of the bridge inspection program.

2. Some elements that are supposed to be rated 8 or 9 have been rated inappropriately. Detailed review of inspection reports shows that these inconsistencies may have been caused because of a few inspectors (i) interpreting the instructions in the bridge inspection manual differently, (ii) not being fully familiar with the bridge inventory information for the bridge being rated or (iii) not following the bridge inspection guidelines as intended.

3. Higher variability (or relatively lower consistency) in NBIS rating has been observed. More illustrations in the NYSDOT bridge inspection manual on NBIS ratings of selected elements may be helpful in addressing this issue.

4. Since NYSDOT already holds annual bridge inspector's meeting, implementation of the control bridge program should be considered to monitor and support continuous quality improvements. Implementation of the control bridge program will involve

   (i) Selection of 1-2 bridges annually that can be inspected by a sample of bridge inspectors. Different types of bridges can be selected every year.
   (ii) Development of an online system that can analyze the consistency of inspection ratings for discussion during the annual bridge inspector's meeting. Online system can be configured to have input of ratings by the bridge inspectors after they have inspected the bridge. This will minimize the labor costs involved in managing the control bridge program.
   (iii) Selection of inspectors on a rotation basis such that 20% of the bridge inspectors from each NYSDOT region are able to participate in the program during the 5-year period. This will help in completing one cycle during a 5 year period.

5.4. RECOMMENDATIONS ON INSPECTION QUALITY

1. Action should be taken to clarify the desired content of inspection reports to improve the consistency of reporting of inspections. QC engineers may wish to use the optional check list included in the BIM, or a shortened check-list to ensure that the final inspection report contains appropriate notes, photographic location sketches, etc., identified in the quality control checklist.
2. Special emphasis details requirements should be reviewed to address the variation in the inclusion of sketches and reporting of 100% hands-on inspection in the inspection report.
3. Practices and procedures for evaluating and reporting section loss in steel members could be clarified to improve the consistency of assessments
4. Additional training on 100% hands-on inspection requirements may improve the consistency in the reporting of cracking at special emphasis details. Generally, some

improvements in the reliability of crack detection could be realized by utilizing the suggested visual acuity testing procedures and lighting requirement included in the Chapter 1.

5. Additional training focused on the evaluation of scour may improve consistency in scour assessments, although naturally changing conditions in the field will always present a challenge.
6. The outcome of the research reported here and in associated reports should be reviewed with all bridge inspection teams. This training tool can be used to provide clarification on the desired content of the reports. These reports can also assist inspectors in developing a more uniform approach for reporting key damage modes. An activity to reach consensus on what should be reported in terms of these specific damage modes will help build a more uniform inspection process in the future.
7. Control bridge testing: Future use of the control bridge model should be considered to monitor quality improvements and support continuous quality improvements. This testing, coupled with associated collaboration to discuss results and resolve inconsistencies, can help continuously improve the quality of inspection results.

STATEMENT ON IMPLEMENTATION

The main outcome of this project is the report on consistency of inspection ratings and inspection report quality. NYSDOT engineers can use the report content and recommendations to provide required training of bridge inspectors during the annual inspector's meeting organized by NYSDOT and modification of rating instructions for some identified elements to improve consistency of the program. Implementation of recommendations in this report has already started with the training at the 2013 Bridge Inspector's Meeting. NYSDOT may use the findings and recommendations of this report for many years.

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APPENDIX A

Table A.1: Detailed Information on Inspection of Elements with the Consistency of 95% when the Rating of Elements is Supposed to be Between 7 to 1.

