New Hampshire DOT
Department of Transportation

I-89 Lebanon, NH - Hartford, VT Bridge Reconstruction & Widening Project

October 2017

TIGER

TIGER 9 - Benefit Cost Analysis

Executive Summary

This Tiger Grant Application is being requested by the New Hampshire Department of Transportation (NHDOT) for the superstructure replacement of the Lebanon-Hartford Interstate 89 bridges over the Connecticut River. This Benefit Cost Analysis (BCA) was completed in accordance with the 2016 Benefit-Cost Analysis Guidance for Tiger Grant Applications and the Tiger Grant BCA Resource Guide. This project will rehabilitate two Structurally Deficient Bridges, improve the geometry and operations of the existing Interstate ramps in close proximity to the bridges, improve the non-standard roadway cross section geometry of the existing structures, improve stormwater runoff treatment, improve access to both the Exit 20 Lebanon NH area and Interstate 91 in Hartford VT, and reduce the crash potential within the area.

The Connecticut River serves as the boundary between the State of New Hampshire and the State of Vermont and these two bridges, one carrying I-89 northbound and one carrying I-89 southbound, provide a vital link for commercial, consumer, commuter, freight, and recreational traffic within the region. In addition, there are two important interchanges in close proximity to these bridges. Exit 20 in NH serves a busy commercial corridor along NH Route 12A and the Interstate 91 interchange in Vermont which provides connection to US Route 5, also a busy commercial corridor. The two I-89 bridges were originally constructed in 1963 and 1966 and are considered narrow by current interstate standards with two twelve foot lanes, a three foot inside shoulders, and a three foot outside shoulders. The existing bridges are listed as Structurally Deficient (per NBIS condition rating guidelines). Both bridges are experiencing concrete spalling of the deck with moderate section loss on a number of the girders and vertical cracks in critical plate girders.

To the maximum extent possible given the available data, this formal BCA prepared in connection with this TIGER grant application reflects quantifiable economic benefits. It covers all five of the primary long-term impact areas identified in the TIGER grant application guidelines. Table 1 shows the Project Summary Matrix.

The reconstruction of the two I-89 bridges over the Connecticut River results in a Benefit-Cost Ratio (BCR) of 2.05, with a BCR of 0.43 at a 7 percent discount rate, and a BCR of 0.87 at a 3 percent discount rate.

Table 1 – Project Summary Matrix

<table>
<tr><th>Current Status/Baseline & Problem to be Addressed</th><th>Change to Baseline/Alternatives</th><th>Type of Impacts</th><th>Population Affected by Impacts</th><th>Economic Benefit</th><th>Summary of Results</th><th>Page Reference in BCA</th></tr>
<tr><td rowspan="3">Two deteriorating and structurally deficient Interstate bridges over the Connecticut River between NH and VT and the New England Central Railroad</td><td rowspan="5">Replace existing super structures and replace and widen the bridge decks to meet current AASHTO Guidelines and provide auxiliary lanes to improve adjacent ramp geometry and reduce crash potential.

Removal of the existing anti-icing system that is no longer required with the proposed geometric improvements.</td><td rowspan="4">Improve safety for the traveling public and reduce future bridge maintenance cost

Improve existing stormwater treatment system and water quality

Reduce impact to traffic when there is an incident or maintenance work with the addition of full width shoulders and auxiliary lanes.

Improving scour protection, especially for winter ice conditions, will improve the resiliency of the structure.</td><td rowspan="3">Local, state, regional and international commercial, freight and recreational users.</td><td>Monetized value of lower bridge maintenance cost/Removal of Bridge Anti-Icing System</td><td>$1.4 Million compared to rehabilitation of existing structures</td><td>12</td></tr>
<tr><td>Water quality improvements to the Connecticut River</td><td>Qualitative description of expected improvements</td><td>14</td></tr>
<tr><td>Monetized value of crash reductions</td><td>$54.3 Million</td><td>11</td></tr>
<tr><td>Geometrically nonstandard bridge cross section (i.e. narrow shoulders both sides)

Deficiency in the scour protection on the existing bridge piers.</td><td rowspan="2">The general public in the form of reduced travel and work zone delays compared with the current conditions reductions and crash potential and the need for emergency response as better operations/lower crash potential should result in less calls for services.</td><td>Monetized value of travel time savings for both daily travel and for Work Zone issues.</td><td>Work Zone related reduction: $3,626,836

Daily Travel Time Savings: $210,183</td><td>10</td></tr>
<tr><td>Geometrically nonstandard interstate ramp acceleration length and ramp spacing that are limited by the existing bridge configuration</td><td>Improve travel time through this area by improving operations at the ramp intersections with main line.</td><td>Reduction in emergency response calls, improved operations

Improved access to commercial, medical, retail, railway and airport uses which are the basis of the local economy</td><td>Qualitative description of expected Improvements (non-monetized)</td><td>13</td></tr>
</table>

• **State of Good Repair:** The Interstate 89 bridges are in poor condition and an increasing amount of money is required each year to maintain these bridges in a usable condition. Each year, however, the condition gets worse as these bridges show their age and the work required to maintain them exceeds the funding and personnel available. These bridges have reached the point where a full superstructure and deck replacement is required and is beneficial from a short and long-term standpoint as compared to the rehabilitation option as shown in this BCA. In addition, the analysis has shown that the existing bridge piers lack the proper scour protection required to reduce water ice induced scour. In the Northeast over the last few years we have seen an increase in severe weather events both during the summer and winter. Scour can be very detrimental to bridge structures and additional wear could result in changes to the bridge load rating or possible closure. Installing new scour protection on the bridge piers will help maintain the resiliency of this structure and reduce the risk of a load rate reduction or closure.

The southbound bridge also has a fixed automated spray technology (FAST) anti-icing system which is more costly to operate and maintain than traditional chloride treatments alone. With the proposed replacement of the bridge superstructure and deck and the intended improvements to the existing roadway geometry and drainage system this anti-icing system can be eliminated.

• **Safety:** The non-standard roadway cross section on these bridges coupled with the deficient acceleration/deceleration lengths on the adjacent ramps has led to a large number of crashes each year within the project area and within the influence area of the project. Both of these deficiencies will be corrected with the widening of the bridges and the installation of auxiliary lanes as part of this project, thereby reducing the potential for crashes and injuries. In addition, while not quantified in the analysis, the addition of a twelve-foot-wide outside shoulder allows room for future inspections and underdeck repair work to be completed without the need to reduce the number of travel lanes on the bridge. Reducing the need to provide a work zone that restricts the roadway to one travel lane can reduce the potential for crashes associated with lane merges and queuing issues.

• **Economic Competitiveness:** This project does not provide additional capacity along the interstate; however, the bridges will be widened to provide wider outside shoulders and an auxiliary lane across both bridges. The auxiliary lanes will stretch between both interchanges and provide improved Levels of Service and more consistent travel speeds through the corridor. Improving the ability of vehicles on the mainline and ramps to traverse this area in a more efficient manor will result in a reduction of travel times and costs and will allow local, regional and international commercial users to reduce transportation costs, improve their logistics practices, and expand markets for both domestic and international shipments.

• **Quality of Life:** Improved operations of the mainline and ramp intersections will reduce the travel times and make the travel safer for many of the individuals in and around Lebanon, NH and Hartford, VT who rely on this roadway and these ramps for their daily commute, as well as for trips for education, shopping, medical appointments, and other services. In addition, the improvements in travel time reliability and safety will allow for future expansion of businesses in the area which create additional job opportunities that allow people to work in the area where they work thus reducing commuting times and distances. Many of the major local business, such as the Dartmouth Hitchcock Hospital, pay for the cost of the local bus service so it is free to riders. The local bus system sees the highest ridership of any system in NH. Therefore, any increase in local business development that results from better access to the Interstate causes an increase in ridership and less dependence on vehicles using the roadways. This results in a reduction in congestion, emissions, and crashes which generally promotes a healthier lifestyle.

• **Environmental Sustainability:** Currently the stormwater runoff from the bridge enters the existing scuppers and is deposited, untreated into the river. Providing stormwater runoff treatment facilities as part of this project will have a measurable benefit to the water quality of the Connecticut River.

General Assumptions

Real Discount Rate

In an effort to avoid forecasting future inflation rates and the need to grow future values for benefits and costs accordingly, all benefits and cost were valued in current year dollars. Future values are deflated to reflect current values, even in the case where cost are expressed in future year values. The use of current dollar values requires the use of a real discount rate for present value discounting.

In accordance with the US DOT 2016 Benefit Cost Guidelines for Tiger Grant Applicants, a real discount rate of 7% was used for this analysis[1]. In addition, a 3% real discount rate was used for sensitivity analysis.

Evaluation Period

The evaluation period of benefits and cost of a project are typically for a period that includes the construction of the project and the operational period which is 20-50 years on average. For this project, the analysis period includes the project development stage with the construction anticipated to begin in 2019 and be completed in 2023 and a 50-year operational life. Therefore, this BCA calculates all benefits and costs until 2073. As a simplifying assumption, all benefits and costs are assumed to occur at the end of each year.

Forecasting Traffic Growth Assumptions

A Traffic Assessment of the operational characteristics, speeds, and crash occurrences in the project corridor was completed in 2013.[2] This Assessment looked at the existing operations and future No-Build and Build conditions for the area between Exit 20 in NH and the I-91 Interchange in VT inclusive of the bridges. For this analysis, the build condition assumed the reconstruction of the existing bridges with wider structures that would meet current AASHTO Guidelines and provide and auxiliary lane between the adjacent on and off ramps to improve operations within the corridor. The results of this analysis are shown in the Appendix. The Traffic Assessment assumed an opening year of 2019 and a 20-year design life (2039) consistent with NHDOT Design Guidelines[3] for roadway improvement projects. However, since this project also includes the replacement of the two interstate bridges over the Connecticut River, a design life of 50 years has been provided in this BCA.

The Traffic Assessment collected peak hour traffic data in 2013 and adjusted these volumes upward by a factor of 1.05 to obtain the anticipated 2016 conditions. These values were found

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[1] White House Office of Management and Budget, Circular A-94 Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Program (October 29, 1992)
[2] I-89 Connecticut River Bridge Traffic Assessment - RSG, Inc. Vermont, 2013.
[3] Highway Design Manual – New Hampshire Department of Transportation, 1999 with revisions.

to be lower than the actual 2016 volumes collected at the permanent count station located at the existing bridges. Therefore the 2016 volumes were used as the base and were grown by the background growth rate of 1.01 to obtain the 2019 opening year and by a factor of 1.21 to grow the volumes from 2019 opening year to 2039 design year[4]. Since the Traffic Assessment only grew traffic volumes out to 2039 it was necessary to determine the growth rate from 2019 out the future design year of 2073 to account for the expected life span of the bridge. However, Vermont's Continuous Traffic Counter Grouping Study and Regression Analysis[5] report only includes values out to the 2059 future year. A growth rate for the additional 13 years required to obtain the 2073 future year was computed using the average rate of change between the 2039 to 2059 years and applying this for the additional ten years beyond the 2059 year to obtain the 2073 future year volumes. For this project, the rate was determined to be 1.23 for adjusting the 2019 to 2073 volumes.

Daily and Annual Traffic Assumptions

The traffic volumes collected for use in the Traffic Assessment was for the peak hours only, however the BCA requires volumes expressed in Daily Values. Therefore, is was necessary to obtain daily traffic volumes from the NHDOT Permanent count station located in the cross over at the State Line for the same calendar year that the peak hour counts were collected[6]. This data represents both the 2013 adjusted average daily traffic volume (37981 vpd) and the 2013 computed total annual traffic volume (13,859,526 vpy). These values were then grown by the factors noted above to obtain 2016 conditions and again compared to the 2016 count station date and were found to be slightly lower. Therefore the 2016 count data were used as the based and factored as noted above to obtain the 2019 opening year design year average daily traffic volumes and the computed annual yearly volumes, 41,389 vpd and 15,271,235 vpy, respectively. In addition, the 2019 opening year design year average daily traffic volumes were grown to obtain 2073 opening year design year average daily traffic volume and the computed annual yearly volumes the 51,296 vpd and 18,723,040 vpy, respectively.

Trip Distance

The distance used to compare the trips and corresponding vehicular miles traveled for the "No-Build" and the "Build" conditions were limited to the assumed influence zone of the project. It is anticipated that the influence zone for this project will extend beyond the actual bridge and ramp reconstruction to account for lane changes and reduced speeds that have been observed to occur in advance of the I-89 Exit 20 northbound on ramp in NH and the I-89 southbound on ramp from I-91 in Vermont. The actual limits used in this analysis are 1,000 feet south of the Exit 20 NB on ramp north to 1,000 feet past the I-91 NB off ramp and from 1,500 feet north of the I-91 NB off ramp south to 1,000 feet past the Exit 20 southbound off ramp. While these lengths

[4] Continuous Traffic Counter Grouping Study and Regression Analysis Based on 2012 data, Vermont Agency of Transportation: Traffic Research Unit (March 2013)
[5] Continuous Traffic Counter Grouping Study and Regression Analysis Based on 2016 data, Vermont Agency of Transportation: Traffic Research Unit (August 2017)
[6] Automatic Traffic Record Report – Calendar Year 2013

vary slightly between the northbound and southbound barrels of the interstate, the longest distance was used for ease of calculations. Therefore, the project distance was assumed to be one mile.

Benefit Cost Analysis Introduction

Originally constructed in 1963 and 1966, the two Interstate 89 bridges over the Connecticut River and the New England Central Railroad connect Hartford, Vermont and Lebanon, New Hampshire. The bridges currently service over 41,000 vehicles per day. Each bridge consists of a 6-span plate girder superstructure and a concrete deck measuring 847 feet. The most recent bridge inspection reports list these bridges as structurally deficient and both bridges are on the State's Red List. A rehabilitation study [7] was completed in July 2014 and looked at both rehabilitation and replacement of the superstructures and concrete decks. This analysis also took the existing nonstandard roadway and bridge geometry into consideration including: the narrow shoulder widths on each bridge, insufficient merge distance for vehicles entering the mainline from the I-91 Southbound on ramp, and the less than desirable 2,000 feet between the I-91 Southbound on-ramp and the Exit 20 Southbound off-ramp. Based on the results of this report and consultations with both the New Hampshire Department of Transportation and the Vermont Agency of Transportation, the decision was made to replace the existing superstructure and deck based on the complexity and cost of the ongoing repairs that would be required to maintain the bridges in a state of good repair and maintain a load rating consistent with an Interstate functional classification.

The Benefit-Cost Analysis (BCA) looks at the project from the standpoint of society as a whole and summarizes the net benefits and net costs based on the criteria in the 2017 Tiger Grant Application Guidance. The analysis presented here addresses quantifiable benefits from travel time savings for both daily traffic and as a result of work zones, crash reduction, and maintenance cost savings due to the removal of the anti-icing system. Several other benefits of the bridge reconstruction and geometric improvements are difficult to quantify, including economic competitiveness, livability, and environmental sustainability. In addition to providing an alternative analysis comparison, the cost for the reconstruction option over the 50-year analysis period was compared to the cost for the rehabilitation option over the 50-year analysis period. All data is included in the Appendix.

Baseline Assumptions

The BCA focuses on the reconstruction of the existing bridges, including the full replacement of the steel superstructure, concrete deck replacement, installation of bridge scour protection on the existing piers, and bridge widening to provide improvements to the existing geometry while maintaining the required travel lanes during construction. The project is evaluated by comparing

[7] *Bridge Rehabilitation Study Report*, New Hampshire Department of Transportation, 2014.

the existing conditions, which is considered to be the baseline, and a future scenario where the superstructure has been repaired and concrete deck has been replaced, but not widened, to the reconstruction alternative. It is anticipated that if no major capital improvements are made, these bridges would need to have weight restrictions imposed on them and ultimately closed to all traffic. Because these bridges carry interstate traffic, the long-term closure of the bridges and the rerouting of traffic on other state and local routes was not considered a viable option because introducing the large volume of traffic that uses these bridges onto the already congested area roadways would result in excessive congestion, operational issues, and safety concerns on those roadways. The BCA uses information from other sources which are referenced or included in the Appendix as required.

Benefits and Costs Estimation

Estimation of Benefits for Bridges and Highway

The following section provides a detailed explanation and computation of the benefits to automobile and truck users of this segment of roadway within the project limits. For the purpose of estimating benefits, it is assumed that the reconstruction of the bridges will begin in 2019 with the completion in 2023. It is assumed that the first half of the bridge will be open in 2021 so that the realization of some portion of the benefits will begin in 2021.

Determining Travel Data

The following section provides information about the traffic volume estimates that were utilized for the Benefit-Cost Analysis. These traffic volume estimates provide the basis for the benefits and costs associated with the reconstruction of the Lebanon/Hartford Bridges over the Connecticut River.

The traffic data compiled during the Traffic Assessment for the proposed I-89 Bridge Rehabilitation Project outlines the operational improvements expected as part of the project and serves as the basis for this BCA. This Traffic Assessment consisted of a review of the 2013 existing operational conditions and included an analysis of the future 2019 opening year condition and the 20-year, 2039 design year condition for the proposed roadway improvements. However, since this project is predicated on the reconstruction of a Structurally Deficient Bridge, a longer analysis period of 50 years was used for this BCA since it involves the reconstruction of bridges that will have a minimum of a 75-year design life. The traffic data was adjusted as noted in the section titled; Forecasting Traffic Growth Assumptions of this BCA.

This segment of Interstate 89, including its proximity to Interstate 91, serves as an important part of the local, interstate and international trucking routes to destinations in Vermont, New

Hampshire, Canada, and points further south throughout New England. The truck percentages used in the Traffic Assessment were compared to the 2016 Automatic Vehicle Classification Report data for Urban Interstates[8]. The 2016 rates were found to be slightly higher than the 2012 rates used in the Traffic Assessment indicating a slight increase in truck traffic through this section of roadway over the last few years. The 2014 Daily truck percentages used in this analysis are shown in Table 2.

Table 2 - Estimated Urban Interstate Heavy Vehicle Distribution

Analysis Period	Passenger Vehicles	Single Unit Trucks	Tractor-Trailer Trucks
Daily	89.8%	6.30%	3.90%

This BCA also estimated the Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT) for both cars and trucks. The average daily and annual traffic volumes for the 2019 base year and the 2069 future design year volumes are shown in Table 3.

Table 3 - Present and Future Year Traffic Volumes

	2019 Base Year		2073 Design Year	
	Daily Traffic	Annual Traffic	Daily Traffic	Annual Traffic
Total Traffic	41,389	15,106,985	51,296	18,723,040
Car Traffic	37,167	13,565,955	46,064	16,813,360
Truck Traffic	4,222	1,541,030	5,232	1,939,680

As noted in the Trip Distance section the influence area of this project is approximately one mile. Therefore, the Vehicle Miles Traveled (VMT) was determined by multiplying the daily traffic volume by the distance each car travels within the project corridor. The Vehicle Hours Traveled (VHT) is a function of the time each vehicle takes to travel through the corridor, which is reflected in the average travel speed. The Traffic Assessment collected data on the average vehicle speeds through the corridor under the existing conditions during each of the peak hours. These values were found to be below the posted speed limit of 65 mph in all cases, especially at the Exit 20 on-ramp merge and the I-91 northbound off-ramp diverge. The lower observed vehicle speeds were found to occur in the southbound direction during the AM Peak Hour and in the northbound direction during the PM Peak Hour consistent with the commuter traffic patterns. This is to be expected given the non-standard acceleration length from the I-91 northbound off-ramp to I-89 southbound and the 3-5 percent mainline grade north of the Exit 20 on ramp. These conditions affect the operations of these ramp merges. As vehicles entering from the ramps pull out into the mainline traffic at increasingly lower speeds, the mainline vehicles are required to either slow down to make room or move into the outside lane. This congestion results in increased travel time through this area as vehicles are slowing down to complete these maneuvers. With the construction of the proposed auxiliary lanes between the Exit 20 and I-91 ramps, the vehicle

[8] *2016 Automatic Vehicle Classification Report* – Vermont Agency of Transportation – Traffic Research Unit, July 2017

operations will be improved and the vehicle speeds will be closer to the posted speed, thus improving travel time reliability through the project area. Table 4 outlines the 2019 baseline and 2073 future year traffic volumes used in this BCA.

Table 4: Present and Future Year Vehicle Miles Traveled and Vehicle Hours Traveled.

	2019 Base Year		2073 No-Build		2073 Build		2073 Difference	
	VMT	VHT	VMT	VHT	VMT	VHT	VMT	VHT
Total	41,389	690	51,296	916	51,296	814	0	102
Cars	37,167	619	46,064	823	46,064	731	0	92
Trucks	4,222	70	5,232	93	5,232	83	0	10

Note: The No-Build assumes that the bridge is rehabbed and not widened.

Estimating Travel Time Savings – Daily and Work Zone Related

The travel data for this project was developed for two specific conditions. The first is the “no-build” condition in which the two I-89 bridges over the Connecticut River are routinely maintained, but no major widening is performed to improve operations. The second is the “build” condition in which both bridges are widened to provide an auxiliary lane between the Exit 20 and I-91 ramps, the shoulders are widened to meet AASHTO Guidelines, scour protection is added to the existing piers, and the existing superstructure and concrete decks are replaced to increase the life span of the structures.

The Traffic Assessment provides data for the observed vehicle speeds for the existing conditions and the modeled vehicle speeds for the future 2039 no-build and build conditions. For this analysis, it was assumed that there would be little change in the speeds between 2039 and 2073 because the change in the anticipated volumes is minimal during the peak hours. For this analysis, an average for the observed vehicle speeds of 60 mph was used for the existing daily rate and vehicle speeds of 56 mph and 63 mph were used for the 2073 future no-build and build conditions, respectively. Therefore, using a 7-mph improvement in speed through the corridor, vehicles can be expected to experience a total time savings of 102 hours per year based solely on single vehicle occupancy as shown in Table 4.

The first step in determining the Travel Time Savings is to determine the expected make-up of the daily traffic. Based on data provided by the US DOT[9] it is assumed that 78.6% of the automobile travel is for business use and the remaining 21.4% of automobile travel is for personal use. However, data[10] provided by VTrans indicates that vehicles are generally occupied by more than one person. On average vehicle occupancy is 1.51 occupants for vehicle for all trips and 1.16 occupants per vehicle for work trips. These values result in an affected population that is actually greater than the daily traffic volumes because vehicles include more than one person and each

[9] *The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2* – US Department of Transportation, Washington DC, 2016.

[10] *The Vermont Transportation Energy Profile*, Vermont Agency of Transportation, 2013

person's time must be accounted for in the calculation of the Travel Time Savings. Therefore, the percentage of the daily traffic volume associated with work trips is multiplied by 1.16 and the percentage of the daily traffic volume associated with personal trips is multiplied by 1.51 to estimate the total affected persons. These volumes of affected persons are then multiplied by the corresponding values of time to arrive at the total Travel Time Savings.

The second step is to determine the value of each person's time. The automobile value in 2016 dollars for business travel is $25.40 and the automobile value in 2016 dollars for personal travel is $19.00. For truck travel, it was assumed that 100% is of the truck traffic is for business use with a value of $27.20 in 2016 dollars. These rates were then applied to the total affected volume to compute the total travel time savings on a yearly basis as shown in the Appendix. In the analysis, cumulative travel time savings are estimated to be $210,183.

In addition, there is a cost savings associated with the reduction in work zone lane restrictions required to inspect and maintain the existing bridges with the narrow shoulders compared to the proposed bridges with the wider shoulder. To determine the cost savings, it was assumed that each of the bridges experiences a lane closure at least eight times in the initial year and these closures increase over time as additional time is spent inspecting or repairing the bridges. Once a substantial repair has been constructed then the number of lane closures required drops down again to approximately eight per year and would increase at a much lower rate out to the end of the analysis. It was assumed that during these times traffic would be impacted by a 20 mph drop in the travel speed through the work zone. Since the work zone would only be allowed between 9:00am and 3:00pm daily an average volume of traffic during those time periods was determined from historical data and applied to the future volumes and the affected population (based on occupancy rates). The total time saved was then determined by applying the value of time to the affected population based on the travel usage. The total value of savings because of the work zone time saved is $3,626,836.

Crash Reduction Benefits

This project will not result in any changes to the total VMT within this corridor, so there are no anticipated reductions in vehicle crashes as a result of a change in VMT. However, as part of the reconstruction of the bridge, the roadway will be widened to provide a larger overall cross section in conformance with AASHTO Guidelines. The proposed cross section will include a 4'-0" inside shoulder, two 12'-0" travel lanes, a full width auxiliary lane between the Exit 20 and I-91 ramps, and a 12'-0" outside shoulder. A review of the Highway Safety Manual (HSM)[11] determined that a reduction in the amount of vehicle crashes can be anticipated with the construction of a wider outside shoulder and an auxiliary lane between the exit and entrance ramps.

Determining the reduction in crashes as a result of the proposed improvements first requires the determination of the current and future average annual crash rates for this segment of roadway.

[11] *Highway Safety Manual 1st Edition*, American Association of Highway and Transportation Officials, Washington DC, 2010.

Crash history data for the project area was collected for a ten-year period between 2007 and 2016 from NHDOT and VTrans records[12]. To determine the average annual crash rate by crash type, the total crashes were divided by the number of years the data was collected. The existing average crash rate for the project area was calculated to be 9.2 crashes per year involving property damage only (PDO) and 2.1 crashes per year involving injuries. There was one fatal crash during the review time period within the influence area of the project. This data was used to forecast the anticipated increases in the crashes over the analysis period under the no-build conditions. Since the relative occurrence of crashes is a function of the volume of traffic on a given roadway, the rate of increase of crashes was compared to the increase in traffic volumes over the analysis period to determine the anticipated yearly increase in crash occurrences. This data is provided in the Appendix.

The HSM shows that the crash rates are directly related to the geometry of the roadway and that changes to the geometry can have an effect on the occurrences of crashes. The relationship between roadway geometry and crash occurrence is quantified through the use of Crash Modification Factors (CMF's). These values are determined through research and are directly related to the type of proposed improvement. The Crash Modification Factors Clearinghouse[13] was consulted to determine which CMFs best represent the intended improvements and the effect they will have on crash occurrences. A CMF for the construction of an Auxiliary Lane was found to be 0.80 for all crash types while the CMF for the construction of wider outside shoulder varied based on the crash type. For Property Damage Only (PDO) crashes the CMF is 0.83, for injury crashes it is 0.76 and for fatalities the CMF is 0.96. When considering the effect of multiple CMFs on the reduction of crashes for a segment the HSM recommends multiplying the individual CMFs together and applying the result to the anticipated average annual crash rate for each type of crash that can be mitigated by the specific CMFs to determine the reduction in the number of crashes of each type per year. The benefit of a reduction in crashes per year was calculated based on the type of crash and summarized as a yearly savings. In the analysis, the cumulative crash reduction savings is estimated to be $67,424,298. All data is provided in the Appendix.

Bridge Anti-Icing System Removal Cost Benefits

The existing southbound I-89 bridge is narrow; with a three foot inside shoulder and a three foot outside shoulder, its proximity to the Interstate 91 on-ramp, a downhill grade of approximately 3 percent and its elevation, 70 feet, over the Connecticut River. This combination of factors makes it difficult to plow and maintain this bridge free of ice and snow and had resulted in several severe crashes. In an effort to improve the roadway surface conditions during subfreezing temperatures, the NHDOT installed an automated potassium acetate anti-icing system on the I-89 southbound bridge in 2006 to supplement their existing snow and ice removal procedures. While the delivery system is automated based on data received from the Road and Weather

[12] *I-89 Connecticut River Bridge Traffic Assessment, RSG White River VT 2013*
VTrans Online Crash Query Tool, 2012-2016, Vermont Agency of Transportation.
NHDOT Crash Study 2012-2016data only, New Hampshire Department of Transportation, October 2017.
[13] Crash Modification Factor Clearinghouse"; http://www.cmfclearinghouse.org, accessed 3/18/2015.

Information System and sensors in the deck, it requires a significant amount of routine maintenance to operate properly. With the proposed improvements to the geometry of the bridge, including wider shoulders, the construction of the auxiliary lane, and revised cross slopes, this system will no longer be required in the future. Therefore, the annual cost savings for the removal of this system were calculated and are included in the Appendix. In the analysis, the cumulative cost savings are estimated to be $875,000 ($2016).

Non-Monetized Benefits

In addition to the quantifiable monetized benefits above, the project also generates some benefits that are tangible, but difficult to quantify. Below is a description of some of these benefits.

<u>Economic Competitiveness:</u>

These bridges serve as a vital link between Tax Free shopping in New Hampshire and many recreational and cultural activities in Vermont. One of the largest industries in NH and VT is tourism and this project will provide a safer, more efficient connection between these attractions and their users. In addition, these bridges form one of the major links in the commercial shipping corridor between Canada, Vermont, New Hampshire, and points further south throughout New England. Therefore, the proposed improvements will maintain long-term efficiency of the system, travel time reliability for all users, and cost competitiveness of goods.

The Lebanon Municipal Airport, located off Exit 20 in New Hampshire is the state's third largest airport. The Airport is a large economic contributor to the region with nearly $2.4 Million spent in 2013 by airport visitors[14]. It hosts three major aviation service providers and is a critical resource for the Dartmouth-Hitchcock Advanced Response Team (DART). Many businesses in the region rely on Lebanon Municipal Airport for the transportation of goods or persons, including educational and healthcare institutions, large retailers, and financial firms. The proposed improvements will provide a safer, more efficient connection between New Hampshire, Vermont, and the region, which is key to maintaining the economic stability and growth of this airport.

In addition, there is an existing Amtrak Train Station in White River Junction just over the Vermont border that provides daily year-round service from St. Albans, VT to Washington DC with intermediate stops in New York City and connections to New Jersey, Pennsylvania, Maryland, and Delaware. This facility also provides freight service along the entire route, some of which is bound for points in NH which are serviced via I-89 and the bridges over the Connecticut River. Maintaining safe, reliable access to this facility is critical to passenger and freight service in this area. And for every passenger that uses this facility or freight that is shipped via rail it is one less car or truck on the roadways.

[14] *2015 NH State Airport System Plan*, New Hampshire Department of Transportation, 2015

While the savings associated with a reduction in crashes as a whole was summarized previously, it should be noted that these savings directly affect the local communities that provide the emergency service response. The savings associated with fewer emergency response calls result in lower taxes for many communities already struggling to maintain low taxes. Lower taxes allow these communities to stay competitive in attracting and retaining businesses and homeowners.

The reconstruction of these bridges will create approximately 75-100 new short-term jobs associated with the actual construction of the project. In addition, there may be some additional retail activity associated with these workers frequenting local business to eat or shop during the day or prior to coming to work in the morning or going home in the evening.

As one of the fastest growing regions in the state of New Hampshire in terms of new development, the Lebanon-Hanover region has seen continued growth in new and emerging technology businesses looking to be close to both Dartmouth Hitchcock Medical Center and Dartmouth College in Hanover. Maintaining these roadways in a good state of repair helps ensure that these businesses will continue to grow and thrive in this area.

<u>Quality of Life:</u>

Maintaining these bridges in a state of good repair, improving operations of the interchanges, and improving safety all have a positive impact on travel through this area for both business and personal endeavors including work, shopping, school, medical treatment, and recreational activities. In addition, this area contains one of the largest VA Hospitals in White River Junction Vermont as well as one of the top cancer research and children's hospital in the region - Dartmouth Hitchcock Medical Center in Hanover New Hampshire. The proposed improvements will continue to provide safe, efficient access to these facilities ensuring that people are able to continue to obtain excellent medical care.

<u>Environmental Sustainability:</u>

Improving the water quality of the Connecticut River is important to both Vermont and New Hampshire. In fact*, "The Connecticut River is the flagship natural resource for New England, just as the Chesapeake Bay is to the mid Atlantic region. Running 410 miles from the Canadian border to Long Island Sound, it is the region's longest river and one of only 14 designated American Heritage Rivers in the nation recognized for its distinctive natural, economic, agricultural, scenic, historic, cultural and recreational qualities. In May 2012, U.S. Interior Secretary Ken Salazar designated the Connecticut River as America's first National Blueway, saying the restoration and preservation efforts on the river were a model for other American rivers."*[15] The reconstruction of these bridges includes the construction of two new stormwater treatment facilities to handle stormwater runoff from the paved roadway surfaces where there is currently no such treatment.

[15] *"About the River"*, http://www.connecticutrvier.us/site/content/about-river, accessed 3/22/2016.

The proposed infiltration ponds, one in Vermont and one in New Hampshire, will provide improved water quality by increasing the removal of Total Suspended Solids, Total Nitrogen, and Total Phosphate from highway runoff and will provide water recharge to the existing groundwater table. In addition, a cleaner, healthier river ecosystem provides a better habitat for aquatic, riparian, and mammalian species.

Estimation of Cost for Bridges and Highway

The following section provides a detailed explanation and computation of the construction costs and operation and maintenance costs of the project. When estimating costs, it was assumed that the reconstruction of the bridges will begin in 2019 with the completion of both bridges in 2022 with final project completion in 2023. It is assumed that the realization of construction cost will begin in 2019 and the first bridge will be open in 2021 so some benefits will be realized before the end of construction. Operation and maintenance costs occur annually while construction costs are only incurred during the relevant construction period.

Construction Costs

The Interstate 89 bridges over the Connecticut River are structurally deficient and without major repairs would lose functionality and eventually need to receive major rehabilitation or be closed. However, because these bridges are Interstate structures with an Average Annual Daily Traffic (AADT) over 41,000 vpd, it is not considered feasible to close these bridges and reroute this traffic through other state routes or local streets as noted previously. Therefore, the only options are continual repair and maintenance of the existing bridges or reconstruction and widening of these bridges. While the overall operations and maintenance cost would appear to be lower if the bridges were closed, the long-term costs associated with the maintenance of the state and local roadways used to detour traffic would eventually catch up to the cost of repairing the existing bridges as many of these roadways were not built to handle 41,000 vpd or more. In many cases this would require a more intense maintenance schedule and perhaps even complete roadway reconstruction of the roadways and intersections along the detour route. In addition, many of the proposed detour routes contain bridges whose maintenance costs would also increase with the anticipated increase in traffic. The cost associated with rehabilitation of the existing bridges and reconstruction and widening of the bridges is included in the Appendix.

The cost of the project consists of the initial construction cost associated with the reconstruction of the two I-89 bridges over the Connecticut River and the future operation and maintenance (O&M) costs. Reconstruction of the bridges is expected to cost approximately $35.6 Million ($2016).

Pavement Maintenance Costs

The existing bridges were last resurfaced in 2012 as part of the Lebanon 11700 Exit 20 project. The treatment varied as part of that project, but within the vicinity of the bridges the treatment consisted of a step box widening including 4" of new Bituminous Concrete Pavement. The existing pavement is in good condition. Typically, a crack seal would be performed 5 to 7 years out from the last treatment (2012) followed by the application of a travel lane only preservation treatment 8 to 12 years from the last pavement treatment (2012). This would mean that if the bridges were not reconstructed or the project was delayed, that a crack seal treatment would need to be performed in 2019 at a cost of $100,000 and a bridge wearing course treatment would need to be performed in 2022 at a cost of $400,000.

With the reconstruction of these bridges and the approach roadways as part of this project, the anticipated 2019 and 2022 pavement treatments will not be required so there are anticipated pavement maintenance cost savings of $500,000 which have been shown as a negative cost in the analysis.

Operation and Maintenance Costs

The proposed reconstruction of the two I-89 bridges over the Connecticut River will include complete superstructure and deck replacement as well as minor repairs to the existing abutments and piers. Even with a new structure, there will be some cost for annual operations and maintenance associated with inspections and incidental repairs to keep the bridges in peak operational condition. Over time the costs of annual repairs will increase as additional repair work becomes necessary as the bridges age. Within the 50-year analysis period it is assumed that the bridge decks will not need to be replaced. Operation and maintenance cost of the bridges including cleaning, deck patching, crack sealing and repaving are estimated to be over $10.3 Million ($2016) over the analysis period.

The useful life of the bridges is estimated to be a minimum of 75 years, which is significantly longer than the analysis period. At the end of the analysis period in 2073 the bridges will have approximately 25 years remaining before major rehabilitation of the superstructure and substructure or complete replacement would be required. Therefore, the bridges will carry a residual value past the end of the analysis period that has been estimated as a negative cost for this analysis. This value is $12.6Million ($2016) and $0.2 Million when discounted 7 percent and $2.3 Million when discounted at 3 percent. Underlying this estimate is the assumption that the bridge will depreciate on a straight-line analysis, with the residual value of the bridge equal to the ($2016) construction cost multiplied by the proportion of its useful life at the end of the analysis period compared to the useful life of 75 years.

In summary, the total project cost used in this BCA net of all adjustments is $38.2 Million ($2016), $27.8Million when discounted at 7 percent, and $33.7 Million when discounted at 3 percent.

Summary of Benefit - Cost Results

The reconstruction of the two I-89 bridges over the Connecticut River will result in a total benefit of $71.9 Million dollars at current value. The present value of total costs associated with this project is $350 Million and the net present value is $38.2 Million. The BCR is 2.05 for present value, a BCR of 0.43 at a 7 percent discount rate, and a BCR of 0.84 at 3 percent discount rate.

Since some of these BCR's are below 1.0, the cost of the reconstruction project was also compared to the only other viable option which is rehabilitation of the existing steel and replacement of the concrete deck on both bridges. The construction cost of this alternative including the temporary bridge needed to maintain the required travel lanes during construction would be $19.7 Million ($2016). The operation and maintenance cost of $11.7 Million for the rehabilitated bridges would be greater than the operation and maintenance of the reconstructed bridges $10.3 Million because of the need for additional long term steel repair, repainting cost, and the cost of the continued use of the anti-icing system associated with the existing bridges. When compared to the construction and long-term operation and maintenance costs of the reconstruction alternative, it appears that the rehabilitation alternative has a cost savings of $0.9 Million in the 50-year analysis period which does not get figure directly into the BCR.

However, the evaluation of the rehabilitation alternative undertaken by NHDOT in 2015 showed that with the proposed steel repairs and concrete deck replacement, the life expectancy of the rehabilitated bridges was only 50 years. This is 25 years shorter than the expected life span of the reconstructed bridge. With an expected residual value of $12.6 Million in the analysis year, without taking into account the added benefits of the roadway improvements associated with the reconstruction option, the reconstructed bridge is the better overall value.

APPENDIX

I-89 CONNECTICUT RIVER BRIDGE TRAFFIC ASSESSMENT
VALUE OF TIME GUIDANCE DOCUMENT
BRIDGE REHABILITATION STUDY REPORT
TRAFFIC DATA
GUIDANCE ON THE TREATMENT OF THE ECONOMIC VALUE OF STATISTICAL LIFE
CRASH MODIFICATION FACTORS
BENEFIT COST ANALYSIS WORKSHEETS
BRIDGE INSPECTION REPORTS

I-89 CONNECTICUT RIVER BRIDGE TRAFFIC ASSESSMENT

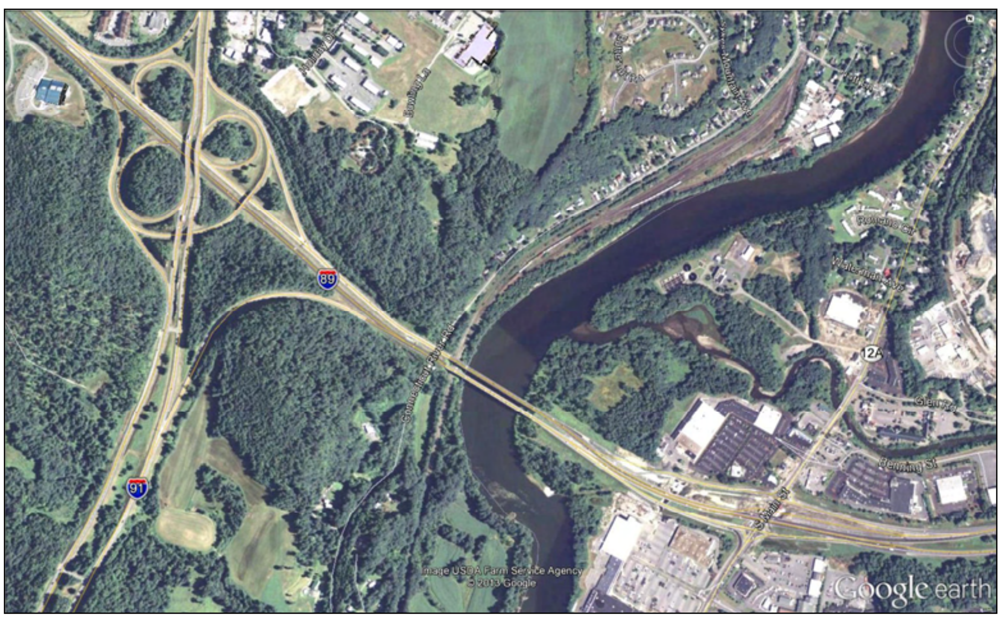
TECHNICAL MEMORANDUM

To: Gene McCarthy, McFarland Johnson
From: David Saladino, P.E.; Ivan Hooper, P.E.
Subject: I-89 Connecticut River Bridge Traffic Assessment
Date: 10 April 2013 *(updated 2 May 2013)*

Introduction

The New Hampshire Department of Transportation (NHDOT) is planning to rehabilitate the I-89 bridges over the Connecticut River on the New Hampshire/Vermont state line (bridge numbers 044/104 and 044/103). The Connecticut River bridges are located along I-89 between two interchanges approximately one mile apart. On the west side in Hartford, Vermont is the I-91 system interchange and on the east side, in Lebanon, New Hampshire, is the NH-12A (Exit 20) service interchange. Figure 1 is an aerial photo of the project study area.

Figure 1. Project Study Area



As part of this bridge rehabilitation project the NHDOT is considering whether bridge deck widening is needed in either or both directions. RSG was tasked with evaluating whether additional lanes on the bridge are justified or not based on an assessment of traffic and safety conditions. The primary reasons for considering bridge widening is the close proximity between the I-91 and Exit 20 ramps and the relatively steep grades on the Vermont side, which lead to sub-optimal merge and weaving areas.

RSG evaluated the bridge and adjacent area for conformity with design standards, existing and forecasted traffic performance, and crash history to develop our recommendation.