Bridge	Element	Median Rating	Inconsistent Rating	Inspection Note
1026970	Bearings, Bolts, Pads (End Abut)	6	3 (Team S)	End Bearings (fixed, plain elastomeric, 3/8" thick) are distorted laterally ("squashed") up to 1" outside their original rectangular footprints.
	Drainage (Approach)	6	4 (Team D)	Up to 6" high vegetative and soil build-up under approach rail at all 4 quadrants. Storm water channeled along shoulder as point flow, rather than down embankment as sheet flow.
	Embankment (Approach)	5	7 (Team S)	Approach Embankment and Erosion elements exhibit no significant deficiencies.
	Erosion (Approach)	5	7 (Team S)	
	Pavement (Approach)	5	7 (Team Q)	NO NOTE IN THE INSPECTION REPORT
	Guide Railing (Approach)	5	2 (Team J)	The box beam rail at the end left has three backup posts that are too low. The top of the backup post is below the bottom of the rail, posing a potential safety hazard.
	Railing, Parapets (Deck, Span 1)	5	8 (Team A)	NO NOTE IN THE INSPECTION REPORT
	Railing, Parapets (Deck, Span 2)	5	8 (Team A)	NO NOTE IN THE INSPECTION REPORT
	Railing, Parapets (Deck, Span 3)	6	8 (Team A)	NO NOTE IN THE INSPECTION REPORT
	Joints (Superstructure, Joint 2)	5	3 (Team J)	The pier 2 joint is popped up and abraded by traffic. It is also debonded in the new joint area - the right lane, allowing water and debris to penetrate below.
	Bearings, Bolts, Pads (Pier, Span 1)	5	3 (Team S)	At Piers 1 & 2, fixed bearings are distorted laterally (squashed) up to 1" outside their original rectangular footprints. Expansion bearings are typically canted to the left by ¼" to ¾", and the top and bottom elastomer layers are bulging out up to ¼" at the sides. At Pier 1, the expansion bearing for Span 2 Girder G3 has shifted, and overhangs the left edge of the pedestal by ¼".
2205690	Erosion, Scour (Beg Abut)	3	6 (Team G)	Begin and End Abutments are founded on solid bedrock. Isolated areas of Begin and End Stem Footings have deterioration in concrete caused by stream abrasion due to poor stream alignment. End Rt. stem and wing wall footing have the worst condition with spalled area of footing measuring up to 2 ft horizontal and +/- 1" vertical.
	Footings (Wingwall, End Abut)	6	4 (Team G)	
	Erosion or Scour (Wingwall, Beg Abut)	3	6 (Team G)	
	Stream Alignment (Channel)	3	5 (Team S)	Upstream channel directs stream flow at a 30-40° skew towards Begin Right Wingwall and along the Begin Stem. No evidence of scour or siltation because of this alignment.
	Settlement (Approach)	4	6 (Team K)	2008 inspection mentions settlement of "1/2 to 1 inch" in both approaches. Evidence of this settlement could not be found during this inspection. Evidence of recent paving not found.
	Railings, Parapets (Deck)	4	2 (Team J)	Bridge Rail post #2 has a cracked weld where it attaches to the plate, and the bottom weld that