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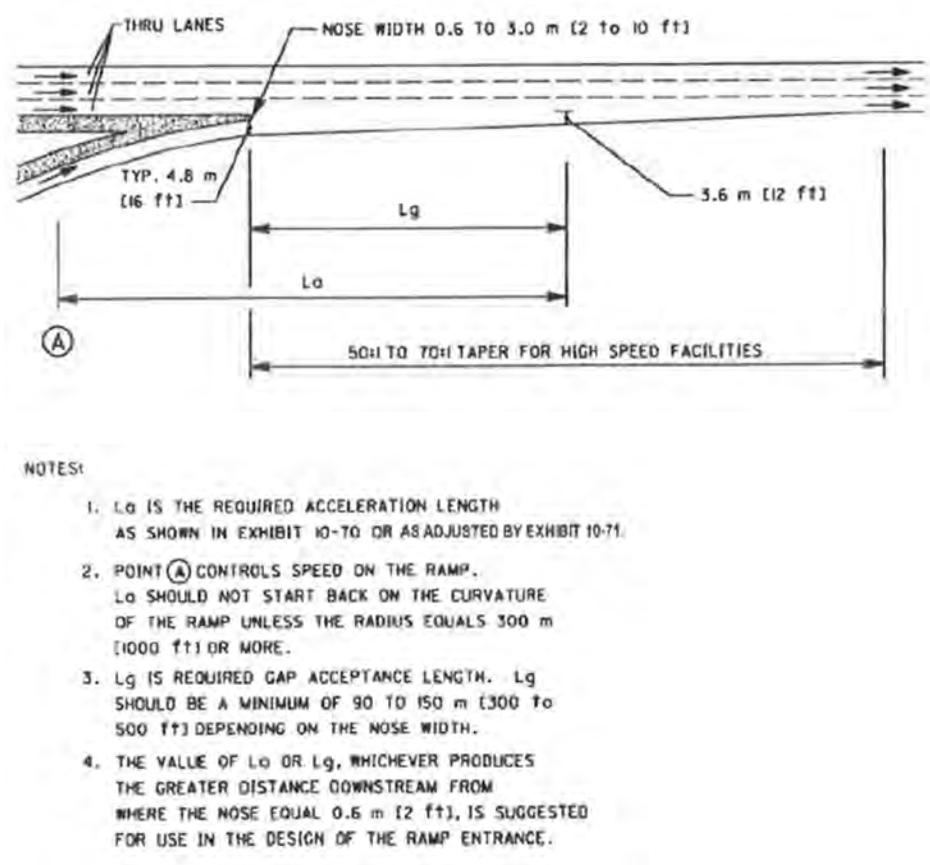
Design Standard Review

Because design standards change over time, a review was conducted of the existing interchanges to determine how well they comply with current design standards, which were taken from *A Policy on Geometric Design of Highways and Streets,*[1] which is commonly referred to as the "Green Book" and is the generally accepted national standard for highway design. The standards consulted in the *Green Book* related to the length of freeway ramp merges and the application of auxiliary lanes.

FREEWAY RAMP MERGES

There are two types of freeway ramp merges described in the *Green Book*. The first is the tapered design wherein the on-ramp gradually tapers into the mainline, typically over a distance of 700 to 1,300 feet depending on a variety of factors, including: the freeway grade, the width of the ramp, and the speed on the ramp. The second type is the parallel design which brings the on-ramp into a short new parallel lane on the freeway that runs for 300 to 800 feet before tapering into the adjacent through lane over an additional 300 or more feet. The same factors are utilized to determine the length of the parallel lane. The freeway on-ramps in the project area are of the tapered type. Figure 2 shows the portion of Figure 10-69 from the *Green Book* that illustrates the various components that go into calculating the required merge distance for a tapered design.

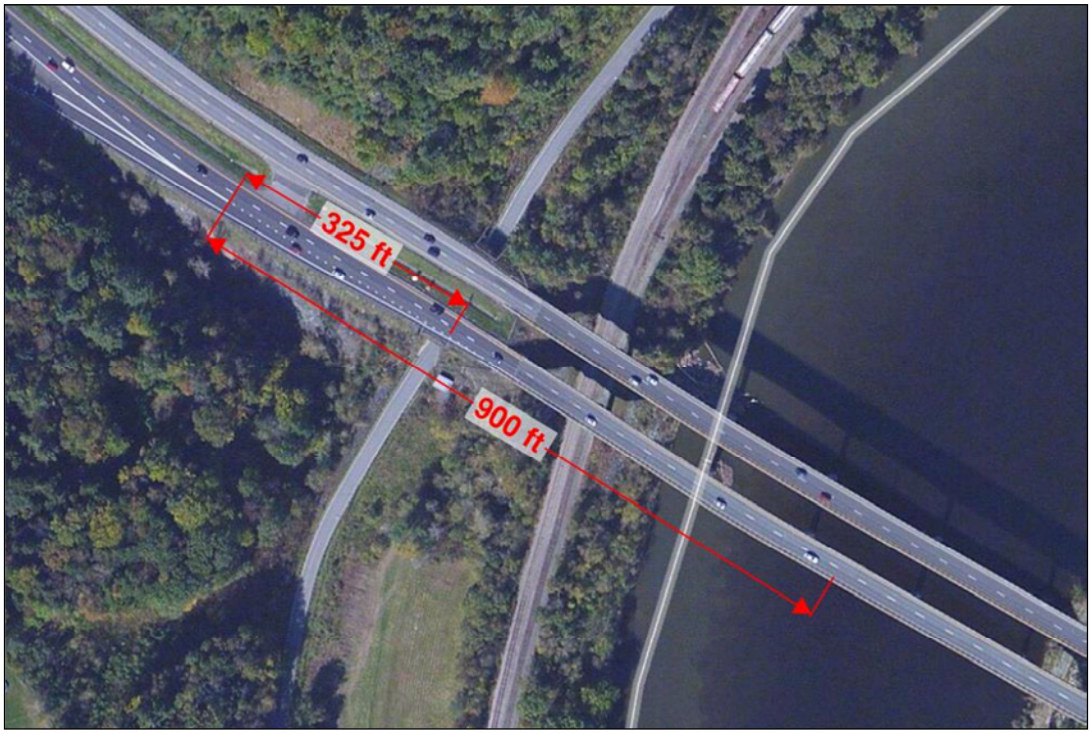
Figure 2. On-Ramp Merge Length Parameters



[1] American Association of State Highway and Transportation Officials (AASHTO), *A Policy on Geometric Design of Highways and Streets*, 6th Edition (Washington DC: AASHTO, 2011).

We performed an analysis on the on-ramp from northbound I-91 to southbound I-89 to compare the required merge distance (per *Green Book* standards) with the actual merge length provided. Assuming that the on-ramp is 16 feet wide with a two foot nose width and a 50:1 taper, then the on-ramp would require 900 feet to fully merge with the mainline. The existing northbound I-91 on-ramp has a merge distance of approximately 325 feet meaning that about 575 additional feet of merge distance are required to meet the current *Green Book* standard. Provision of this additional merge distance would necessitate widening of the I-89 southbound bridge as shown in the figure below.

Figure 3: Existing and Minimum Required Merge Distances (On-Ramp from I-91 Northbound)



Since the on-ramp from NH-12A at Exit 20 was just fully reconstructed, we have assumed that the ramp merge geometry complies with all appropriate design standards and as such did not perform a similar analysis for that ramp.

AUXILIARY LANES

Auxiliary lanes are continuous lanes that connect an on-ramp to an adjacent off-ramp. They are generally utilized when traffic volumes are high or when the distance between ramps is limited. The *Green Book* recommends that auxiliary lanes be utilized when the distance between the on- and off-ramps of adjacent interchange is 1,500 feet or less. The distance between the two study ramps on I-89 southbound is approximately 1,850 feet while the distance between the adjacent I-89 northbound ramps is about 3,000 feet. Per Figure 10-68 in the *Green Book*, the recommended spacing between adjacent on- and off-ramps when the on-ramp is from a system interchange is 2,000 feet. When the on-ramp is a service interchange the recommended spacing is 1,600 feet. Since the southbound on-ramp from I-91 is part of a system interchange the available spacing distance of 1,850 feet is less than the recommended 2,000 feet, which suggests that a southbound auxiliary lane may be applicable between the two interchanges in this direction.

Traffic Analysis

A micro-simulation traffic analysis was performed for the study area using VISSIM software, which is widely utilized to analyze complex roadway geometries. The VISSIM model geometry was developed using aerial photography and engineered drawings of the new Exit 20 interchange, which was obtained from NHDOT.[1] The analysis was performed for the weekday AM and PM peak hours and for the Saturday peak hour. The three analysis periods were analyzed for existing (2013) conditions, year of project opening (assumed to be 2019), and twenty years after opening (assumed to be 2039).The following sub-sections describe how the analysis was performed and the results of the analysis.

TRAFFIC DATA COLLECTION

To analyze traffic on I-89 between the I-91 and Exit interchanges, it was important to understand the traffic patterns among the various facilities. An origin-destination (O-D) study was performed using sensors to record the travel patterns of Bluetooth-enabled devices through the study area. Five sensors were deployed for a week in February 2013 at strategic locations on I-89 and I-91. Each sensor recorded a unique identifier of each Bluetooth-enabled device as it passed by. These unique identifiers were then matched up to determine the path that the vehicle took through the study area. By counting the number of times each of the possible routes through the study area occurred, an initial O-D table was developed for each time-of-day study periods. The O-D tables included I-89, I-91, and the Exit 20 ramps to/from the west. The three tables were then calibrated using a manual traffic count of the Exit 20 ramps conducted by RSG staff on 14 March 2013 and then scaled to match January 2013 traffic counts at the bridges from the NHDOT continuous traffic counter located immediately adjacent to the bridge (station # 253090). The resulting O-D tables were the basis for all of the subsequent traffic analyses. Appendix A contains a detailed description of the Bluetooth data collection process.

There was a desire for the analysis to reflect conditions during the peak time of the year, which is during the summer. However, the Bluetooth data was adjusted to January 2013 volumes. To get the O-D tables to represent summer 2013 conditions seasonal factors ranging from 1.08 to 1.16 were applied to the O-D tables. The seasonal factors were developed from NHDOT continuous traffic counters data in the general study area.

To represent the pulsing of traffic onto the freeway when the traffic lights turn green, the Exit 20 ramp terminals were included in the VISSIM model. Intersection turning movement counts from 2008 were utilized to determine the O-D patterns for the ramp terminals. These volumes were adjusted to match the Exit 20 ramp volumes in the summer 2013 O-D table. Appendix B contains figures showing the O-D tables, freeway volumes, and ramp terminal volumes.

Peak hour factors (PHF) for the analysis were obtained from the intersection turning movement counts and were 0.86 for the weekday AM peak hour, 0.93 for the weekday PM peak hour, and 0.95 for the Saturday peak hour. PHF values less than 0.95 were assumed to gradually increase over time as traffic volumes increase. In 2039 the assumed PHFs were 0.92 for the AM and 0.95 for the PM and Saturday.

Heavy vehicle percentages were primarily obtained from the *Vermont 2012 Automatic Vehicle Classification Report*[2] and were classified as single unit trucks and tractor-trailer trucks. Using data from the VTrans continuous traffic counter on I-89 north of the I-91 interchange and from the ramps comprising that interchange, an approximate heavy vehicle percentage was estimated for the I-89 Connecticut River bridges segment. Daily heavy vehicle data was used to estimate the AM percentages, peak hour data to estimate the PM percentages, and an average of the two to estimate Saturday

[1] Lebanon 11700 – Project Specific Information, New Hampshire DOT, Accessed March 9, 2013, http://www.nh.gov/dot/projects/lebanon11700/index.htm.

[2] Vermont Agency of Transportation; Policy, Planning & Intermodal Development; Traffic Research Unit; *2012 Automatic Vehicle Classification Report* (March 2013).

percentages. Figure 4 shows the resulting heavy vehicle percentages utilized for the micro-simulation analysis.

Figure 4: Assumed Freeway Heavy Vehicle Percentages

Analysis Period	Passenger Vehicles	Single Unit Trucks	Tractor-Trailer Trucks
Weekday AM Peak Hour	91.1%	5.6%	3.3%
Weekday PM Peak Hour	94.1%	3.5%	2.4%
Saturday Peak Hour	93.1%	4.5%	2.4%

Heavy vehicle percentages for NH-12A were taken from 2008 intersection turning movement volumes, which were 6% for the AM, 3% for the PM, and 4% for Saturday peak hours. The freeway proportions of single unit to tractor-trailer trucks were utilized for NH-12A.

TRAFFIC ANALYSIS METHODOLOGY

This section describes the process utilized to estimate the future year volumes, the measures of effectiveness used to compare scenarios, and how the VISSIM modeling was performed.

Future Year Volume Estimation

Future year volumes for 2019 and 2039 were estimated using interstate facility growth factors obtained from Vermont's *Continuous Traffic Counter Grouping Study and Regression Analysis Based on 2012 Traffic Data*[1] report.[2] The growth factors obtained from that report were 1.05 for adjusting from 2013 to 2019 and 1.21 for adjusting from 2013 to 2039. These factors were applied to the summer 2013 values to estimate the future year volumes for 2019 and 2039. Appendix B contains figures showing the 2019 and 2039 freeway and ramp terminal volumes.

VISSIM Modeling Approach and Calibration

The VISSIM micro-simulation software, developed by PTV was used for the traffic operations analysis. Version 5.4-07 of VISSIM was used to evaluate traffic operations in the study area. The model was run for an hour and ten minutes with no data being collected for the first ten minutes while the network was seeded. Data was then collected for the next four 15-minute intervals. The traffic volumes for the second 15-minute period were increased in accordance with the peak hour factor and the volumes for the other three 15-minute periods were correspondingly reduced so that the total hourly volume was unchanged.

Traffic signal timing data for the Exit 20 ramp terminals were developed for all scenarios using the Synchro software and a cycle length of 90 seconds. Because no evaluation was performed for the ramp terminals it was not necessary to match existing signal timing plans. The important thing was to have appropriate timing plans that fed vehicles onto the freeway in an appropriate manner.

The VISSIM model was calibrated to vehicle travel speeds measured by RSG personnel using the floating car method during peak- and off-peak periods. The average observed travel speeds were 63 mph in the southbound direction and 60 mph in the northbound direction. The January 2013 PM peak hour model was run five times and the speeds between I-91 and Exit 20 were averaged and compared to the target values. Adjustments were made to the desired vehicle speeds until the modeled speeds were within one

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[1] Vermont Agency of Transportation; Policy, Planning & Intermodal Development; Traffic Research Unit; *Continuous Traffic Counter Grouping Study and Regression Analysis Based on 2012 Traffic Data* (March 2013).

[2] We initially looked to conduct a trendline regression analysis on the historic AADT's reported at the NHDOT Continuous Count Station located on I-89 immediately east of the bridges. However, we found that the growth projections varied significantly depending on which year the regression analysis was started in and that the count station has not been functioning in recent years due to adjacent construction activities. We therefore, utilized the VTrans average interstate facility growth factors to grow traffic across the bridges.

mph of the observed speeds. The calibrated model that was used for all of the analyses had an average southbound speed of 63.3 mph and an average northbound speed of 59.3 mph.

The same desired vehicle speeds were assumed for both directions. The speed difference between the two directions was due primarily to the grades on the freeway. In the northbound direction the VISSIM analysis assumed a positive grade of 2% from Exit 20 to the Vermont side of the bridge at which point the grade increased to 5% until approximately the I-91 mainline overpasses. The same grades were assumed for the same locations in the southbound direction, only as negative instead of positive grades.

An important component of micro-simulation modeling is making sure that enough model runs are performed to ensure a statistically reliable result. Using the same speed data from the calibration model run, the following formula was used to calculate the minimum number of runs to achieve a 95% confidence interval.

$$N = \left(\frac{t_{0.05,N-1} * S_s}{Z}\right)^2$$

Where: t = t-test statistic for 95% confidence level with N-1 degrees of freedom
Z = number of standard deviations from the mean (1.96 for a 95% confidence level)
S_s = sample standard deviation
N = minimum number of runs (sample size)

Using data from the five model calibration runs, the standard deviation of the speed data was determined to be 0.29 mph in the southbound direction and 0.78 mph in the northbound direction. Using a t value of 2.78, the minimum number of runs was determined to be 0.2 runs in the southbound direction and 1.2 runs in the northbound direction; therefore 5 runs were adequate to provide satisfactory results. The VISSIM model was run five times for all of the scenario analyses and the results were averaged.

Measures of Effectiveness

The measures of effectiveness (MOEs) are the criteria used to compare the various scenarios. Two primary MOEs were utilized for the Connecticut River bridge analysis. The first was freeway level of service (LOS) and the second is a detailed examination of average speed along the length of the freeway segments.

Level-of-service (LOS) is a qualitative measure describing the operating conditions as perceived by motorists driving in a traffic stream. LOS is estimated using the procedures outlined in the *2010 Highway Capacity Manual (HCM).*[1] The HCM divides freeway facilities into three types of segments: (1) basic – sections with no ramps, (2) merge or diverge – 1,500 foot sections with either an on ramp or an off ramp, and (3) weaving – sections with an on-ramp followed within 2,500 feet or less by an off-ramp. Freeway LOS for all three segment types is based on vehicle density per lane, which is calculated by dividing the number of vehicles by the number of lanes and the average speed of those vehicles. Figure 5 shows the various LOS grades and descriptions for the three freeway segment types. New Hampshire and Vermont have a goal for freeway facilities to operate at LOS C within the general study area.

[1] Transportation Research Board, National Research Council, *Highway Capacity Manual* (Washington, DC: National Academy of Sciences, 2010).

Figure 5. Level-of-Service Criteria for Freeway Segments

LOS	Characteristics	Basic Segment Density (pc/hr/ln)	Merge/Diverge Density (pc/hr/ln)	Weaving Segment Density (pc/hr/ln)
A	Free flow operation	≤ 11.0	≤ 10.0	≤ 10.0
B	Reasonably free flow	11.1-18.0	10.1-20.0	10.1-20.0
C	Restricted freedom to maneuver	15.1-26.0	20.1-28.0	20.1-28.0
D	More restricted maneuverability	26.1-35.0	28.1-35.0	28.1-35.0
E	Closely spaced vehicles	35.1-45.0	> 35.0	35.1-43.0
F	Breakdowns in vehicular flow	> 45.0	Exceeds Capacity	> 43.0

Using the VISSIM software it is possible to estimate the freeway LOS for the various segments. In the southbound direction the section between the on-ramp from northbound I-91 and the Exit 20 off-ramp is considered a *weaving* segment since they are less than 2,500 feet apart. In the northbound direction, there is a *merge* segment at the Exit 20 on-ramp, followed by a short *basic* segment, and finally a *diverge* segment associated with the off-ramp to northbound I-91.

Some of the traffic issues in the study area are localized in nature occurring right at an on-ramp merge area, with the effects being diminished when looking at a 1,500 foot or longer segment over a 15 minute analysis period. To better understand traffic operations in these sections, the freeway section was divided into 100-foot segments and the average speed recorded in 60 second intervals. By having short segments and short time intervals it was possible to pick up on smaller disturbances in the traffic flow.

EXISTING CONDITIONS ANALYSIS

The existing conditions analysis was performed using the summer 2013 VISSIM models. Figure 6 shows the resulting volumes, speeds, and LOS for the weekday AM, weekday PM, and Saturday peak hours. The figure shows that all of the segments operate at LOS C or better. Appendix C contains some additional information regarding how well the simulation model volumes matched the target (input) volumes.

Figure 6. Existing Conditions Freeway LOS

Segment	AM Peak Hour			PM Peak Hour			Sat. Peak Hour		
	Vol.	Speed	LOS	Vol.	Speed	LOS	Vol.	Speed	LOS
I-89 Southbound									
Basic North of NB I-91 On Ramp	1,330	63	B	1,160	64	A	1,110	64	A
Weave NB I-91 On Ramp to Exit 20	1,680	59	B	1,360	62	B	1,460	60	B
Basic Between Exit 20 Ramps	920	64	A	820	65	A	600	65	A
I-89 Northbound									
Basic North of NB I-91 Off Ramp	640	61	A	1,370	53	B	930	61	A
Diverge at NB I-91 Off Ramp	1,070	61	A	2,110	57	C	1,350	61	B
Basic Exit 20 to NB I-91 Off Ramp	1,110	62	A	2,180	59	C	1,390	63	B
Merge at Exit 20 On Ramp	1,110	62	A	2,180	59	C	1,390	62	A
Between Exit 20 Ramps	850	65	A	1,220	65	A	950	65	A

Note: Speed and LOS results taken from peak 15-minute period.

Detailed speed data were extracted from the simulation models in the southbound direction from the weekday AM peak hour since that is when volumes are the highest. Figure 7 graphically illustrates the speeds along the freeway over time during 2013 AM peak conditions. The x-axis represents time and the y-axis distance. The green colors represent speeds of over 50 mph, while the orange is speeds of 40-50 mph. The figure shows consistent turbulence where the ramp from I-91 northbound merges with I-89 southbound (indicated as "NB I-91 On Ramp" in the figure below) with average speeds always below 60 mph and occasionally dropping below 40 mph. This turbulence generally dissipates over 500-700 feet, but occasionally continues all the way to Exit 20.

Figure 7. Existing Conditions AM Southbound Speed Details

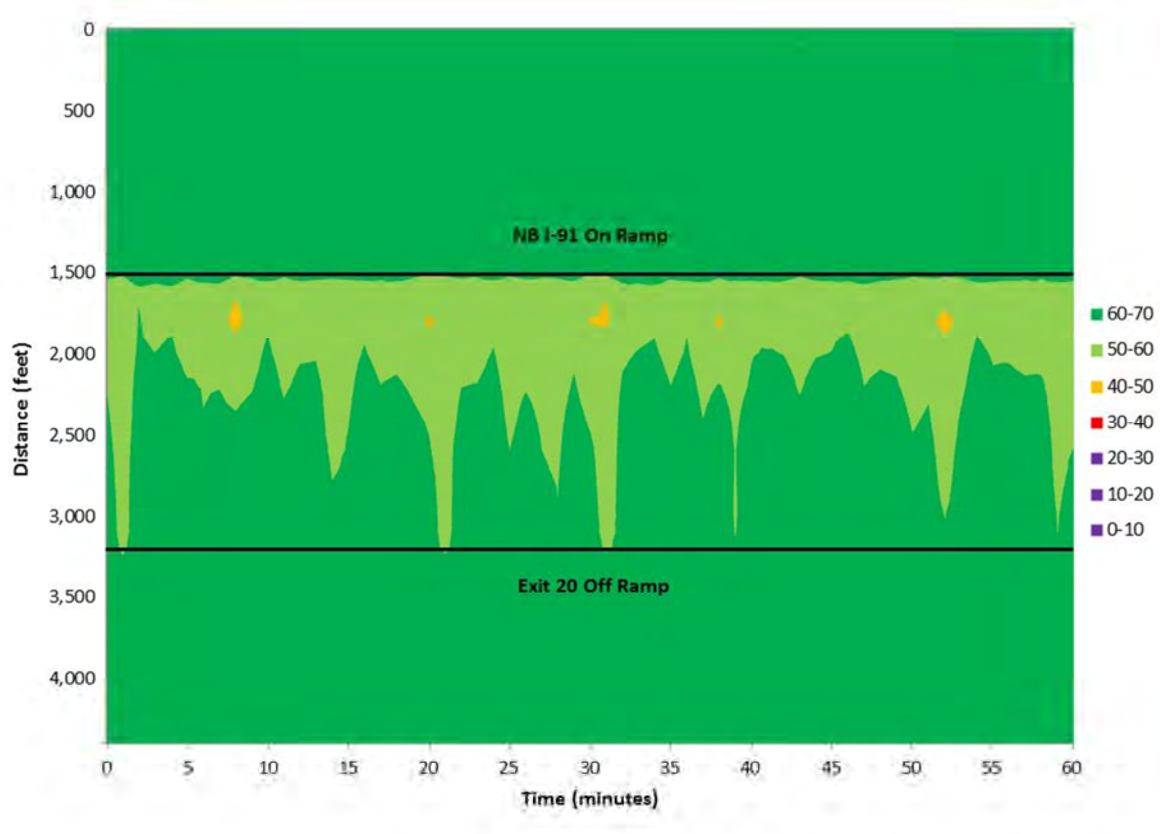
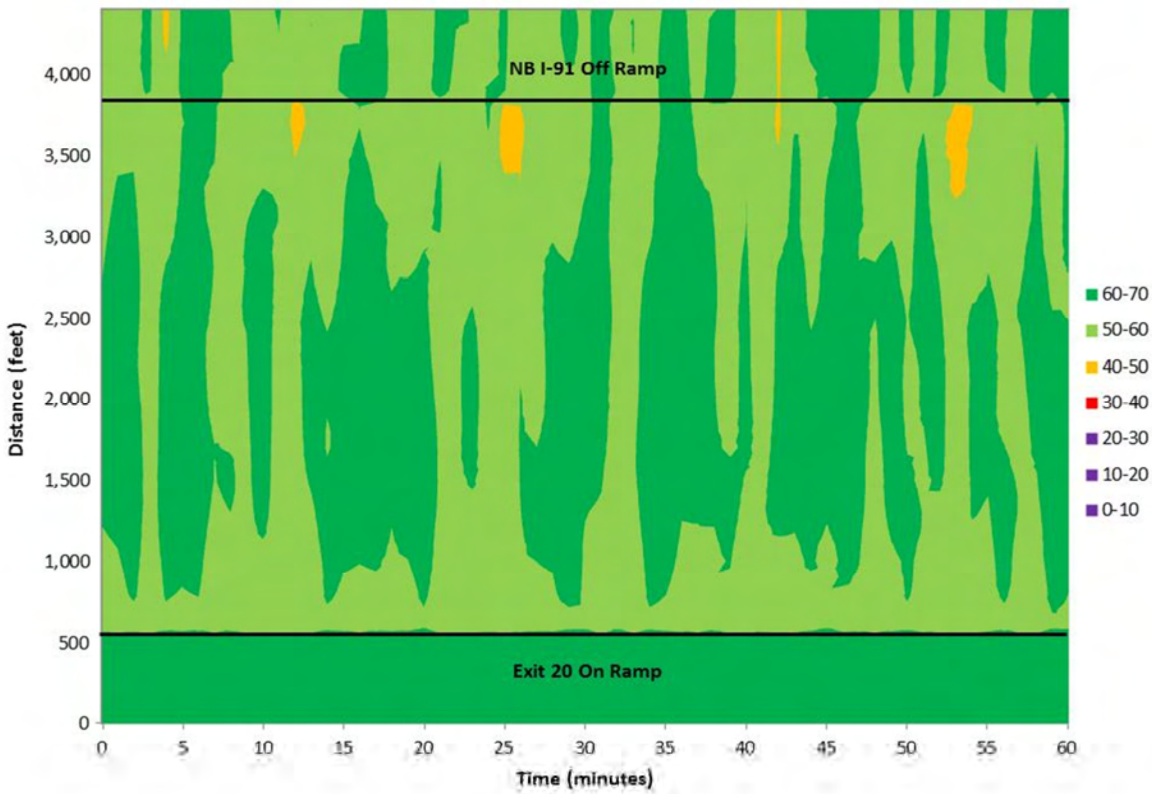


Figure 8 shows the same information for the northbound direction, which is much more turbulent than the southbound direction. This is due to the positive grades of 2 to 5% along these segments and the affect that they have on traffic, particularly heavy vehicles. However, one can see that the turbulence increases at the merge and diverge points where lane changing operations are occurring. The effect is noticeably pronounced at the northbound I-91 off ramp where there is a 5% grade and lane changing operations for vehicles desiring to take the off ramp to I-91.

Figure 8. Existing Conditions PM Northbound Speed Details



A numerical analysis was performed on the "cells" that lie between the on- and off-ramps in both directions. Each cell is 100 feet by one minute. Figure 9 lists the number of cells in each direction and the percentage of those cells that fall within the various speed categories. The northbound direction has more cells because the distance between the ramps is longer than the southbound direction.

Figure 9. Existing Conditions Speed Detail Summary

	Southbound	Northbound
# of Cells	1,020	1,980
< 40 mph	0%	0%
40 - 50 mph	1%	1%
50 - 60 mph	42%	54%
> 60 mph	57%	44%

YEAR 2019 ANALYSIS

The year 2019 analysis was performed in the same manner as the existing conditions with a couple of differences in the MOEs that were reported and the scenarios that were evaluated. The detailed speed analysis was not performed for 2019 since it represents a mid-point between the existing conditions and the 2039 conditions and is therefore not as useful.

Because 2019 represents the opening year of the project, a build scenario was evaluated that added an auxiliary lane to I-89 in each direction between the ramps on either side of the bridges. For the purposes of the analysis, the auxiliary lane was assumed to come in at the on-ramp and drop as a single lane exit at the off-ramp. This configuration is not consistent with the principles of lane balance described in the

Green Book, which says that between the mainline and the ramp there should be one more lane exiting the diverge area than entered it. Lane balance is generally achieved by having two-lane off ramps or by continuing the auxiliary lane beyond the exit and then dropping it before the next ramp (or usually before the next structure to save money). This approach was chosen because it represents the lowest capacity weaving section where every weaving vehicle is required to make one lane change. As such, it provides a conservative estimate of traffic performance.

Figure 10 compares the build and no build 2019 scenarios for the key freeway segments. The freeway is expected to operate effectively at LOS C or better in both scenarios. In the peak direction of the peak hour, the build scenario improves freeway speeds between I-91 and Exit 20 by 4-7 miles per hour. Additional information on each scenario can be found in Appendix C.

Figure 10. 2019 Freeway Performance Comparison

Segment	No Build			Build (*auxiliary lane*)		
	Volume	Speed	LOS	Volume	Speed	LOS
Weekday AM Peak Hour						
I-89 SB - Basic North of NB I-91 On Ramp	1,390	62	B	1,390	62	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,760	58	B	1,820	63	A
I-89 SB - Basic Between Exit 20 Ramps	970	64	A	970	65	A
I-89 NB - Basic North of NB I-91 Off Ramp	670	61	A	670	62	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,120	60	A	1,160	62	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	1,160	62	A	1,160	64	A
I-89 NB - Merge at Exit 20 On Ramp	1,160	62	A	1,160	64	A
I-89 NB - Between Exit 20 Ramps	890	65	A	890	65	A
Weekday PM Peak Hour						
I-89 SB - Basic North of NB I-91 On Ramp	1,220	64	A	1,220	64	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,430	62	B	1,470	64	A
I-89 SB - Basic Between Exit 20 Ramps	860	65	A	860	65	A
I-89 NB - Basic North of NB I-91 Off Ramp	1,440	53	B	1,440	60	B
I-89 NB - Diverge at NB I-91 Off Ramp	2,210	53	C	2,280	60	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	2,280	58	C	2,280	62	B
I-89 NB - Merge at Exit 20 On Ramp	2,280	58	C	2,280	62	B
I-89 NB - Between Exit 20 Ramps	1,280	64	A	1,280	64	A
Saturday Peak Hour						
I-89 SB - Basic North of NB I-91 On Ramp	1,160	64	A	1,160	64	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,530	59	B	1,610	63	A
I-89 SB - Basic Between Exit 20 Ramps	620	65	A	620	65	A
I-89 NB - Basic North of NB I-91 Off Ramp	970	60	A	970	62	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,410	61	B	1,460	62	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	1,460	62	B	1,460	64	A
I-89 NB - Merge at Exit 20 On Ramp	1,450	62	B	1,460	63	A
I-89 NB - Between Exit 20 Ramps	990	65	A	990	65	A

Note: Speed and LOS results taken from peak 15-minute period.

2039 Conditions

The year 2039 analysis was performed in the same manner as the other years and all of the MOEs and scenarios were evaluated. The build scenario assumed the same lane configuration as described in the

2019 Conditions section. Figure 11 compares the build and no build 2039 scenarios for the key freeway segments. The freeway is expected to operate effectively at LOS C or better in both scenarios. In the peak direction of the peak hour the Build scenario improves freeway speeds between I-91 and Exit 20 by 4-6 miles per hour and improves the LOS from C to B. Additional information on each scenario can be found in Appendix C.

Figure 11. 2039 Freeway Performance Comparison

Segment	No Build			Build		
	Volume	Speed	LOS	Volume	Speed	LOS
Weekday AM Peak Hour						
I-89 SB - Basic North of NB I-91 On Ramp	1,610	62	B	1,610	62	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	2,040	56	C	2,110	63	B
I-89 SB - Basic Between Exit 20 Ramps	1,120	64	A	1,120	64	A
I-89 NB - Basic North of NB I-91 Off Ramp	770	59	A	770	62	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,300	59	B	1,350	62	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	1,350	62	B	1,350	64	A
I-89 NB - Merge at Exit 20 On Ramp	1,350	62	A	1,340	64	A
I-89 NB - Between Exit 20 Ramps	1,030	65	A	1,030	65	A
Weekday PM Peak Hour						
I-89 SB - Basic North of NB I-91 On Ramp	1,400	64	B	1,400	64	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,640	62	B	1,690	64	A
I-89 SB - Basic Between Exit 20 Ramps	990	65	A	990	65	A
I-89 NB - Basic North of NB I-91 Off Ramp	1,660	52	B	1,660	57	B
I-89 NB - Diverge at NB I-91 Off Ramp	2,540	52	C	2,640	57	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	2,630	57	C	2,640	62	B
I-89 NB - Merge at Exit 20 On Ramp	2,630	57	C	2,630	62	B
I-89 NB - Between Exit 20 Ramps	1,480	64	B	1,480	64	B
Saturday Peak Hour						
I-89 SB - Basic North of NB I-91 On Ramp	1,350	64	B	1,350	64	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,780	57	B	1,860	63	A
I-89 SB - Basic Between Exit 20 Ramps	730	64	A	730	65	A
I-89 NB - Basic North of NB I-91 Off Ramp	1,120	56	A	1,120	61	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,630	59	B	1,680	62	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	1,680	61	B	1,680	64	A
I-89 NB - Merge at Exit 20 On Ramp	1,680	61	B	1,680	63	A
I-89 NB - Between Exit 20 Ramps	1,150	65	A	1,150	65	A

Note: Speed and LOS results taken from peak 15-minute period.

As with the existing conditions analysis, detailed speed data were extracted from the simulation models in the southbound direction from the weekday AM peak hour and in the northbound direction from the weekday PM peak hour. Figure 12 graphically illustrates the speeds along the southbound freeway for the 2039 No Build scenario. The figure shows consistent turbulence at the northbound I-91 on ramp merge with average speeds always below 60 mph and regularly below 50 and occasionally even dropping below 30 mph. By 2039 it will be much more common for the slower speeds to continue all the way to Exit 20.

Figure 12. 2039 AM No Build Conditions Southbound Speed Details

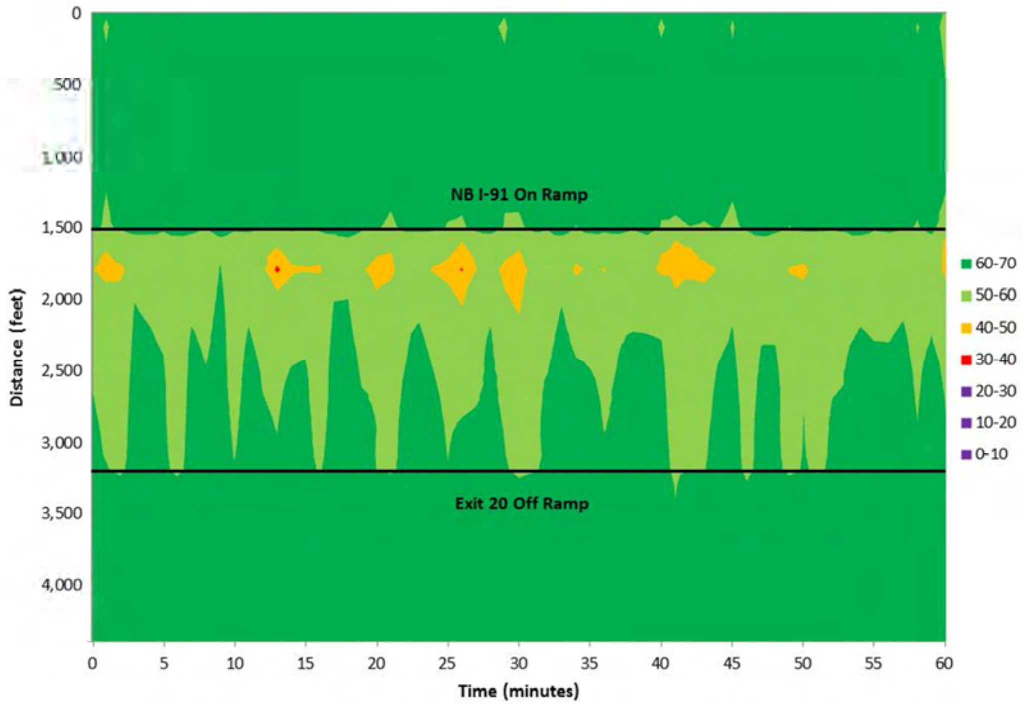


Figure 13 shows the same information for the 2039 Build scenario and clearly illustrates that adding a southbound auxiliary lane will eliminate virtually all of the areas of speeds below 60 mph.

Figure 13. 2039 AM Build Conditions Southbound Speed Details

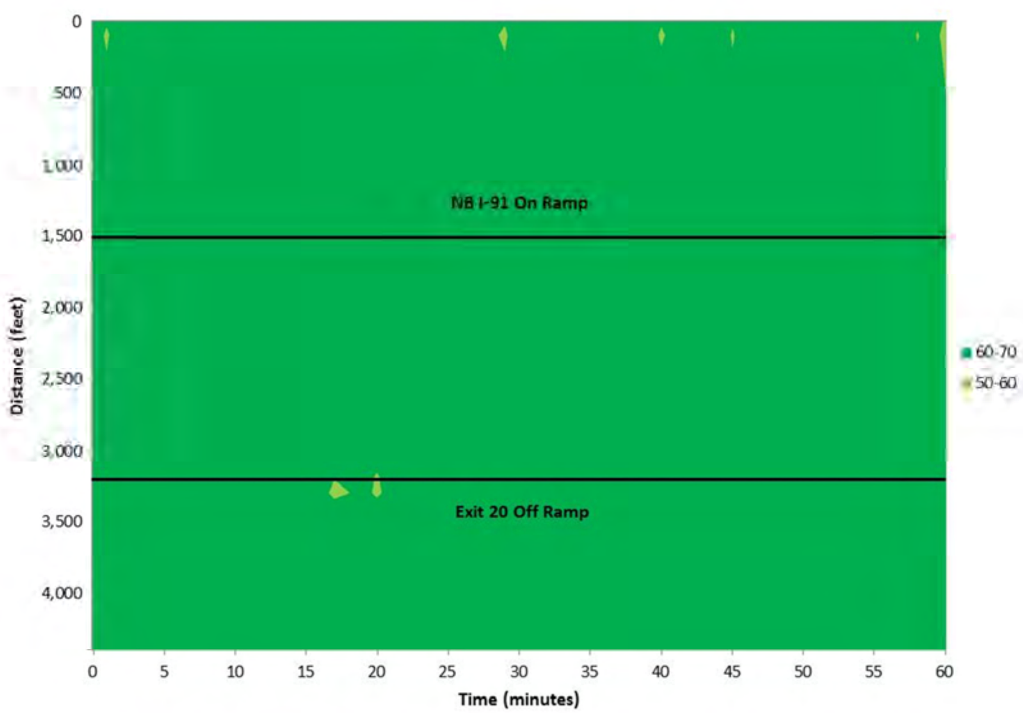


Figure 14 shows 2039 PM peak hour detailed speed information for the northbound direction, which, as seen in the existing conditions analysis, is much more turbulent than the southbound direction, again due to the positive grades. By 2039 nearly the entire section between ramps can be expected to operate at speeds less than 50 mph with substantial time at speeds less than 50 mph at the northbound I-91 off-ramp.

Figure 14. 2039 PM No Build Conditions Northbound Speed Details

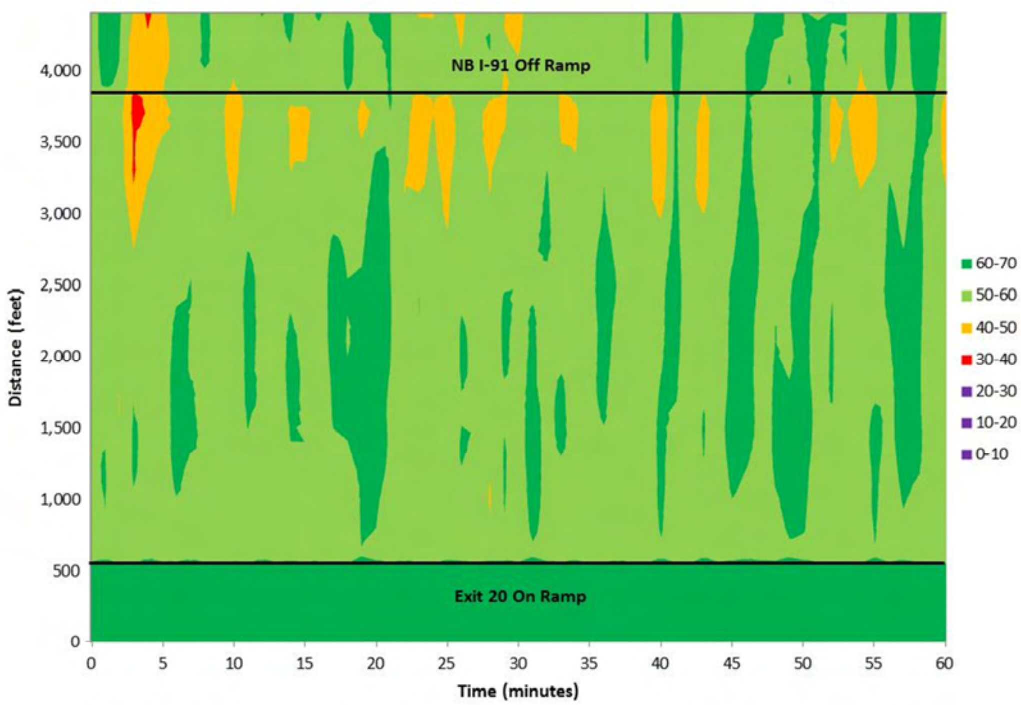
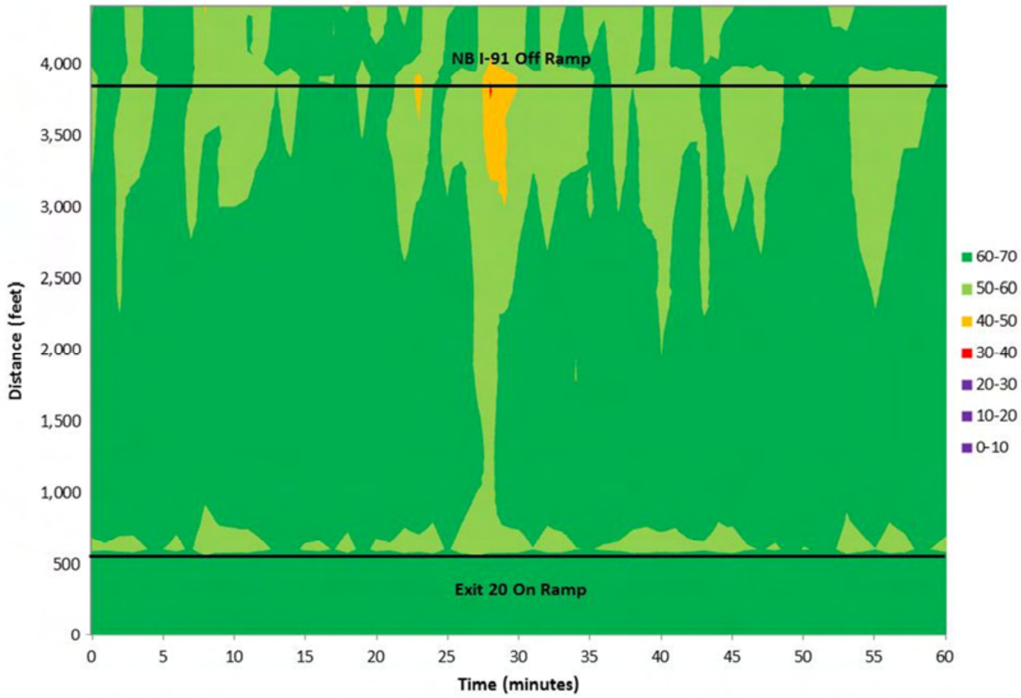


Figure 15 shows that the 2039 PM Build scenario dramatically improves the average vehicle speeds in the northbound direction, although not to the same level as previously shown for the southbound direction. Most of the section would operate at speeds over 60 mph, but there would still be occasional pockets of lower speeds.