				attaches the plate to the bottom flange is also cracked.
	Primary Members (Superstructure)	4	6 (Team H)	Stringer S1 is in fair condition, but has rust formation with minor delamination because of leakage. At the right bridge rail post 2, an apparent +/-5.5 inches long crack is present in the weld connecting the railing plate to the bottom flange. The primary member rating is based on its ability, as a system, to perform as intended. The cracked weld does not alter this rating.
3308970	Seats and Pedestals (Abutment, End Abut)	5	3 (Team K)	Bird debris has accumulated on the bridge seats and is piled against some of the bearings. The Rating is based on this condition.
	Walls (Wingwall, Beg Abut)	6	4 (Team B)	Both begin wingwalls are 90% mapcracked. The left is beginning to leak efflorescence.
	Erosion or Scour (Channel)	5	7 (Team B)	The channel bottom is comprised of silt, gravel, small cobbles and is relatively flat. Channel bottom scour is not a problem.
	Drainage (Approach)	4	6 (Team B)	The bridge is higher than both approaches and both approaches drain away from the bridge. Both approaches show no evidence of ponding or embankment erosion.
	Railing, Parapets (Deck)	6	8 (Team K)	NO NOTE IN THE INSPECTION REPORT
	Structural Deck (Superstructure)	6	4 (Team S)	The Timber Deck panels are curled up 1/8" to 1/4" at the panel edges, creating a washboard effect and reflective cracking and leakage throughout the wearing surface. Many panels bobble slightly under traffic.
3350660	Stem (Abutment, End Abut)	6	4 (Team S)	The Begin and End Stems exhibit hollowness and softness in the timber plank sheathing. This indicates significant decay not evident through visual inspection alone. Because the timber components retain fill, timber conditions affect the condition rating.
	Walls (Wingwall, Beg Abut)	6	3 (Team S)	The Begin Wingwalls exhibit moderate to advanced decay of the timber. Wingwall piles are hollow-sounding and control the condition rating.
	Walls (Wingwall, End Abut)	5	3 (Team P)	The right wingwall has a 6" high x 18" long opening. Backfill is spilling out at this location, creating sink holes above. The left wingwall has a similar but less severe opening.
	Erosion or Scour (Channel)	3	5 (Team C)	The stream channel under spans 2 and 3 is scoured and exposed for nearly the full depth of the pier 1 and pier 2 footings.
	Waterway Opening (Channel)	4	7 (Team J)	Disagree with the severity of the previous rating. The channel bottom has eroded such that the structure's waterway opening is greater than originally designed.
	Drainage (Approach)	3	5 (Team V)	Evidence of ponding was not noted as previously reported along the end right shoulder near the bridge. The previously reported erosion hole behind the end right wingwall has been filled up with a mixture of sand and granite material.
	Embankment (Approach)	5	3 (Team T)	There is a 4 ft long x 1.5 ft wide x 2 ft deep sinkhole behind the end right wingwall at the stem juncture due to fill actively being lost under the exposed lagging bottom here. The edge of the sinkhole is 2 ft behind the guide rail face.
	Secondary Member (Superstructure Span 1)	6	8 (Team S)	There are no Secondary Members. Transverse, diaphragm-like framing in the first interior bay on the Left and Right sides of the bridge are associated solely with the bridge railing system.
	Secondary Member (Superstructure Span 2)	6	8 (Team S)	
	Secondary Member (Superstructure Span 3)	6	8 (Team S)	

Table A.2: Detailed Information on Inspection of Elements with the Consistency of 90-95% when the Rating is Supposed to be 7 to 1.

Bridge	Element	Median Rating	Inconsistent Rating	Inspection Notes
1026970	Waterway Opening (Channel)	6	4 (Team A)	Water only flows under span 2. At the outlet, both banks are protruding into the channel thus narrowing the channel. Vegetation growth in the channel bed at the inlet and outlet.
			4 (Team D)	
2205690	Erosion or Scour (Abutment, End Abut)	3	5 (Team D)	The footings are on bedrock. No undermining at the end abutment or at the end wingwalls. Bedrock streambed visible under about 18" of clear moving water. Poor stream alignment causing deterioration due to abrasion in isolated areas of Begin and End Stem Footings.
			6 (Team G)	
	Erosion or Scour (Wingwall, End Abut)	3	5 (Team D)	
			6 (Team G)	
3308970	Bearings, Bolts, Pads (Beg Abut)	6	4(Team P)	G6 has lifted 1/4" from the bridge seat possibly due to differential footing settlement. There is also a 1/2" gap between the top of the girder and the deck at the abutment.
			3(Team S)	All Begin and End Bearings have 1/8" to 3/8" pack rust under the girder flanges, lifting the girders by a corresponding amount, and generally inhibiting expansion and contraction.
	Bearings, Bolts, Pads (Abutment, End Abut)	6	4(Team Q)	Girders ends on expansion bearings embedded into the backwall. Timber deck appears to have slightly lifted up across the end abutment allowing asphalt from above to spill thru.
			3(Team S)	All Begin and End Bearings have 1/8" to 3/8" pack rust under the girder flanges, lifting the girders by a corresponding amount, and generally inhibiting expansion and contraction.
	Primary Members (Superstructure)	6	4(Team C)	Bay 4 begin and center diaphragm angles, welded to the top of the compression zone on primary girders, are cracked. No indication of cracks propagating into the base girders web.
			4(Team F)	The rolled multi girder steel superstructure has three sets of X braces roughly at ¼. points in every bay. The G-4 girder has cracks on the right side at the first and second set of X braces.
	Recommendation (Superstructure)	6	4(Team C)	NO NOTE IN THE INSPECTION REPORT
			4(Team F)	NO NOTE IN THE INSPECTION REPORT
3350660	Erosion (Approach)	5	7(Team T)	The previous end right wingwall erosion gully is actually a sinkhole rated under Embankment. All 4 quadrants do not exhibit any erosion. Rating changed to '7'.
			3 (Team W)	The end approach drainage problem channels water behind the end right wingwall, which is causing an erosion hole 1'-8' x 3'-0" x 2'-8" deep. The water drains to the base of the timber wingwall and is washing out the wingwall backfill.
	Guide Railing (Approach)	4	2 (Team J)	The 'W' panel approach rail has missing posts towards the end of their runs at the begin right and left. At the begin left, the first post is also disconnected from the rail.
			6 (Team K)	New galvanized rails placed on existing posts. Top of the End, Left rail is dented downward.
	Recommendation (Pier, Span 1)	5	2 (Team S)	NO NOTE IN THE INSPECTION REPORT
			3 (Team W)	NO NOTE IN THE INSPECTION REPORT
	Recommendation (Pier, Span 2)	5	3(Team S)	NO NOTE IN THE INSPECTION REPORT
			3(Team W)	NO NOTE IN THE INSPECTION REPORT
	Sign Structure (Utility, Span 3)	4	1 (Team J)	The usable shoulders narrow as they approach the structure. There were existing hazard markers at all 4 corners of the structure. The hazard marker at the end left is missing.
			1 (Team P)	Both the begin HCM's have bullet holes. The begin left HCM has impact damage.
			6 (Team M)	NO NOTE IN THE INSPECTION REPORT