Figure 15. 2039 PM Build Conditions Northbound Speed Details



As with the existing conditions, a numerical analysis was performed on the “cells” that lie between the on- and off-ramps. Figure 16 lists the number of cells in each direction and the percentage of those cells that fall within the various speed categories. As shown in the previous figures and quantified here, the Build scenario does a good job of increasing I-89 speeds between I-91 and Exit 20, particularly in the southbound direction.

Figure 16. Speed Detail Summary Comparison

	Existing Conditions		2039 No Build Conditions		2039 Build Conditions	
	Southbound	**Northbound**	**Southbound**	**Northbound**	**Southbound**	**Northbound**
# of Cells	1,020	1,980	1,020	1,980	1,020	1,980
< 40 mph	0%	0%	0%	0%	0%	0%
40 - 50 mph	1%	1%	4%	6%	0%	1%
50 - 60 mph	42%	54%	59%	73%	0%	22%
> 60 mph	57%	44%	37%	21%	100%	77%

Safety Analysis

A safety analysis was performed for the study area to better understand the crashes that have taken place and to determine if high crash rates might provide justification for widening the I-89 bridges across the Connecticut River.

CRASH HISTORIES

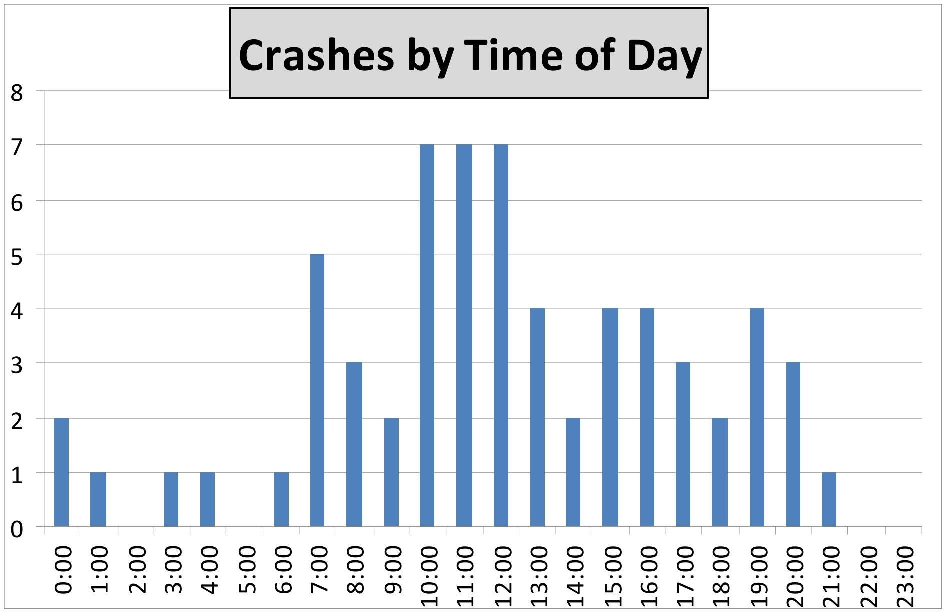
Five year crash histories for the study area on and around the Connecticut River bridges were collected from NHDOT and VTrans. The total number of crashes based on both NHDOT and VTrans data that occurred in the five year period between 2007 and 2011 is shown in Figure 17. There are several locations that jump out as high crash locations, although they are all outside of the study area defined by the red rectangle. The highest concentrations of crashes (~120) occur at the Exit 20 ramp terminals, which isn't too surprising given that intersections typically have the highest crash rates largely due to all of the conflicting turning movements made there. The other location that stands out is at the merge of the southbound and northbound I-89 ramps to northbound I-91, which had 41 crashes during this time period.

Figure 17. Study Area Crash Locations

Study Area Crashes

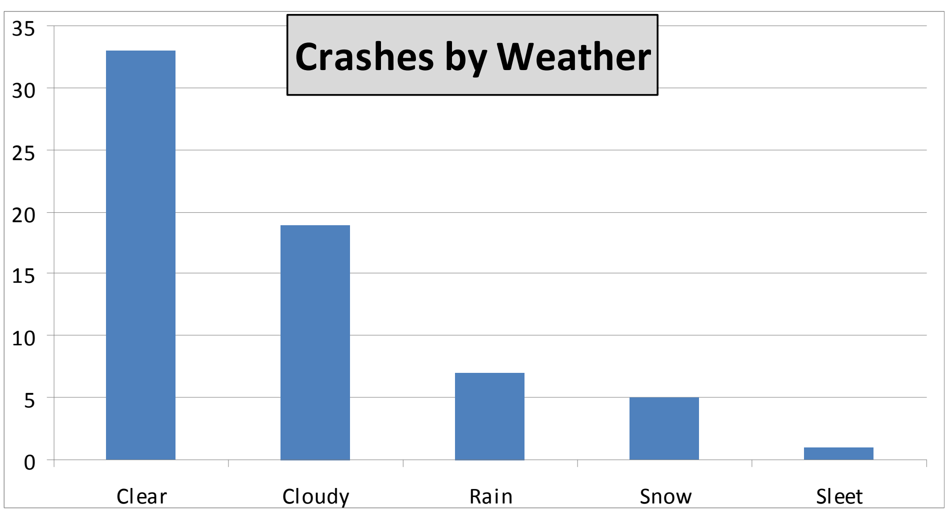
Within the study area (ie. red rectangle shown in the figure above) there were a total of 65 reported crashes with 18 injuries and no fatalities in the period between 2007 and 2011. As illustrated in Figure 18, the peak crash period occurs between 10am and 1pm, with 21 (32%) accidents occurring in this span. Nearly half (48%) of all crashes occur between the hours of 7:00 am and 1:00 pm.

Figure 18. Study Area Crashes by Time of Day



The three highest crash months are: July (10), January (8) and October (8). Crashes appear to be declining during the interval examined, with 17 in 2007, 15 in 2008 and 2009, 13 in 2010, and 5 in 2011. Adverse weather conditions do not seem to be a major factor in causing crashes. Figure 19 shows that 33 occurred while conditions were clear, 19 while conditions were cloudy, 7 while it was raining, 5 while it was snowing, and 1 during sleet conditions. Forty-eight (74%) crashes involved multiple vehicles while 17 involved only a single vehicle.

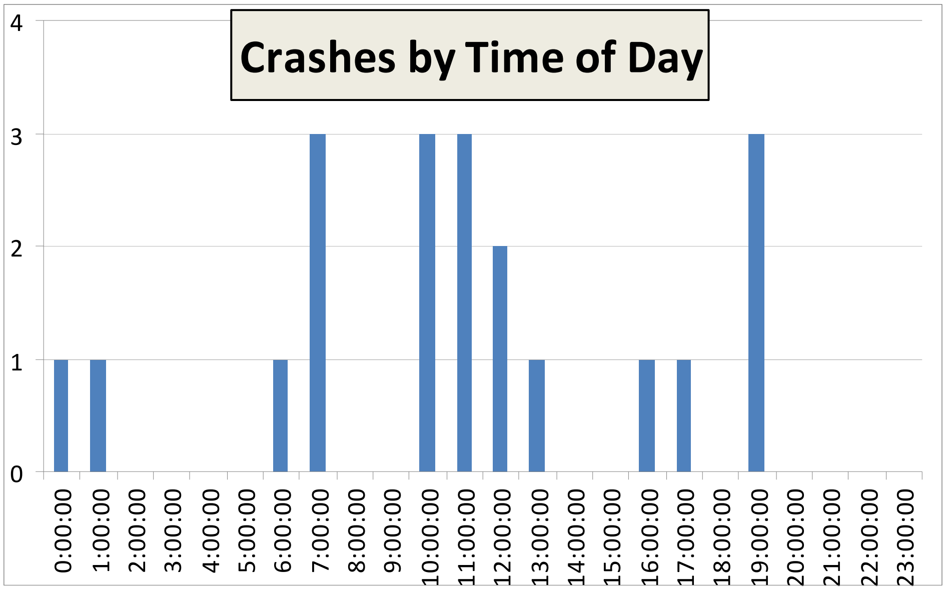
Figure 19. Study Area Crashes by Weather



Crashes on the Bridge

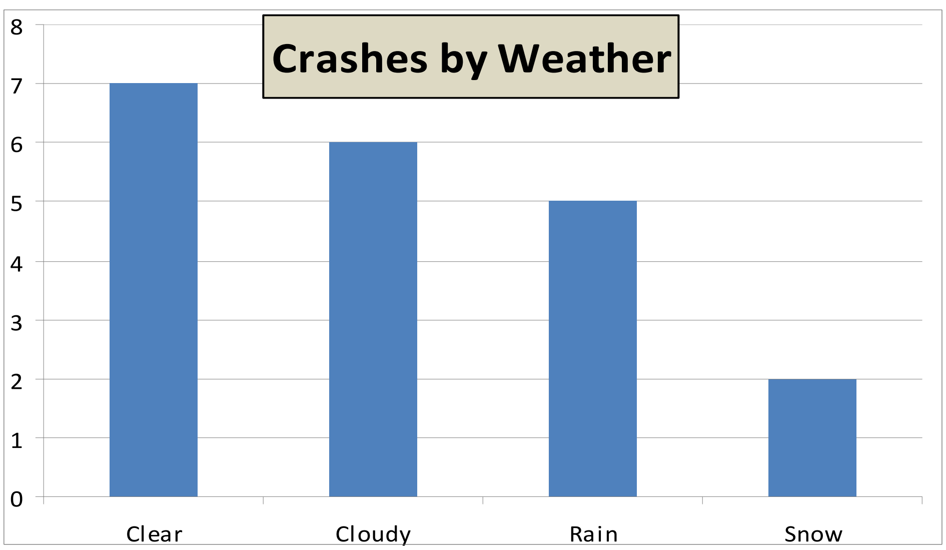
Looking specifically at crashes that occurred on the bridge itself, there were a total of 20 crashes in the five year span with 6 injuries and 0 deaths. Figure 20 shows that the peak crash time on the bridge is between 7am and 1pm, with 6 accidents (30%) occurring in this time period. The peak crash months are: October (4), December (4), January (3), and July (3). Crashes appear to be declining, with 8 in 2007, 7 in 2008, 2 in 2009 and 2010, and 1 in 2011.

Figure 20. Bridge Crashes by Time of Day



Weather does not seem to play a significant factor in causing crashes on the bridge, with 7 occurring while it was clear, 6 while cloudy, 5 during rain, and 2 during snow, as shown in Figure 21. However, of the 7 accidents in the study area that happened during rainy conditions, 5 of them occurred on the bridge. Twelve accidents on the bridge involved multiple cars while 8 involved only one car.

Figure 21. Bridge Crashes by Weather



Crashes at Northbound I-91 to Southbound I-89 Merge

Of particular relevance to the question of whether to widen the bridges or not are those crashes that occurred at the merge of the on-ramp from northbound I-91 to southbound I-89. In this area there were a total of 9 reported crashes comprising 14% of the total study area crashes with two injuries and no fatalities. Weather does not seem to play a significant factor as 6 accidents (67%) occurred while conditions were clear. However, 89% of the crashes involved multiple vehicles, with 7 cases or 78% of the crashes citing "followed too closely" as the principle reason for the accident. It is likely that the majority of these crashes are occurring as vehicles attempt to merge onto the I-89 mainline. It is not unreasonable to think that the presence of a longer acceleration lane or a continuous auxiliary lane would reduce the accident rate in this location.

Conclusions

The preceding analyses were performed to determine whether there is a reasonable rationale to widen the I-89 bridges over the Connecticut River as part of a current bridge rehabilitation project. This analysis considered the study area's compatibility with current design standards, future traffic performance, and crash history. Based on the results of this analysis, it is recommended that a continuous auxiliary lane be added to southbound I-89 between the on-ramp from northbound I-91 and the Exit 20 off ramp for the following reasons:

1. The review of geometric design standards found that the on-ramp merge distance is currently insufficient, suggesting that either the acceleration lane should be extended or an auxiliary lane should be built.
2. The review of geometric design standards also found that there would ideally be 2,000 feet between the two ramps; since the distance between ramps is virtually unchangeable, having an auxiliary lane would help mitigate this issue.
3. The traffic operations analysis found that vehicle speeds on southbound I-89 between the two ramps will continue to fall as traffic volumes increase. Adding an auxiliary lane is estimated to eliminate nearly all of the delay.
4. The crash analysis showed that there are several crashes where the on-ramp from northbound I-91 merges with southbound I-89. Many of these crashes are likely due to the sub-standard merge distance and if an auxiliary lane were provided the crash rate would be expected to decrease in this area.

The case for a northbound auxiliary lane is not nearly so compelling. The recently reconstructed Exit 20 interchange provides sufficient merge length and many of the vehicle speed issues are related to the high positive grade on the Vermont side of the river. There is a noticeable decrease in vehicle speeds at the exit to northbound I-91. While an auxiliary lane would certainly provide an improvement, it is possible that lengthening the deceleration lane would also be beneficial, but at a fraction of the cost.

Overall, it is our recommendation to pursue further consideration of an auxiliary lane on southbound I-89 between the on-ramp from northbound I-91 and not additional auxiliary lane or widening on the northbound section of I-89.

Appendix A – Bluetooth Data Collection Process

BLUETOOTH DATA COLLECTION OVERVIEW

Bluetooth Technology

Bluetooth technology is a wireless communications system that is used in mobile phones, computers, personal digital assistants, car radios, and other short range wireless communications devices. Bluetooth technology operates by proximity – Bluetooth-enabled devices that are close to one another can connect to allow transmission of voice and/or data. In order for a connection to occur, each device needs to be in “discoverable” mode, with the Bluetooth enabled.

Bluetooth devices are rated as Type I (100 meter detection zone); Type II (10 meter detection zone); or Type III (1 meter detection zone). The Bluetooth detectors used to record data in this project were Type I detectors which can detect any other Bluetooth device within its range. All Bluetooth-enabled devices operate within a globally available frequency band of 2.45 GHz.

Each device emits a unique, 48-bit electronic identifier known as a Media Access Control (MAC) address, or MAC ID. The MAC ID is generated in two parts: the first half of the MAC ID is assigned to the device manufacturer, while the second half of the MAC ID is assigned to the specific device. While the MAC ID is unique to each Bluetooth device, it is not linked to an individual person.

Bluetooth for Traffic Data Collection

Traffax, Inc., a company based in Maryland, has developed a Bluetooth system that can be used for traffic data collection. Traffax’s technology consists of a series of Bluetooth devices, named BlueFax sensors, which are placed on or near a roadway to capture the signals of other Bluetooth-enabled devices as they travel through the corridor. The BlueFax sensors are self-contained, discrete units that contain a Bluetooth device set to “discovery” mode, a GPS system, a small computer to record the data, and a battery to power the unit (Figure 1).

Figure 1: BlueFax Device (left) and Typical Post-Mounted Deployment on SR-826 (right)

When a Bluetooth-enabled device passes by a BlueFax sensor, the unique MAC ID of the device and the date and time are captured and stored in the on-board computer. As vehicles with Bluetooth-enabled devices travel through the corridor, they will pass other BlueFax sensors, where the MAC ID and timestamp will be recorded again. At the end of the study period, the data from each BlueFax device can be downloaded and aggregated into a database for analysis. By searching for the common MAC IDs recorded across pairs of BlueFax sensors, it is possible to identify origin-destination and travel time information for each vehicle.

DATA ANALYSIS

At the end of the deployment period, the data from the BlueFax sensors were downloaded and aggregated into a single dataset. For developing OD estimates, custom code using Python was written to process the raw Bluetooth data. OD tables were estimated for week day AM, week day PM, and Saturday peak hours. To develop the OD tables, the following steps were used.

Step 1. Establish Bluetooth Detector Locations

Each Bluetooth detector is outfitted with a GPS unit which records its latitude and longitude. Each detector location was buffered with a 100 meter radius (approximately 325 feet) to establish the detector area. This is the approximate range of Bluetooth devices. The broader detector area is used to determine whether other surface street traffic might be included in the raw data.

Step 2. Get all Plausible Paths through and around the Study Area, Assign Detector Sequences

Step two started by getting the set of all *plausible paths* through the study area. The study area has several entry points and exit points, most of which constitute "plausible paths" (i.e. paths, or trips, that make sense given the network).

Once we had generated a list of plausible paths, we determined the *actual detector sequence* (ADS) for each path, where an ADS is the sequence of detectors areas that the path passes through on its way from origin to destination.

Step 3. Process the Bluetooth Data to Get Observed Detector Sequence (ODS) Frequencies

To make the raw Bluetooth data useful we follow three sub-steps:

- assemble the Bluetooth data into trajectories
- remove redundant detections
- divide trajectories into trips

The first sub-step, to assemble the Bluetooth data into trajectories, is straightforward. We group the data from all detectors by device ID, then and sort by date and time, all while retaining the ID for the detector where each detection occurred. The result is a collection of trajectories, where each trajectory is a sequence of places and times where a particular Bluetooth device was detected.

Trip trajectories were formed using the following criteria:

1. *Trips were formed using a single MAC ID. Consecutive reads of the same MAC ID at the same detector, as would occur if a vehicle were idling in place, were clustered into one unique read using a 5 minute rule: if consecutive reads of the same ID were recorded within 5 minutes, they were considered as one read occurring at an averaged time point. Consecutive reads of the same MAC ID that occurred more than 5 minutes apart were considered as the end and/or beginning of different trips.*

2. *Within each MAC ID, links of consecutive sensor pairs were joined together in chronological order to form complete trips linking each sensor in sequence.*

3. *To determine whether any specific trip segment was an outlier, the zone-to-zone travel times of any specific trip were compared to the 30 travel times closest by time of day (e.g. if the trip occurred at 9:00, the 30 trips closest to 9:00 AM over the entire week were used to determine the mean travel speed for OD pair). The Blustats software uses this rule for determining segment speed, which is based on a statistical rule of thumb for a normal distribution with a 90% confidence. The travel times of these 30 trips were used to develop a normal distribution. Any trip length that is outside of +/- 3 standard deviations from the mean was determined to be an outlier, indicating a break in the trip sequence.*

4. *Any given trip could not pass the same sensor twice.*

The unique combination of MAC ID, sensor location, and timestamp were only included in a single trip.
To illustrate the trip itinerary concept, a subset of the data for a sample MAC ID is shown below. Based on the timestamps for this MAC ID and the trip linking criteria, two trips were generated as shown in

Figure 2. These two records would enter the OD matrix as one vehicle trip in two cells: the 15 → 8 cell and the 8 → 15 cells. The intermediate station information is retained to validate the estimates in a later stage of the analysis.

Figure 2: Example of Two Unique Trip Trajectories

Raw Data

MAC ID	Location	Date	Time
00:24:9F:D8:F9:E3	15	9/18/2011	1:09:23 PM
00:24:9F:D8:F9:E3	14	9/18/2011	1:12:57 PM
00:24:9F:D8:F9:E3	12	9/18/2011	1:16:12 PM
00:24:9F:D8:F9:E3	12	9/18/2011	1:16:17 PM
00:24:9F:D8:F9:E3	10	9/18/2011	1:19:54 PM
00:24:9F:D8:F9:E3	10	9/18/2011	1:19:59 PM
00:24:9F:D8:F9:E3	8	9/18/2011	1:24:48 PM
00:24:9F:D8:F9:E3	8	9/18/2011	11:47:28 PM
00:24:9F:D8:F9:E3	10	9/18/2011	11:51:02 PM
00:24:9F:D8:F9:E3	12	9/18/2011	11:54:05 PM
00:24:9F:D8:F9:E3	14	9/18/2011	11:56:38 PM
00:24:9F:D8:F9:E3	14	9/18/2011	11:56:43 PM
00:24:9F:D8:F9:E3	15	9/18/2011	11:59:36 PM
00:24:9F:D8:F9:E3	15	9/18/2011	11:59:42 PM
00:24:9F:D8:F9:E3	15	9/18/2011	11:59:47 PM

Clustered Data

MAC ID	Location	Date	Time
00:24:9F:D8:F9:E3	15	9/18/2011	1:09:23 PM
00:24:9F:D8:F9:E3	14	9/18/2011	1:12:57 PM
00:24:9F:D8:F9:E3	12	9/18/2011	1:16:17 PM
00:24:9F:D8:F9:E3	10	9/18/2011	1:19:59 PM
00:24:9F:D8:F9:E3	8	9/18/2011	1:24:48 PM
00:24:9F:D8:F9:E3	8	9/18/2011	11:47:28 PM
00:24:9F:D8:F9:E3	10	9/18/2011	11:51:02 PM
00:24:9F:D8:F9:E3	12	9/18/2011	11:54:05 PM
00:24:9F:D8:F9:E3	14	9/18/2011	11:56:43 PM
00:24:9F:D8:F9:E3	15	9/18/2011	11:59:42 PM

Trip 1

MAC ID	Location	Date	Time
00:24:9F:D8:F9:E3	15	9/18/2011	1:09:23 PM
00:24:9F:D8:F9:E3	14	9/18/2011	1:12:57 PM
00:24:9F:D8:F9:E3	12	9/18/2011	1:16:17 PM
00:24:9F:D8:F9:E3	10	9/18/2011	1:19:59 PM
00:24:9F:D8:F9:E3	8	9/18/2011	1:24:48 PM

Trip 2

MAC ID	Location	Date	Time
00:24:9F:D8:F9:E3	8	9/18/2011	11:47:28 PM
00:24:9F:D8:F9:E3	10	9/18/2011	11:51:02 PM
00:24:9F:D8:F9:E3	12	9/18/2011	11:54:05 PM
00:24:9F:D8:F9:E3	14	9/18/2011	11:56:43 PM
00:24:9F:D8:F9:E3	15	9/18/2011	11:59:42 PM

The second sub-step is to remove redundant detections, which can occur because the detectors record new detections every five seconds. If a Bluetooth device is within range of a detector for more than five seconds, it can result in multiple recorded detections. To correct this problem we group redundant detections into clusters, and then choose the middle detection of each cluster to represent that cluster in a new, shorter version of the trajectory. Clusters consist of adjacent detections that are not more than 5 minutes apart. This rule ensures that a cluster really represents just one visit to a detector, rather than a visit and return visit to a detector.

The final sub-step is to divide the trajectories into sub-trajectories, since each trajectory could contain data from more than one trip. We divide the trajectories where the time difference between two adjacent detectors is too large, where we define "too large" to be greater than the free flow travel time between the two detectors plus 30 minutes. This rule separates trajectories at the point where one trip has ended and another begins, since diverting a trip to a particular destination plus participating in the activity at that destination usually takes longer than 30 minutes. At the same time the rule allows trips subject to congestion to remain intact.

We aggregate by time of day, then we drop the time stamps from the sub-trajectories so that only the sequence of detectors remains. We call this sequence the *observed detector sequence* (ODS), and group together sub-trajectories that have identical ODSs. The result of aggregating these two ways is a data set which contains the number of sub-trajectories that fall into each unique combination of time-of-day group and ODS group. We average these frequencies to represent one average weekday, and call the result the *ODS frequencies* dataset.

Comparing the ODSs to the ADSs shows that most ODSs do not perfectly match any ADS. In some cases, the ODSs would match the ADSs if you allow for "missed" detections, or detections that appear in the ADS but not in the ODS. The ODS data indicate that Bluetooth devices can be missed at intermediate detector stations.

Step 4. Distribute the ODS Frequencies to the Plausible Paths to Get Path Volumes

The task in step five is to apportion the counts from the ODS frequencies dataset to the plausible paths as *path volumes*. We do this in two sub-steps. First we apportion the ODS frequencies to the ADSs to form an ADS frequencies database, then we apportion the ADS frequencies to the paths to create the path volumes.

Once we have an ADS frequencies dataset, we can apportion the ADS counts to the associated paths.

Step 5. Summarize the Path Volumes in an Aggregated OD Table

The last step is to summarize the path volumes. We do this by tabulating the path volumes by first and last detector to form an OD table

Appendix B – Traffic Volume Data

CT River Bridge Analysis Intersection Volumes

Exit 20 Ramp Intersections

April 3, 2013

#	Intersection	Northbound			Southbound			Eastbound			Westbound			Total	PHF
		Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right		
2008 Traffic Counts															
1	SB Ramps - AM	0	426	238	44	601	0	210	0	418	0	0	0	1,937	0.86
2	NB Ramps - AM	191	445	0	0	292	120	0	0	0	353	0	148	1,549	
1	SB Ramps - PM	0	1,006	317	68	1,000	0	200	0	358	0	0	0	2,949	0.93
2	NB Ramps - PM	492	714	0	0	643	403	0	0	0	425	1	195	2,873	
1	SB Ramps - Sat	0	1,069	464	95	1,240	0	198	0	495	0	0	0	3,561	0.95
2	NB Ramps - Sat	401	866	0	0	891	229	0	0	0	444	1	186	3,018	
Adjusted to January 2013															
1	SB Ramps - AM	0	485	271	50	684	0	239	0	476	0	0	0	2,204	0.86
2	NB Ramps - AM	142	582	0	0	472	89	0	0	0	262	0	110	1,657	
1	SB Ramps - PM	0	942	295	63	935	0	186	0	334	0	0	0	2,756	0.93
2	NB Ramps - PM	460	668	0	0	601	377	0	0	0	397	1	182	2,687	
1	SB Ramps - Sat	0	952	580	119	1,145	0	248	0	619	0	0	0	3,662	0.95
2	NB Ramps - Sat	258	942	0	0	979	147	0	0	0	285	1	120	2,731	
Adjusted to Summer 2013															
1	SB Ramps - AM	0	560	310	60	790	0	280	0	550	0	0	0	2,550	0.86
2	NB Ramps - AM	160	680	0	0	550	100	0	0	0	300	0	130	1,920	
1	SB Ramps - PM	0	1,070	330	70	1,060	0	210	0	380	0	0	0	3,120	0.93
2	NB Ramps - PM	520	760	0	0	680	430	0	0	0	450	0	210	3,050	
1	SB Ramps - Sat	0	1,030	630	130	1,250	0	270	0	670	0	0	0	3,980	0.95
2	NB Ramps - Sat	280	1,020	0	0	1,070	160	0	0	0	310	0	130	2,970	
Adjusted to Summer 2019															
1	SB Ramps - AM	0	590	330	60	830	0	290	0	580	0	0	0	2,680	0.88
2	NB Ramps - AM	170	710	0	0	580	110	0	0	0	320	0	140	2,030	
1	SB Ramps - PM	0	1,120	350	70	1,110	0	220	0	400	0	0	0	3,270	0.94
2	NB Ramps - PM	550	800	0	0	710	450	0	0	0	470	0	220	3,200	
1	SB Ramps - Sat	0	1,080	660	140	1,310	0	280	0	700	0	0	0	4,170	0.95
2	NB Ramps - Sat	290	1,070	0	0	1,120	170	0	0	0	330	0	140	3,120	
Adjusted to Summer 2039															
1	SB Ramps - AM	0	680	380	70	960	0	340	0	670	0	0	0	3,100	0.92
2	NB Ramps - AM	190	820	0	0	670	120	0	0	0	360	0	160	2,320	
1	SB Ramps - PM	0	1,290	400	80	1,280	0	250	0	460	0	0	0	3,760	0.95
2	NB Ramps - PM	630	920	0	0	820	520	0	0	0	540	0	250	3,680	
1	SB Ramps - Sat	0	1,250	760	160	1,510	0	330	0	810	0	0	0	4,820	0.95
2	NB Ramps - Sat	340	1,230	0	0	1,290	190	0	0	0	380	0	160	3,590	

January 2013 OD Table

AM Peak		4	5	7	8	9	
		Exit 20 SB	I-89 SB-South	Exit 20 NB	I-89 NB to I-91 NB	I-89 NB-North	
1	I-89 SB-North	196	367				**563**
2	I-91 SB to I-89 SB	333	254				**587**
3	I-91 NB to I-89 SB	185	176				**361**
4	Exit 20 SB		321				**321**
6	I-89 NB-South			372	248	475	**1,095**
7	Exit 20 NB				158	73	**231**
		714	**1,117**	**372**	**406**	**548**	**3,158**

PM Peak		4	5	7	8	9	
1	I-89 SB-North	186	375				**561**
2	I-91 SB to I-89 SB	264	201				**465**
3	I-91 NB to I-89 SB	70	155				**225**
4	Exit 20 SB		359				**359**
6	I-89 NB-South			581	231	843	**1,655**
7	Exit 20 NB				465	372	**837**
		520	**1,090**	**581**	**696**	**1,215**	**4,102**

Sat. Peak		4	5	7	8	9	
1	I-89 SB-North	278	322				**600**
2	I-91 SB to I-89 SB	300	122				**422**
3	I-91 NB to I-89 SB	289	111				**400**
4	Exit 20 SB		699				**699**
6	I-89 NB-South			406	167	709	**1,282**
7	Exit 20 NB				251	154	**405**
		867	**1,254**	**406**	**419**	**862**	**3,808**

	AM	**PM**	**Sat**
I-89 SB - North End	**563**	**561**	**600**
I-89 SB - SB I-91 On Ramp	587	465	422
I-89 SB - SB I-91 On to NB I-91 On	**1,150**	**1,026**	**1,022**
I-89 SB - NB I-91 On Ramp	361	225	400
I-89 SB - NB I-91 On to Exit 20	**1,511**	**1,251**	**1,422**
I-89 SB - Exit 20 Off Ramp	714	520	867
I-89 SB - Between Exit 20 Ramps	**797**	**731**	**555**
I-89 SB - Exit 20 On Ramp	321	359	699
I-89 SB - South End	**1,117**	**1,090**	**1,254**
I-89 NB - North End	**548**	**1,215**	**862**
I-89 NB - NB I-91 Off Ramp	406	696	419
I-89 NB - Exit 20 to NB I-91 Off Ramp	**954**	**1,911**	**1,281**
I-89 NB - Exit 20 On Ramp	231	837	405
I-89 NB - Between Exit 20 Ramps	**723**	**1,074**	**876**
I-89 NB - Exit 20 Off Ramp	372	581	406
I-89 NB - South End	**1,095**	**1,655**	**1,282**

Summer 2013 OD tables

Adjustment Factors:	AM	PM	Sat.
	1.16	1.13	1.08

		4 Exit 20 SB	5 I-89 SB-South	7 Exit 20 NB	8 I-89 NB to I-91 NB	9 I-89 NB-North	
1	I-89 SB-North	227	423				**650**
2	I-91 SB to I-89 SB	386	294				**680**
3	I-91 NB to I-89 SB	215	205				**420**
4	Exit 20 SB		370				**370**
6	I-89 NB-South			430	288	552	**1,270**
7	Exit 20 NB				185	85	**270**
		828	**1,292**	**430**	**473**	**637**	**3,660**

		4	5	7	8	9	
1	I-89 SB-North	209	421				**630**
2	I-91 SB to I-89 SB	301	229				**530**
3	I-91 NB to I-89 SB	77	173				**250**
4	Exit 20 SB		400				**400**
6	I-89 NB-South			660	260	950	**1,870**
7	Exit 20 NB				528	422	**950**
		587	**1,223**	**660**	**788**	**1,372**	**4,630**

		4	5	7	8	9	
1	I-89 SB-North	301	349				**650**
2	I-91 SB to I-89 SB	327	133				**460**
3	I-91 NB to I-89 SB	311	119				**430**
4	Exit 20 SB		760				**760**
6	I-89 NB-South			440	180	760	**1,380**
7	Exit 20 NB				273	167	**440**
		938	**1,362**	**440**	**453**	**927**	**4,120**

	AM	PM	Sat
I-89 SB - North End	**650**	**630**	**650**
I-89 SB - SB I-91 On Ramp	680	530	460
I-89 SB - SB I-91 On to NB I-91 On	**1,330**	**1,160**	**1,110**
I-89 SB - NB I-91 On Ramp	420	250	430
I-89 SB - NB I-91 On to Exit 20	**1,750**	**1,410**	**1,540**
I-89 SB - Exit 20 Off Ramp	830	590	940
I-89 SB - Between Exit 20 Ramps	**920**	**820**	**600**
I-89 SB - Exit 20 On Ramp	370	400	760
I-89 SB - South End	**1,290**	**1,220**	**1,360**
I-89 NB - North End	**640**	**1,370**	**930**
I-89 NB - NB I-91 Off Ramp	470	790	450
I-89 NB - Exit 20 to NB I-91 Off Ramp	**1,110**	**2,160**	**1,380**
I-89 NB - Exit 20 On Ramp	270	950	440
I-89 NB - Between Exit 20 Ramps	**840**	**1,210**	**940**
I-89 NB - Exit 20 Off Ramp	430	660	440
I-89 NB - South End	**1,270**	**1,870**	**1,380**

Summer 2019 OD tables

Adjustment Factor: 1.05

		4	5	7	8	9	
		Exit 20 SB	I-89 SB-South	Exit 20 NB	I-89 NB to I-91 NB	I-89 NB-North	
1	I-89 SB-North	237	443				**680**
2	I-91 SB to I-89 SB	403	307				**710**
3	I-91 NB to I-89 SB	226	214				**440**
4	Exit 20 SB		390				**390**
6	I-89 NB-South			460	299	571	**1,330**
7	Exit 20 NB				191	89	**280**
		865	**1,355**	**460**	**490**	**660**	**3,830**

		4	5	7	8	9	
1	I-89 SB-North	219	441				**660**
2	I-91 SB to I-89 SB	318	242				**560**
3	I-91 NB to I-89 SB	81	179				**260**
4	Exit 20 SB		420				**420**
6	I-89 NB-South			690	273	997	**1,960**
7	Exit 20 NB				556	444	**1,000**
		618	**1,282**	**690**	**829**	**1,441**	**4,860**

		4	5	7	8	9	
1	I-89 SB-North	315	365				**680**
2	I-91 SB to I-89 SB	341	139				**480**
3	I-91 NB to I-89 SB	325	125				**450**
4	Exit 20 SB		800				**800**
6	I-89 NB-South			470	187	793	**1,450**
7	Exit 20 NB				285	175	**460**
		981	**1,429**	**470**	**473**	**967**	**4,320**

	AM	PM	Sat
I-89 SB - North End	**680**	**660**	**680**
I-89 SB - SB I-91 On Ramp	710	560	480
I-89 SB - SB I-91 On to NB I-91 On	**1,390**	**1,220**	**1,160**
I-89 SB - NB I-91 On Ramp	440	260	450
I-89 SB - NB I-91 On to Exit 20	**1,830**	**1,480**	**1,610**
I-89 SB - Exit 20 Off Ramp	870	620	990
I-89 SB - Between Exit 20 Ramps	**960**	**860**	**620**
I-89 SB - Exit 20 On Ramp	390	420	800
I-89 SB - South End	**1,350**	**1,280**	**1,420**
I-89 NB - North End	**660**	**1,440**	**970**
I-89 NB - NB I-91 Off Ramp	490	830	470
I-89 NB - Exit 20 to NB I-91 Off Ramp	**1,150**	**2,270**	**1,440**
I-89 NB - Exit 20 On Ramp	280	1,000	460
I-89 NB - Between Exit 20 Ramps	**870**	**1,270**	**980**
I-89 NB - Exit 20 Off Ramp	460	690	470
I-89 NB - South End	**1,330**	**1,960**	**1,450**

Summer 2039 OD tables

Adjustment Factor: 1.21

		4 Exit 20 SB	5 I-89 SB-South	7 Exit 20 NB	8 I-89 NB to I-91 NB	9 I-89 NB-North	
1	I-89 SB-North	276	514				**790**
2	I-91 SB to I-89 SB	465	355				**820**
3	I-91 NB to I-89 SB	261	249				**510**
4	Exit 20 SB		450				**450**
6	I-89 NB-South			520	350	670	**1,540**
7	Exit 20 NB				226	104	**330**
		1,002	**1,568**	**520**	**576**	**774**	**4,440**

		4	5	7	8	9	
1	I-89 SB-North	252	508				**760**
2	I-91 SB to I-89 SB	364	276				**640**
3	I-91 NB to I-89 SB	93	207				**300**
4	Exit 20 SB		480				**480**
6	I-89 NB-South			790	316	1,154	**2,260**
7	Exit 20 NB				639	511	**1,150**
		709	**1,471**	**790**	**955**	**1,665**	**5,590**

		4	5	7	8	9	
1	I-89 SB-North	366	424				**790**
2	I-91 SB to I-89 SB	398	162				**560**
3	I-91 NB to I-89 SB	376	144				**520**
4	Exit 20 SB		920				**920**
6	I-89 NB-South			540	216	914	**1,670**
7	Exit 20 NB				329	201	**530**
		1,139	**1,651**	**540**	**545**	**1,115**	**4,990**

	AM	PM	Sat
I-89 SB - North End	**790**	**760**	**790**
I-89 SB - SB I-91 On Ramp	820	640	560
I-89 SB - SB I-91 On to NB I-91 On	**1,610**	**1,400**	**1,350**
I-89 SB - NB I-91 On Ramp	510	300	520
I-89 SB - NB I-91 On to Exit 20	**2,120**	**1,700**	**1,870**
I-89 SB - Exit 20 Off Ramp	1,000	710	1,140
I-89 SB - Between Exit 20 Ramps	**1,120**	**990**	**730**
I-89 SB - Exit 20 On Ramp	450	480	920
I-89 SB - South End	**1,570**	**1,470**	**1,650**
I-89 NB - North End	**780**	**1,660**	**1,120**
I-89 NB - NB I-91 Off Ramp	570	960	540
I-89 NB - Exit 20 to NB I-91 Off Ramp	**1,350**	**2,620**	**1,660**
I-89 NB - Exit 20 On Ramp	330	1,150	530
I-89 NB - Between Exit 20 Ramps	**1,020**	**1,470**	**1,130**
I-89 NB - Exit 20 Off Ramp	520	790	540
I-89 NB - South End	**1,540**	**2,260**	**1,670**

APPENDIX C – SCENARIO SPECIFIC SIMULATION RESULTS

CT River Bridge Traffic Analysis

Summer 2013 AM No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,330	1,330	100%	63	12	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,680	1,750	96%	59	15	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	920	920	100%	64	8	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	640	640	100%	61	6	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,070	1,110	96%	61	10	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,110	1,110	100%	62	10	A
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,110	1,110	100%	62	10	A
I-89 NB - Between Exit 20 Ramps	500	850	840	101%	65	8	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis

Summer 2013 PM No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,160	1,160	100%	64	10	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,360	1,410	97%	62	11	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	820	820	100%	65	7	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,370	1,370	100%	53	13	B
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	2,110	2,160	98%	57	20	C
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	2,180	2,160	101%	59	20	C
I-89 NB - Merge at Exit 20 On Ramp	1,500	2,180	2,160	101%	59	18	C
I-89 NB - Between Exit 20 Ramps	500	1,220	1,210	101%	65	10	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2013 Sat No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,110	1,110	100%	64	9	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,460	1,540	95%	60	12	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	600	600	100%	65	5	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	930	930	100%	61	8	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,350	1,380	98%	61	12	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,390	1,380	101%	63	12	B
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,390	1,380	101%	62	11	A
I-89 NB - Between Exit 20 Ramps	500	950	940	101%	65	8	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis

Summer 2019 AM No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,390	1,390	100%	62	12	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,760	1,830	96%	58	16	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	970	960	101%	64	8	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	670	660	101%	61	6	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,120	1,150	97%	60	11	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,160	1,150	101%	62	11	A
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,160	1,150	101%	62	10	A
I-89 NB - Between Exit 20 Ramps	500	890	870	102%	65	8	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis

Summer 2019 PM No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,220	1,220	100%	64	10	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,430	1,480	96%	62	11	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	860	860	100%	65	7	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,440	1,440	100%	53	14	B
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	2,210	2,270	97%	53	22	C
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	2,280	2,270	101%	58	21	C
I-89 NB - Merge at Exit 20 On Ramp	1,500	2,280	2,270	100%	58	19	C
I-89 NB - Between Exit 20 Ramps	500	1,280	1,270	101%	64	11	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2019 Sat No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,160	1,160	100%	64	10	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,530	1,610	95%	59	13	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	620	620	100%	65	5	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	970	970	100%	60	8	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,410	1,440	98%	61	12	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,460	1,440	101%	62	12	B
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,450	1,440	101%	62	11	B
I-89 NB - Between Exit 20 Ramps	500	990	980	101%	65	8	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2019 AM Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,390	1,390	100%	62	12	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,820	1,830	100%	63	11	A
I-89 SB - Basic Between Exit 20 Ramps	1,100	970	960	101%	65	8	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	670	660	101%	62	6	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,160	1,150	101%	62	7	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,160	1,150	101%	64	7	A
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,160	1,150	101%	64	7	A
I-89 NB - Between Exit 20 Ramps	500	890	870	102%	65	8	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2019 PM Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,220	1,220	100%	64	10	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,470	1,480	100%	64	8	A
I-89 SB - Basic Between Exit 20 Ramps	1,100	860	860	100%	65	7	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,440	1,440	100%	60	13	B
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	2,280	2,270	101%	60	13	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	2,280	2,270	101%	62	13	B
I-89 NB - Merge at Exit 20 On Ramp	1,500	2,280	2,270	100%	62	13	B
I-89 NB - Between Exit 20 Ramps	500	1,280	1,270	101%	64	11	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2019 Sat Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,160	1,160	100%	64	10	A
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,610	1,610	100%	63	9	A
I-89 SB - Basic Between Exit 20 Ramps	1,100	620	620	100%	65	5	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	970	970	100%	62	8	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,460	1,440	101%	62	8	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,460	1,440	101%	64	8	A
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,460	1,440	101%	63	8	A
I-89 NB - Between Exit 20 Ramps	500	990	980	101%	65	8	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2039 AM No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,610	1,610	100%	62	14	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	2,040	2,120	96%	56	18	C
I-89 SB - Basic Between Exit 20 Ramps	1,100	1,120	1,120	100%	64	9	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	770	780	98%	59	7	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,300	1,350	96%	59	12	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,350	1,350	100%	62	12	B
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,350	1,350	100%	62	11	A
I-89 NB - Between Exit 20 Ramps	500	1,030	1,020	101%	65	9	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis

Summer 2039 PM No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,400	1,400	100%	64	11	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,640	1,700	96%	62	13	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	990	990	100%	65	8	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,660	1,660	100%	52	17	B
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	2,540	2,620	97%	52	25	C
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	2,630	2,620	101%	57	24	C
I-89 NB - Merge at Exit 20 On Ramp	1,500	2,630	2,620	100%	57	22	C
I-89 NB - Between Exit 20 Ramps	500	1,480	1,470	101%	64	12	B

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2039 Sat No Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,350	1,350	100%	64	11	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,780	1,870	95%	57	15	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	730	730	101%	64	6	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,120	1,120	100%	56	10	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,630	1,660	98%	59	15	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,680	1,660	101%	61	14	B
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,680	1,660	101%	61	13	B
I-89 NB - Between Exit 20 Ramps	500	1,150	1,130	101%	65	9	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis

Summer 2039 AM Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,610	1,610	100%	62	14	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	2,110	2,120	100%	63	12	B
I-89 SB - Basic Between Exit 20 Ramps	1,100	1,120	1,120	100%	64	9	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	770	780	98%	62	7	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,350	1,350	100%	62	8	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,350	1,350	100%	64	8	A
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,340	1,350	100%	64	8	A
I-89 NB - Between Exit 20 Ramps	500	1,030	1,020	101%	65	9	A

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis

Summer 2039 PM Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,400	1,400	100%	64	11	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,690	1,700	100%	64	9	A
I-89 SB - Basic Between Exit 20 Ramps	1,100	990	990	100%	65	8	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,660	1,660	100%	57	15	B
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	2,640	2,620	101%	57	16	B
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	2,640	2,620	101%	62	15	B
I-89 NB - Merge at Exit 20 On Ramp	1,500	2,630	2,620	100%	62	15	B
I-89 NB - Between Exit 20 Ramps	500	1,480	1,470	101%	64	12	B

Note: Speed and LOS results taken from peak 15-minute period.