Table A.3: Detailed Information on Inspection of Elements with the Consistency of 80-90% when the Rating is Supposed to be 7 to 1.

Bridge	Element	Median Rating	Inconsistent Rating	Inspection Note
1026970	Bearings, Bolts, Pads (Pier, Span 2)	6	3 (Team S)	At Piers 1 & 2, fixed bearings are distorted laterally (squashed) up to 1" outside their original rectangular footprints. Expansion bearings are typically canted to the left by ¼" to ¾", and the top and bottom elastomer layers are bulging out up to ¼" at the sides. At Pier 1, the expansion bearing for Span 2 Girder G3 has shifted, and overhangs the left edge of the pedestal by ¼".
			4(Team B)	Begin pedestal 12 on pier 2 has spalled resulting in 10% loss of bearing. The remaining peds and bearings would rate 6.
			4(Team F)	Bearings over piers 1 and 2 are sliding or tilted to the left side of the bridge and are sliding towards the fixed ends.
			4(Team H)	Fixed elastomeric pads have random shifting present. They also appear to be bulging, perhaps due to excessive loads for their bearing type. The expansion bearings are all in a neutral or slight contraction mode in the longitudinal direction. However, almost all these bearings are laterally shifted to the left.
2205690	Sign Structure (Utility)	4	1(Team H)	The bridge is load posted. 15 ton weight limit signs are present at the begin right and end left. The marker sign face and post are now missing at the end left, downrated to 1.
			1(Team J)	There are no advance warning signs on either end for this 15 ton posted structure. There is no place for a vehicle to turn around once they reach the structure and the average person would be tempted to drive over the structure.
			6(Team T)	The horizontal clearance marker on the end right has been replaced with a new sign with the proper stripe orientation.
			7(Team K)	Sign is replaced with a correct sign. This bridge is 15 tons load posted.
3308970	Guide Railing (Approach)	6	2(Team J)	The guiderail at the begin left and right and at the end right is substandard.
			4(Team F)	The End Left terminus post is not attached to the turn down beam section. The other three corners appear to be attached at the 2010 inspection. There is a 2" long tear in the beam rail opposite the detached post.
			4(Team G)	Both begin shoulders have tall berms of dirt in front of box beam guide rail. Reduction in rail height because of berms was considered to reduce rails ability to retain a vehicle.
3350660	Erosion or Scour (Wingwall, End Abut)	5	3(Team B)	All 4 wingwalls are made up of railroad ties with no footings or piles.
			3(Team H)	Wingwalls are undermined, creating a void. Backfill material is spilling through the bottom of the wingwall creating a void in the embankment at the top of the wingwall.
			3(Team S)	Wingwalls are undermined, creating a void. Backfill material is spilling through the bottom of the wingwall creating a void in the embankment at the top of the wingwall.
			3(Team T)	Scour has lowered grade to up to 2 ft lower than the bottom of the right wingwall lagging over a 5 ft length at the stem juncture. In the left wingwall, at the stem juncture, scour has lowered grade to 2 ft below the bottom of the lagging.