CT River Bridge Traffic Analysis
Summer 2039 Sat Build Freeway Operations

Segment	Length (ft)	Volume (vph)	Volume Target	% Served	Speed (mph)	Density	LOS
Southbound							
I-89 SB - Basic North of NB I-91 On Ramp	1,500	1,350	1,350	100%	64	11	B
I-89 SB - Weave NB I-91 On Ramp to Exit 20	1,800	1,860	1,870	100%	63	10	A
I-89 SB - Basic Between Exit 20 Ramps	1,100	730	730	101%	65	6	A
Northbound							
I-89 NB - Basic North of NB I-91 Off Ramp	500	1,120	1,120	100%	61	10	A
I-89 NB - Diverge at NB I-91 Off Ramp	1,500	1,680	1,660	101%	62	9	A
I-89 NB - Basic Exit 20 to NB I-91 Off Ramp	300	1,680	1,660	101%	64	9	A
I-89 NB - Merge at Exit 20 On Ramp	1,500	1,680	1,660	101%	63	9	A
I-89 NB - Between Exit 20 Ramps	500	1,150	1,130	101%	65	9	A

Note: Speed and LOS results taken from peak 15-minute period.

APPENDIX D - HIGHWAY CAPACITY SOFTWARE RESULTS

CT River Bridge Traffic Analysis

HCS Analysis Summary

AM Peak Hour

Southbound	2013			2019 No Build			2019 Build			2039 No Build			2039 Build		
	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS
I-89 SB - SB I-91 On to NB I-91 On	63.0	13.4	B	63.0	13.7	B	63.0	13.7	B	63.0	15.1	B	63.0	15.1	B
I-89 SB - NB I-91 On to Exit 20 Weave (A)	50.4	17.4	B	49.8	18.4	B	50.0	12.2	B	47.9	22.1	C	48.4	14.6	B
I-89 SB - Between Exit 20 Ramps	61.8	9.0	A	61.7	9.2	A	61.8	9.2	A	61.6	10.3	A	61.6	10.3	A
Northbound	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**
I-89 NB - North End	61.5	8.1	A	61.5	8.2	A	63.0	8.0	A	61.5	9.2	A	63.0	9.0	A
I-89 NB - I-91 Off Ramp Diverge	55.7	13.3	B	55.6	13.5	B				55.5	14.9	B			
I-89 NB - Exit 20 to NB I-91 Off Ramp	61.7	10.9	A	61.7	11.1	B	63.0	6.0	A	61.7	12.4	B	63.0	7.1	A
I-89 NB - Exit 20 Merge	57.5	12.0	B	57.5	12.2	B	(Weaving Section)			57.4	13.7	B	(Weaving Section)		
I-89 NB - Between Exit 20 Ramps	63.0	8.1	A	63.0	8.2	A	63.0	8.2	A	63.0	9.2	A	63.0	9.2	A

PM Peak Hour

Southbound	2013			2019 No Build			2019 Build			2039 No Build			2039 Build		
	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS
I-89 SB - SB I-91 On to NB I-91 On	63.0	10.5	A	63.0	10.9	A	63.0	10.9	A	63.0	12.4	B	63.0	12.4	B
I-89 SB - NB I-91 On to Exit 20 Weave (A)	52.6	13.4	B	52.1	14.2	B	51.7	9.5	A	50.3	16.9	B	50.2	11.3	B
I-89 SB - Between Exit 20 Ramps	62.0	7.3	A	62.0	7.6	A	61.9	7.6	A	61.8	8.7	A	61.8	8.7	A
Northbound	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**
I-89 NB - North End	61.4	15.6	B	61.4	15.8	B	62.9	15.5	B	61.4	18.1	C	62.8	17.7	B
I-89 NB - I-91 Off Ramp Diverge	55.1	22.3	C	55.0	23.1	C				54.8	26.1	C			
I-89 NB - Exit 20 to NB I-91 Off Ramp	61.5	19.5	C	61.5	20.2	C	60.2	12.6	B	61.4	23.1	C	59.0	14.8	B
I-89 NB - Exit 20 Merge	56.7	20.3	C	56.6	20.8	C	(Weaving Section)			56.0	23.8	C	(Weaving Section)		
I-89 NB - Between Exit 20 Ramps	63.0	10.7	A	63.0	11.0	B	63.0	11.0	B	63.0	12.6	B	63.0	12.6	B

Saturday Peak Hour

Southbound	2013			2019 No Build			2019 Build			2039 No Build			2039 Build		
	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS	Speed	Density	LOS
I-89 SB - SB I-91 On to NB I-91 On	63.0	9.9	A	63.0	10.4	A	63.0	10.4	A	63.0	12.1	B	63.0	12.1	B
I-89 SB - NB I-91 On to Exit 20 Weave (A)	51.5	14.9	B	50.8	15.8	B	50.6	10.6	B	49.0	19.1	B	49.1	12.7	B
I-89 SB - Between Exit 20 Ramps	61.9	5.3	A	61.8	5.5	A	61.8	5.5	A	61.7	6.4	A	61.7	6.4	A
Northbound	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**	**Speed**	**Density**	**LOS**
I-89 NB - North End	61.6	10.3	A	61.6	10.8	A	62.6	8.4	A	61.6	12.4	B	63.0	12.1	B
I-89 NB - I-91 Off Ramp Diverge	55.8	14.8	B	55.8	15.3	B				55.8	17.3	B			
I-89 NB - Exit 20 to NB I-91 Off Ramp	61.7	12.2	B	61.7	12.7	B	61.1	7.9	A	61.7	14.7	B	63.0	8.7	A
I-89 NB - Exit 20 Merge	57.5	13.1	B	57.4	13.6	B	(Weaving Section)			57.3	15.7	B	(Weaving Section)		
I-89 NB - Between Exit 20 Ramps	63.0	8.1	A	63.0	8.5	A	63.0	8.5	A	63.0	9.8	A	63.0	9.8	A

APPENDIX E - TRAFFIC ADJUSTMENTS

Continuous Traffic Counter Grouping Study and Regression Analysis Based on 2012 Traffic Data

Vermont Agency of Transportation
Policy, Planning, & Intermodal Development Division
Traffic Research Unit
March 2013

A: Interstate Highways

					Short Term Growth				**2007**	**to**	**2012**	**1.03**
					20 Year Growth				**2012**	**to**	**2032**	**1.16**
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
2007	1.00											
2008	1.01	1.00										
2009	1.01	1.01	1.00									
2010	1.02	1.01	1.01	1.00								
2011	1.02	1.02	1.01	1.01	1.00							
2012	1.03	1.02	1.02	1.01	1.01	1.00						
2013						1.01	1.00					
2014						1.02	1.01	1.00				
2015						1.02	1.02	1.01	1.00			
2016						1.03	1.02	1.02	1.01	1.00		
2017						1.04	1.03	1.02	1.02	1.01	1.00	
2018						1.05	1.04	1.03	1.02	1.02	1.01	1.00
2019						1.06	1.05	1.04	1.03	1.02	1.02	1.01
2020						1.06	1.06	1.05	1.04	1.03	1.02	1.02
2021						1.07	1.06	1.06	1.05	1.04	1.03	1.02
2022						1.08	1.07	1.06	1.05	1.05	1.04	1.03
2023						1.09	1.08	1.07	1.06	1.05	1.05	1.04
2024						1.10	1.09	1.08	1.07	1.06	1.05	1.05
2025						1.10	1.10	1.09	1.08	1.07	1.06	1.05
2026						1.11	1.10	1.09	1.09	1.08	1.07	1.06
2027						1.12	1.11	1.10	1.09	1.09	1.08	1.07
2028						1.13	1.12	1.11	1.10	1.09	1.08	1.08
2029						1.14	1.13	1.12	1.11	1.10	1.09	1.08
2030						1.14	1.13	1.13	1.12	1.11	1.10	1.09
2031						1.15	1.14	1.13	1.13	1.12	1.11	1.10
2032						1.16	1.15	1.14	1.13	1.12	1.12	1.11
2033						1.17	1.16	1.15	1.14	1.13	1.12	1.11
2034						1.18	1.17	1.16	1.15	1.14	1.13	1.12
2035						1.18	1.17	1.17	1.16	1.15	1.14	1.13
2036						1.19	1.18	1.17	1.16	1.16	1.15	1.14
2037						1.20	1.19	1.18	1.17	1.16	1.15	1.15
2038						1.21	1.20	1.19	1.18	1.17	1.16	1.15
2039						1.22	1.21	1.20	1.19	1.18	1.17	1.16
2040						1.22	1.21	1.20	1.20	1.19	1.18	1.17
2041						1.23	1.22	1.21	1.20	1.19	1.18	1.18
2042						1.24	1.23	1.22	1.21	1.20	1.19	1.18
2043						1.25	1.24	1.23	1.22	1.21	1.20	1.19
2044						1.26	1.25	1.24	1.23	1.22	1.21	1.20
2045						1.26	1.25	1.24	1.23	1.22	1.22	1.21
2046						1.27	1.26	1.25	1.24	1.23	1.22	1.21
2047						1.28	1.27	1.26	1.25	1.24	1.23	1.22
2048						1.29	1.28	1.27	1.26	1.25	1.24	1.23
2049						1.30	1.29	1.28	1.27	1.26	1.25	1.24
2050						1.30	1.29	1.28	1.27	1.26	1.25	1.24
2051						1.31	1.30	1.29	1.28	1.27	1.26	1.25
2052						1.32	1.31	1.30	1.29	1.28	1.27	1.26
2053						1.33	1.32	1.31	1.30	1.29	1.28	1.27
2054						1.34	1.33	1.31	1.30	1.29	1.28	1.27
2055						1.34	1.33	1.32	1.31	1.30	1.29	1.28
2056						1.35	1.34	1.33	1.32	1.31	1.30	1.29
2057						1.36	1.35	1.34	1.33	1.32	1.31	1.30

STATE OF NEW HAMPSHIRE, DEPARTMENT OF TRANSPORTATION - BUREAU OF TRAFFIC
IN COOPERATION WITH U.S. DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION
AUTOMATIC TRAFFIC RECORDER DATA FOR THE MONTH OF JANUARY 2013

02 253090 LEBANON- I-89 AT CROSSOVER SOUTH OF VERMONT SL (SB-NB) (01253001-01253002)

MON	DATE	DAY	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	Total
1	1	3	279	183	59	54	109	274	442	523	813	1540	2378	2950	3130	3064	2756	2494	1986	1469	1072	684	437	293	160	79	27228
1	2	4	74	86	117	227	512	1376	2559	2239	1873	2090	2278	2495	2532	2661	2957	3445	3137	1868	1153	813	564	335	296	135	35822
1	3	5	110	106	116	181	518	1343	2434	2313	1919	1922	2056	2332	2428	2725	2913	3356	3254	1990	1272	952	712	391	311	166	35820
1	4	6	107	131	124	212	488	1266	2409	2240	1902	2019	2325	2493	2585	2880	3336	3615	3676	2347	1878	1673	1162	681	413	232	40194
1	5	7	135	111	120	165	198	550	860	1399	1716	2293	2631	2710	2703	2543	2507	2455	2131	1658	1165	937	737	481	283	199	30687
1	6	1	111	76	52	80	108	293	555	809	1292	1720	2233	2571	2561	2733	2765	2679	2217	1645	1092	767	495	320	151	101	27426
1	7	2	72	97	113	202	537	1449	2635	2296	1883	2046	1944	2087	2301	2317	2445	2833	3170	3030	1806	1220	718	544	326	296	36367
1	8	3	131	97	105	120	230	537	1402	2583	2362	1889	1989	2013	2195	2258	2469	2960	3289	3068	1908	1251	779	601	410	270	34916
1	9	4	141	82	92	112	219	519	1465	2662	2314	1872	1927	2052	2162	2264	2525	2978	3293	3110	1849	1243	839	577	382	276	34955
1	10	5	114	128	111	130	236	508	1374	2726	2375	1911	1832	2147	2313	2356	2526	2948	3383	3219	2026	1351	996	764	434	283	36191
1	11	6	146	121	131	116	223	474	1375	2433	2197	1950	2042	2220	2455	2675	2920	3488	3672	3416	2359	1565	1348	1151	747	377	39601
1	12	7	163	134	102	87	128	228	486	856	1354	1719	2196	2655	2560	2444	2541	2594	2439	2016	1601	1181	864	766	497	319	29930
1	13	1	188	119	77	50	67	113	351	482	866	1355	2049	2693	2939	3015	3128	3014	2583	1929	1440	1003	843	574	343	205	29426
1	14	2	131	92	89	102	233	565	1408	2679	2334	1952	1902	2101	2312	2303	2542	2734	3177	2904	1726	1009	751	534	366	248	34194
1	15	3	136	81	111	110	236	541	1440	2571	2262	1775	1839	2007	2169	2162	2396	2808	3098	2987	1820	1119	776	590	349	290	33673
1	16	4	163	93	104	134	202	477	1238	2145	2030	1499	1408	1407	1675	1678	1836	2171	2552	2369	1462	932	715	472	357	270	27389
1	17	5	122	103	105	129	216	487	1399	2547	2238	1920	1867	2043	2182	2265	2484	3008	3302	3170	1992	1263	961	783	414	315	35315
1	18	6	156	115	116	163	219	476	1338	2420	2174	1933	2220	2406	2660	2679	3070	3745	3968	3780	2909	2133	1936	1841	960	481	43898
1	19	7	246	171	110	104	135	203	522	983	1489	1870	2362	2821	2883	2771	2586	2637	2520	2301	1685	1281	894	753	510	316	32153
1	20	1	196	107	77	56	89	120	312	507	874	1394	1907	2309	2564	2537	2510	2432	2291	1855	1315	841	595	479	388	205	25960
1	21	2	108	90	91	113	214	514	1282	2205	2001	1983	2507	2898	3226	3186	3481	3459	3543	3072	1784	1083	663	456	316	233	38508
1	22	3	124	83	121	123	257	479	1287	2514	2166	1723	1716	1967	2005	2050	2270	2625	2966	2811	1627	1037	728	460	316	270	31725
1	23	4	118	92	92	110	192	454	1390	2492	2147	1749	1777	1882	2081	2074	2305	2615	3010	3077	1659	1042	731	589	336	274	32288
1	24	5	118	91	100	132	208	489	1353	2481	2177	1759	1776	1985	2130	2171	2364	2812	3180	3072	1899	1238	933	725	372	305	33870
1	25	6	149	130	111	132	227	488	1311	2417	2071	1954	2040	2239	2476	2555	3062	3362	3729	3584	2549	1897	1536	1239	633	434	40325
1	26	7	233	141	96	109	187	161	495	837	1311	1784	2295	2624	2488	2461	2330	2366	2335	1957	1552	1058	907	717	420	295	29159
1	27	1	184	135	80	56	85	103	360	536	837	1272	1759	2393	2689	2848	2903	2832	2799	2306	1726	1158	699	464	311	177	28712
1	28	2	104	79	80	111	230	546	1443	2691	2284	1848	1922	2018	1949	1752	1756	1925	2222	2019	1095	722	452	413	296	201	28158
1	29	3	103	94	105	121	235	475	1214	2462	2061	1666	1708	1722	1972	2002	2235	2588	2970	2765	1602	1017	579	423	322	222	30663
1	30	4	126	117	102	101	179	454	1262	2221	2070	1834	1867	1902	1999	2062	2398	2718	3058	2899	1738	1135	776	552	521	301	32392
1	31	5	134	91	92	137	227	485	1396	2577	2194	1791	1897	1963	2203	2221	2432	2719	3102	3055	1954	1237	883	699	384	330	34203

	12 AM	1 AM	2 AM	3 AM	4 AM	5 AM	6 AM	7 AM	8 AM	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM	7 PM	8 PM	9 PM	10 PM	11 PM	Total
:al average weekday	**127**	**99**	**104**	**127**	**239**	**550**	**1429**	**2495**	**2186**	**1837**	**1871**	**2009**	**2180**	**2214**	**2446**	**2835**	**3175**	**3019**	**1888**	**1245**	**913**	**720**	**440**	**302**	

VALUE OF TIME GUIDANCE DOCUMENT

U.S. Department of Transportation
Office of the Secretary of Transportation

Assistant Secretary

1200 New Jersey Avenue SE
Washington, DC 20590

September 27, 2016

MEMORANDUM TO: SECRETARIAL OFFICERS
MODAL ADMINISTRATORS

From: Vinn White
Acting Assistant Secretary for Transportation Policy, x69044

Subject: Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis

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The value of travel time is a critical factor in evaluating the benefits of transportation infrastructure investment and rulemaking initiatives. Reduction of delay in passenger or freight transportation is a major purpose of investments, and rules to enhance safety sometimes include provisions that slow travel. As the Department expands its use of benefit-cost analysis in evaluating competitive funding applications under such programs as the TIGER and FASTLANE Grant programs and the High-Speed Intercity Passenger Rail program, it is essential to have appropriate, well-reasoned guidance for valuing delays and time savings.

This version of the guidance updates the value of travel time savings with median household income information for 2015 from the Census Bureau and salary information from the Bureau of Labor Statistics National Occupational Employment and Wage Estimates from May 2015. The household income data are drawn from the Census Bureau's Current Population Survey, Annual Social and Economic Supplements, and are not released until the September following the year in which they are collected; the 2015 data are thus the most recent data available. The percentages of earnings used to determine the value of travel time savings (shown in tables 1 and 2) remain unchanged. The revised dollar values of travel time savings are shown in tables 3, 4, and 5.

DOT published its first guidance on this subject, "Departmental Guidance for the Valuation of Travel Time in Economic Analysis," on April 9, 1997, to assist analysts in developing consistent evaluations of actions that save or cost time in travel. That memorandum recommended an array of values for different categories of travel, according to purpose, mode and distance. For each category, the Guidance specified a percentage of hourly income that would normally be used to determine the value per hour of savings in travel time, a range of percentages defining upper and lower bounds about the normal value for sensitivity testing, and an average hourly income level. Special values were assigned to walking and waiting time, travel by general aviation, and truck drivers.

Revised guidance, labeled as "Revision 1," was issued on February 11, 2003. A further revision, labeled "Revision 2," was issued on September 28, 2011 and adjusted these values for use in 2011, incorporated some additional values and procedures, and redefined the sources of data. In particular, time savings in high-speed rail travel were identified as equivalent to those in air travel and distinguished from intercity travel by conventional surface modes. Although we found no need to alter the normal percentages of hourly income and the ranges of percentages that were assigned in the 1997 memorandum, more recent and appropriate sources were used to specify hourly incomes. In particular, the income data used in that guidance were derived from public and regularly updated sources that allow the Department to update the values annually. This revision also included a bibliography of documents available online that provide an overview of the research literature in the field and the recommendations developed by experts in several countries.

A link to this revised guidance will be found on the Office of Transportation Policy website at: http://www.dot.gov/policy/transportation-policy/economy. Questions should be addressed to Darren Timothy ((202) 366-4051 or darren.timothy@dot.gov) in the Office of Transportation Policy.

Attachment

cc: Regulations Officers and Liaison Officers

The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2016 Update)

Introduction

Many actions by the Department of Transportation and other governmental agencies are designed to benefit travelers by reducing the time spent in traveling. Actions in pursuit of other goals such as improved safety may also have the intended or unavoidable consequence of slowing travel. The purpose of this document is to state the procedures approved for use by all administrations within DOT when evaluating reductions or increases in passenger travel time that result from such actions. The value of travel time savings (VTTS) derived here is to be used in all DOT benefit-cost or cost-effectiveness analyses.

Governments employ benefit-cost analysis to ensure that their regulatory actions and investments in transportation infrastructure will use society's resources most efficiently and to promote transparency in decision-making. Doing so often requires assigning money values to factors that lack observable market prices. As one of the most important of these factors, travel time has been the subject of research in many countries over several decades. Individual experts and official panels have reviewed and summarized this literature repeatedly as it has grown, and this document draws on that body of research and interpretation to establish procedures for use in valuing travel time consistently throughout DOT.

These expert summaries represent only a rough consensus about relevant variables and relationships among values. Because VTTS varies widely, standard values for government decisions must ignore or simplify many important factors. A complete model of real travel choices would require a large number of variables and associated coefficients, yet there are no sources for most of these variables, and the coefficients estimated from available data vary between studies and are subject to considerable uncertainty and interpretation. Combining individual decisions to draw conclusions for an entire society implies subjective assumptions about the influence of incomes and other personal characteristics. Therefore, the object of this guidance must be seen as construction of a useful framework for assigning values to government actions, rather than distilling precise scientific conclusions from the literature or predicting travel behavior.