Table A.4: Detailed Information on Inspection of Elements with the Consistency less than 100% when the Rating is Supposed to be 8.

Bridge	Element	Median Rating (Consistency)	Inconsistent Rating	Inspection Notes
1026970	Mono Deck Surface (Deck, Span 1, 2, 3) Note: Ratings and comments applicable to all three spans	8 (85.7%)	4(Team D)	The surface aggregate is polished smooth and the transverse grooves are worn smooth in the wheel paths. Monodeck rates 4 due to temporary asphalt mill and fill area at right, all spans.
			6(Team H)	The wearing surface consists of a monolithic slab with integral wearing surface. At the right side, the wearing surface was overlaid with asphalt concrete over full length of the bridge.
			7(Team N)	Structure has mono deck. No evidence of spalling was present above deck.
2205690	Bank Protection (Channel)	8 (90.5%)	3 (Team U)	The right wingwall scour apron is cracked at two locations with one location corresponding with the wingwall stem crack and the other roughly at the wingwall stem end.
			3 (Team W)	NO NOTE IN THE INSPECTION REPORT
3308970	Sidewalk / Fascias (Deck)	8 (95.2%)	6 (Team K)	Photograph shows no sidewalk. The inspector is rating the deck surface between the railing and white line.
	Sign Structure (Utility)	8 (95.2%)	1 (Team J)	The usable shoulders narrow at this structure. Hazard Markers are warranted at all 4 corners of the structure where the rail is at the narrowest point.
3350660	Bearings, Bolts, Pads (Abutment: Beg & End)	8 (95.2%)	9 (Team Q)	End of the girders were encased behind the backwall elements at each abutment. Bearing areas were not visible for inspection.
	Piles (Abutment: Beg, End)	8 (90.5%)	9 (Team B)	Plans are not available for this bridge. The depth of the stem footings and the existence of piles is unknown.
			5 (Team U)	Timber piles at abutment stem/wingwall corners are rated under this item. No significant defects noted.
	Joints (Superstructure, Span: 1, 2)	8 (95.2%)	3 (Team J)	The Pier 1 and 2 joints have cracks in the wearing surface that allows moisture to penetrate to the structural components below.
	Joints (Superstructure, Span 3)	8 (95.2%)	5 (Team N)	Note: No comment in the report. The joint of the 3rd span is supposed to be Abutment joint. Hence, should have been rated 8.
	Bearings, Bolts, Pads (Pier, Span: 1, 2)	8 (90.5%)	5 (Team Q)	Girders were welded to the top of the cap beam at each pier. All bearing welds were in "5" or better condition at each pier.
			6 (Team M)	
	Stem Solid Pier (Pier, Span 1)	8 (85.7%)	4(Team U)	Rated under this item is the concrete solid stem below the stem pier columns and cap beam.
			5(Team F)	The steel beam placed horizontally directly on the concrete footing is considered a Stem Solid Pier. The solid pier stem portion of this bridge is steel rather than concrete.
			6(Team N)	Per the Bridge Inspection Manual (page 4D.29), Figure 4D.5.2, the section below the pier columns, but above the footing, is rated as Stem Solid Pier.
	Stem Solid Pier (Pier, Span 2)	8 (85.7%)	5(Team F)	See Span 1 above.
			5(Team U)	Rated under this item is the concrete solid stem below the stem pier columns and cap beam.
			6(Team N)	See Span 1 above.
	Recommendation (Pier, Span 3)	8 (95.2%)	5 (Team U)	Note: No notes in the report. However, since they have rated all items of pier for Span 3 as 8, the pier recommendation should have been 8.

Table A.5: Detailed Information on Inspection of Elements with the Consistency less than 100% when the Rating is Supposed to be 9.

Bridge	Element	Median Rating (Consistency)	Inconsistent Rating	Inspection Notes
1026970	Piles (Abutment, End Abut)	9 (95.2%)	8(Team V)	
3308970	Piles (Abutment: Beg Abut, End Abut)	9 (95.2%)	8 (Team L)	The inventory indicates that the abutments are founded on earth cut with no piles;
	Piles (Wingwall: Beg Abut, End Abut)	9 (95.2%)	8 (Team L)	The inventory indicates that the abutments are founded on earth cut with no piles;
3350660	Piles(Wingwall, Beg Abut)	9	8(Team B)	All 4 wingwalls are made up of railroad ties with no footings or piles.
			8(Team H)	The begin and end abutments and wingwalls are founded on footings with no piles present. Begin and end wingwall piles rating are both changed from 9 to 8.
			8(Team U)	
			8(Team W)	There are no piles per the inventory. Rate 8.
	Piles(Wingwall, End Abut)	9	8(Team B)	All 4 wingwalls are made up of railroad ties with no footings or piles.
			8(Team H)	The begin and end abutments and wingwalls are founded on footings with no piles present. Begin and end wingwall piles rating are both changed from 9 to 8.
			8(Team W)	There are no piles per the inventory. Rate 8.

APPENDIX B

Table B.1: Optional Quality Control Checklist for Inspection Quality Assessment.

No.	Questions
1	Gen. Rec. - Is the number appropriate for the ratings and comments in the inspection report?
2	Access - is the actual access used to inspect the bridge noted on the form?
3	Flag Desc. - Are all current or reissued flags briefly summarized?
4	Span Nos. - Are the correct number of spans inspected?
5	Special Emphasis - Does the special emphasis section in the report indicate non-redundant, fracture-critical, pins and hangers, fatigue-prone details, etc.?
6	100% Hands-On - is this noted as being completed for fracture-critical members and/or special emphasis details?
7	100% Hands-on - is the 100% hands-on inspection completed or waived for weld categories D, E, and/or E' welds?
8	Last Span Pier = 8 - Are all pier items rated 8 for single-span bridges and for the last span of multi-span bridges?
9	Last Span Joint = 8 - Is the superstructure joint for a single span bridge, or for the last span of a multi-span bridge rated 8?
10	Droplines -Were dropline readings taken along both fascias for bridges over water, and if not, is there a valid reason why not?
11	Droplines - are the readings within a tolerance of +/- 1.0 ft from the control inspection readings?
12	Scour - Is the extent of scour clearly documented by sketches, if scour is a notable issue?
13	Scour - Are channel profiles near substructures taken if water depth or turbidity preclude a visual inspection?
14	Is water depth measured and documented?
15	Photos - Are all photos located in the photo location sketch?
16	Photos - Are all photo locations depicted in the sketch accurate?
17	Access Form - was it completed when there was a change from the access shown on the preprinted TP 349?
18	Elect. Prox. - If required, was the Overhead Electric Survey form (BD 241) completed?
19	Welds Located - Were D, E, and E' category welds located on sketches in the Special Emphasis section of the report?
20	Category - Were all D, E, and E' welds properly identified?
21	NR-FCM Drawn - Does the Special Emphasis section have sketches identified in all non-redundant and fracture-critical members/details?
22	Signature - Is report signed by the team leader?
23	Date - Is date on report same date as last day in the field?
24	Insp. Agency - Is this coded correctly?
25	Type of Inspection - Is this coded correctly?
26	9s (Unknown) - Is a comment provided for every item (except footings and piles) that is rated 9?
27	Field Notes - Is the recorded date consistent with dates on all inspection documents?
28	Are the date, arrival, departure, temperature and weather blanks completed?
29	Photos - Are all standard photographs (as per the NYS BIM) present?
30	North Arrow - is the North arrow present in the photo diagram?
31	Flow - Is the stream flow direction shown on the photo location sketch for bridges over water?
32	Photos - are above- and below-deck photographs differentiated on the photo diagram?