The initial Departmental guidance for the valuation of travel time in economic analysis was published on April 9, 1997, and the first tables of revised values were published on February 11, 2003. Part of the reason for the long intervals between revisions was that certain data were available only from private sources or updated infrequently. The resulting delay and lack of transparency was inconvenient, confusing, and a potential cause of economic inefficiency. Consequently, we revised our guidance in 2011 to derive VTTS from public and regularly published data that permits the Department to issue annual updates. We use median income levels, rather than means, as consistently as possible. We believe that this approach reflects the valuations of typical travelers in diverse populations more reliably and yields conclusions that are less sensitive to fluctuations in extreme values.

General concepts

The demand for travel is generally derived from the demand for activities it permits at either end of the trip, just as sporting equipment is valued only for participation in the complementary sport it permits. In contrast, travel time must be conceived as having a negative demand, a consumer's willingness to pay to have less of it. This too is derived, not from complements, but from substitutes, i.e., the time available for activities at origin or destination, which may vary greatly in their value and urgency. The value of time saved from travel will depend on the traveler, the circumstances of the trip, and the available transportation options. There can be no assurance in principle that these factors will be stable. A large share of individual trips, however, particularly commuting to work, have similar purposes and are repeated on daily and weekly schedules. By focusing on a few choices of mode and route (e.g., rail transit vs. private auto, toll highway vs. parallel free thoroughfare) researchers have approximated explanations of travelers' decisions with a manageable number of variables yet with some confidence that their conclusions can be applied to a reasonably large share of travel by the larger community.

The values so derived are broadly representative and practically useful for estimating social benefits—the purpose for which this guidance is intended. They cannot be used to predict the number of travelers who would choose a specific mode or route, however. Such predictions depend on the distribution of time values over the population, rather than the most common value, and on the number of travelers who are close to the margin in deciding between alternatives.

The value of reducing travel time expresses three principles. First, time saved from travel could be dedicated to production, yielding a monetary benefit to either travelers or their employers. Second, it could be spent in recreation or other enjoyable or necessary leisure activities, which individuals value and are thus willing to pay for. Third, the conditions of travel during part or all of a trip may be unpleasant and involve tension, fatigue, or discomfort. Reducing the time spent while exposed to such conditions may be more valuable than saving time on more comfortable portions of the trip. These principles underlie the distinctions among values recommended in this guidance.

Specific topics

Reliability

Closely associated with VTTS, reliability has long been viewed as a source of utility distinct from reduction of the expected trip time. If travelers are uncertain about travel time, they may include a "buffer" in their schedules, leaving early and sacrificing a certain amount of time at the origin to insure against a more costly delay in arriving at the destination. This insurance will be frequently unnecessary or excessive and occasionally inadequate. Alternatively, insuring against delay may mean choosing a more reliable route or mode with a slower expected speed and/or a higher monetary cost.

There are several ways to measure the travelers' experience and define their perception of future delay risks, including standard deviation of trip time; the difference or ratio between the median trip time and a higher percentile trip time (such as the 95th percentile); or the probability of lateness beyond a fixed target. Furthermore, variation of travel time over some period will differ between origin-destination pairs, depending both on the reliability of travel on each trip segment and on the correlation of delays between segments.

Thus, a "value of reliability" is much more complex to estimate than an average VTTS, since it requires knowledge of the joint distribution of travel times and of the rates of change of value at the margins, rather than just the means. Studies have been conducted in several countries, using different measures of reliability, and suggestive results have been produced. Although it may be possible to derive estimates for specific cases, we are not yet prepared to provide guidance for routine valuation of reliability. In contrast to differences in reliability among modes or routes, however, improvements in reliability on a single route will often be linked to reductions in expected travel time, so that one possible approach is to add an allowance to VTTS to reflect the value of improved reliability.

Size of time change

Another subject of discussion has been whether VTTS should be ignored below some threshold increment of time saved. Some research has suggested the conclusion that discrete, small savings may have negligible benefits. See Australia Bureau of Transport Economics, Fosgerau *et al.*, Mackie *et al.* (2001, 2003).

There is no persuasive evidence of where such a threshold might be for any population or how it could be used to predict an appropriate threshold for another. A more important problem is that all changes in travel time resulting from government actions are composed of many smaller changes, and it would be impossible to identify particular changes considered large enough to affect each individual decision. To evaluate the aggregate impact of any action, therefore, we must assume that the value of each minute of saved time is constant, regardless of the total time required for a trip.

Value of Time in Freight Transportation

Most of the VTTS literature focuses on passenger travel, rather than freight transportation. Estimates have been made of the labor costs of freight vehicle operators (e.g., truck drivers or locomotive engineers) and of the operating costs of freight vehicles that would be affected by changes in travel time. The value of time to shippers (i.e., the owners of the freight that is being transported) cannot be estimated so easily, however. Because freight in transit represents unproductive capital that incurs an interest cost, part of the benefit of saved time will be proportional to the time saved, the interest rate, and the value of the freight. The principal obstacle to estimating this value is likely to be the heterogeneity and uncertainty of freight categories affected by any specific time saving. Each corridor or mode would thus require a specific estimate of the composition of freight carried. The cost of freight transportation time will also be influenced by factors independent of value, such as how quickly products become obsolete (because of fashion or technological obsolescence), whether the products spoil over time (as do agricultural commodities), and whether some production process is dependent upon timely delivery. Various reasons, then, explain why products may be "perishable" in the sense that their value declines appreciably while they are in transit. The cost to shippers may also depend on business practices, such as the amount of inventory kept on hand, and the likelihood of running out of inventory because of shipment delays.

The value of time in freight transportation is thus considerably more complex than is the case in passenger travel. Although we are not yet prepared to offer guidance on this issue, we are conducting research, and hope that additional information will permit concrete recommendations in the future.

Determinants of VTTS

Research into VTTS is conducted, not merely to understand the motives of travel decisions taken by the sampled individuals, but to estimate the influence of measurable factors on other groups, often remote in time and place. Each estimate depends on the demographic characteristics of the traveling population, the mode, time, location, and purpose of travel, and the menu of available alternatives, so the selected explanatory variables must be important for these decisions, practically observable or published, and also obtainable for new samples. Not all relevant factors can be controlled for in a single study or measured consistently for new studies or populations affected by government actions. Our object is therefore to express VTTS in terms of a limited number of variables that have been used in empirical research and are likely to be available for application in new analyses. The sources of variation will inevitably be simplified and distorted, but the result may be a realistic approximation. The variables discussed here are those that are most common in the primary research literature and have been found most useful for applied evaluations.

Trip purpose

The principal distinction in trip purpose is that between "on-the-clock" business travel time, for which a market wage is paid, and personal or leisure time allocated according to the traveler's preferences. In some cases, commuting is treated as a separate category, intermediate between personal and business, but more frequently it is included in personal travel. Research has typically found VTTS for personal travel to be lower than the hourly earning rate. This conclusion does not imply that leisure is less intrinsically desirable than paid work. In theory, a worker's hourly wage is equal to his marginal value of time, but with an institutionally fixed working day, this concept can be no better than an approximation. People who earn a salary may have few opportunities to convert saved time into added income, which they would have to do to equate VTTS on and off the clock. Inclusion of commuting in personal travel is consistent with the hypothesis of fixed hours for salaried work. Personal travel may also be undertaken to enjoy the passing scenery or the qualities of a particular mode: a sports car, cruise ship, or steam railroad. In such a case, VTTS could actually be negative, the individual being willing to pay to spend more time traveling along a particular route or via a particular mode.

In business travel, though it may seem paradoxical, the treatment of commercial drivers (whose travel time is spent working) and travelers who are unable to perform work *en route* should be identical. In either case, savings in travel time are made available for additional productive work. When work can be performed by passengers during travel by means of a laptop computer, a mobile telephone, documents on paper, or discussion among travelers, time savings may increase productivity only slightly, if at all, implying a lower VTTS.

Personal characteristics

Demographic variables such as age, sex, education, and employment are widely incorporated as explanatory variables in social and economic research and may well influence VTTS. While they are sometimes included in empirical studies, they are unlikely to be practical for appraising the impact of government actions. More closely associated with VTTS are the distinctions between drivers and passengers and between parents and children. Clearly, in a public transit vehicle or a car pool, each passenger may have an independent value of time, and the value of increasing the speed of the trip can be conceived as the sum of values for individual vehicle occupants. In private vehicles, the case is more ambiguous. Adult or child passengers may be "along for the ride" and have no pressing business that would influence the driver's decisions. Alternatively, the driver's motive for speeding up travel may be altruistic or joint with the passengers' (rushing a child to the emergency room or a group to a show). Without the possibility of distinguishing the composition or motives of ridership, it must be assumed that all travelers' VTTS are independent and additive.

Hourly income

In theory, hourly income influences VTTS through two channels. The simplest model evaluates savings in paid business travel time. While workers are assumed to be indifferent between travel and other ways to spend time for which they are compensated, employers perceive their employees' gross compensation (including payroll taxes and fringe benefits) as the value of the productivity sacrificed to travel. In general practice, VTTS for business-related travel is not estimated empirically but is defined by the gross compensation.

VTTS for personal travel lacks such a theoretical formulation, and leisure time is seen instead as an object of consumption that can be substituted for other desirable objects according to individual preferences. In general, VTTS is estimated to be lower for personal than for business travel. See Mackie *et al.* (2001).
Suggested reasons include:

- Employers' compensation costs include taxes and benefits excluded from workers' disposable income;
- Working hours are typically fixed by employers, preventing workers from earning more by saving personal travel time;
- Compensation is spread over several family members, including non-earners.

While such rationales are plausible, circumstances may dictate high or low willingness to pay for faster travel by either working travelers or dependents, and only empirical research can yield quantitative estimates. Neither specifying a model of household travel decisions nor obtaining the appropriate data for estimation is a straightforward process. Households include varied numbers of earners and dependents for whom work, school, child care, and other demands on time and income may influence VTTS in unknown ways. Travel by families incurs joint costs of lost time that cannot be assigned to particular members. Besides compensation, unearned income from investments or annuities contributes to travel budgets. Among all of these factors, the compensation level of an individual traveler may not be the most important or the most accessible variable. Research tends to use either a few broad household income bands stated by sampled travelers or the median household incomes of the geographic areas studied. See, *e.g.*, Asensio and Matas (2008) and Small *et al.* (2005).

To adjust past estimates for application to new populations, we require income measures that are nationwide, comparable and stable in definition, and regularly updated and published. The most reliable variable for projecting business VTTS is the median hourly wage for all occupations. Since median fringe benefits are not published, the median wage can be scaled upward to approximate the median gross compensation by multiplying by the ratio of mean gross compensation (including fringe benefits and payroll taxes) to mean money wages. The best variable for projecting personal VTTS is annual median household income. In order to present business and personal VTTS on a practical and comparable basis, annual household income is scaled to an hourly rate by dividing by 2,080 hours per year, although it should not be inferred that travelers prorate their household incomes by the hour to make decisions.

In using hourly income as a scaling factor to transfer VTTS estimates to new times and locations it has been common to assume an income elasticity of 1.0 (a one percent increase in VTTS per one percent increase in income), implying a constant proportional relationship. Some recent studies have yielded lower elasticities for personal travel, although they have not been unchallenged. Such studies tend to be based on cross-sectional models, which compare travelers of different incomes at the same time and location. Apart from the credibility of particular results, the assumption that parameters derived from cross-section studies are valid for time series is problematic. Furthermore, use of non-unitary income elasticities would raise a serious question. If VTTS for business travel is defined as equal to the cost of employment, it must display a unitary elasticity, growing at the same rate as growing incomes, while VTTS in personal travel, with a smaller elasticity, would display slower growth. As a result, an ever-larger discrepancy would emerge between VTTS for business and personal travel, negating the hypothesis of a stable ratio between them. VTTS could then be defined only for the period of each study and extrapolated to the present or the future only by complex and arbitrary calculations. Instead, we retain the assumption of fixed VTTS relationships for different trip purposes and an income elasticity of 1.0 for all.

Where travelers of distinct income levels use modes that are not close substitutes, VTTS may be associated with an expected income for each mode. If there are wide and overlapping income ranges in substitutable modes, it is preferable not to differentiate VTTS estimates on the basis of travelers' incomes but to use a single value for all.

<u>Mode and distance</u>

VTTS research is often based on the factors influencing mode choice, including the comfort, privacy, and prestige subjectively ascribed to particular modes, as well as travel time and cost. Since the conclusions of this research are used primarily to evaluate time and cost benefits, analysts must control for the other factors affecting mode choice. The question remains whether differences among modes in VTTS are systematic or are accidents of specification and the data used. For example, should VTTS differ between auto drivers and bus passengers after other factors are taken into account? Should income differences between the groups be assumed to affect the comparative benefits of time savings? As indicated above, where modes are relatively close substitutes in location, purpose, and trip distance, it is appropriate to assume that the incomes and preferences of travelers are distributed identically among and within modes, yielding a common VTTS.

While this uniformity is appropriate among local modes, research has found evidence of a moderate rise in VTTS with trip distance. This tendency may be seen as a consequence of the limited amount of time available for taking a long trip. In addition, it may reflect the high value of time at destinations which justify increased costs of travel and complementary food and lodging. Although some governments have derived VTTS from an estimated distance elasticity, this is an awkward parameter to use, requiring a specific distance for each application, whereas a route segment or mode affected by a government action is likely to support trips of widely varying distance. A more practical approach differentiates trips by broad categories of local travel (i.e., within a metropolitan area) and intercity travel (for trips over 50 miles).

Certain modes, particularly airlines and high-speed railways, are not close substitutes for conventional surface modes. (High-speed railways are associated with the Core Express Corridors defined in the FRA National Rail Plan as connecting large urban areas up to 500 miles apart with 2-3 hour travel time and speeds between 125 and 250 mph.) Since these modes charge higher fares to travelers who place a greater value on time saving, it is reasonable to derive a distinct VTTS from the higher incomes of their passengers. Although income information on travelers in these markets is limited in detail, estimates from the 2001 National Household Travel Survey of the household incomes of air passengers on personal and business trips permit construction of expected VTTS specific to air travel. Because high-speed rail will often compete with air travel for similar consumers, the same VTTS is applied to both modes.

Comfort

Travelers will vary widely in willingness to pay to shorten the time during which they are subject to uncomfortable conditions such as walking, bicycling, and standing on platforms or in vehicles. Indeed, many other conditions—stressful driving in heavy traffic, exposure to weather, crowding, uncomfortable seating, and lack of personal security—could be included in this list, but it would be difficult to assign values to all of them or measure their severity and duration. VTTS estimates already incorporate assumptions about such conditions. Since shortening walking distances and waiting times and increasing seating are routine options in transportation planning, we assign values to their benefits. A distinction should be noted between actions that shorten the time period during which such conditions are experienced (reducing waiting by more frequent train service) and those that improve conditions during the whole trip (adding cars to permit more passengers to be seated). In the former case, VTTS is fixed at a higher level while the travel time varies; in the latter, travel time is constant, but VTTS varies.

Research and syntheses

The appended bibliography compiles references, accessible via the Internet, that demonstrate the evolution of theoretical and empirical research into VTTS and contain even more comprehensive lists of sources. These include reviews of the research literature and recommended guidance for government agencies in the U.S. and abroad. The history of the economic theory of time valuation is discussed in Mackie *et al.* (2001) and more formally in Jara-Díaz and Guevara (1999). The pioneering articles by Becker (1965) and DeSerpa (1971) place time-allocation decisions in a context of consumption choice based on utility maximization, subject to constraints on income and the minimum amount of time required by each activity. With its subsequent extensions, this model permits derivation of equilibrium conditions for time allocation and has provided a widely-used basis for estimation of the parameters of VTTS.

Analysts have employed various techniques for estimating travelers' willingness to pay to save time. Where behavioral patterns such as choice of route or mode can be observed and other causal factors can be controlled for, estimates are derived from revealed preference. More frequently, stated preference methods are employed, using questionnaires to elicit hypothetical choices among trips that vary across several dimensions. This approach allows consideration of a greater number of behavioral alternatives and independent variables. Although revealed preference studies observe actual consumer choices, they are subject to error in the specification and measurement of the explanatory variables. Stated preference studies, in contrast, specify explanatory variables precisely but may be subject to errors when respondents predict their own hypothetical behavior unrealistically. Recent research has also combined these methods, using questionnaires to elicit information on the factors influencing real travel choices. Most research employs discrete choice techniques such as logit analysis to estimate the parameters influencing preference for specific modes or routes. As the number of published studies has grown, some investigators have also used meta-analysis to estimate the causes of variation among the conclusions of separate investigations.

Although VTTS was first investigated in English-speaking countries, concerted efforts to develop national models based on systematic data collection have been undertaken in the Netherlands, Switzerland, and the Scandinavian countries, as well as the United Kingdom (U.K.). VTTS has also been the object of research in Latin America and Asia. While several of these studies are cited in the bibliography, we will not analyze all of their conclusions.

There is wide agreement that the VTTS for business travel should equal the gross hourly cost of employment, including payroll taxes and fringe benefits. Because of international differences in tax structures, labor markets, data resources, and analysts' view of the social groups being studied, however, the definition of hourly income varies. In theory, it is equal to the worker's marginal product that would be sacrificed if travel were slower. Productivity may vary during work hours, allowing travel to be scheduled to minimize losses and, as noted earlier, modern technology can combine work with travel. Still, there is no well-accepted basis for estimating how the generalized value of business travel time differs from the simple gross compensation or predicting its variation in applied evaluation. All of the cited syntheses adopt the assumption that business travel time is equal to gross compensation, except for Boiteux and Baumstark (2001), where VTTS on business is estimated at 61 percent of the hourly cost of employment or 85 percent of the employee's gross salary (relating to the French system of accounts). Whether the earnings to which estimates are applied should be averages over broad or narrow groups (defined by mode, driver/passenger, or type of employment) is often unclear.

For personal travel, the range of recommended values is broader, reflecting the absence of a theoretically compelling hypothesis. Some studies find lower VTTS for auto passengers than for drivers and lower values for shopping or recreational travel than for commuting. Application of such distinctions, even if consistently supported by research, would require data on the specific characteristics and travel purposes of the population affected by government actions. To suggest the values developed in other countries, the following table converts VTTS for commuting auto drivers recommended in several European studies to dollars of the same years as the estimates and projects them to 2008 dollars by the growth in U.S. median household income. These values span a range that is significant but not so wide as to suggest major specification errors or other inconsistencies. It may be observed that the values we now recommend are near the center of this distribution.

Commuter VTTS

Country	Year	VTTS in $/hr.	US income growth to 2008	Equivalent 2008 VTTS
Denmark	2004	$10.98	1.13	$12.46
France	1998	$10.26	1.29	$13.27
Norway	1995	$6.32	1.48	$9.33
Spain	2005	$17.06	1.09	$18.52
Sweden	1994	$4.34	1.56	$6.77
Switzerland	2003	$15.85	1.16	$18.41
UK	2002	$7.71	1.19	$9.15

The U.K. practice, as seen in Mackie *et al.* (2003) and in the U.K.'s Transport Analysis Guidance (TAG) 3.5.6 (the official guidance which Mackie's work informs), is to distinguish modes by mean income but not by distance. VTTS for commuting is set at less than 25 percent of the average for business travel and VTTS for other purposes at 90 percent of the commuting rate. Gwilliam suggests that the World Bank use values of 30 percent of household income per hour for adults and 15 percent for children. Boiteux also recommends 30 percent of total employment cost per hour or 42 percent of gross wages (50 percent of the VTTS on business). The value grows with distance at a rate that diminishes by distance bands. Austroads (the association of Australian and New Zealand road transport and traffic authorities) recognizes a range of 30 to 60 percent of average earnings and suggests a standard of 40 percent. Both Concas and Kolpakov and Zhang *et al.* recommend a rate of 50 percent of the national average wage for both commuting and other personal trips. Boiteux and Baumstark, Mackie *et al.* (2003), and Zhang *et al.* all recommend explicit use of income elasticities of personal VTTS over time: 0.7, 0.8, and 0.75, respectively.

Concas and Kolpakov assign a value of only 35 percent of the wage for reducing seated riding time on transit vehicles but value standing at 100 percent and waiting under unpleasant conditions at up to 175 percent of the wage. Boiteux recommends increasing the VTTS in urban transit by 50 percent in crowded conditions and by 100 percent for walking or waiting. Gwilliam approves a 50-percent increase for both walking and waiting. Both TAG 3.5.6 and Zhang *et al.* prescribe a VTTS twice the normal value for walking or bicycling and 2.5 times the normal value when waiting.

In sum, there is a broad consensus on the approach adopted and the relevant variables and categories, as well as a degree of similarity in the specific values recommended. Still, neither the findings of research nor the judgments of expert panels are sufficiently uniform to eliminate arbitrariness.

Values for DOT applications

All studies have acknowledged the necessity of simplifying the many occasions and determinants of VTTS into a tractable system corresponding to the information available on the sources and targets of valuation. The structure of values that we adopted in 1997 is broadly consistent with those employed in other countries, and it continues to be useful for evaluation of the costs and benefits of government investments or regulations. As stated in the introduction, it is not specific enough to predict travelers' demand for particular modes or routes. In the following tables, the proportions of VTTS to income for personal vs. business, local vs. intercity, and surface vs. air travel are unchanged from our initial guidance of 1997, except for the association of high-speed rail with air travel, rather than with conventional surface modes. Similarly, the ranges of high and low proportions for conceptual testing are identical. Although valuing local personal travel at 50 percent of hourly income and intercity travel at 70 percent places our estimate among the higher ones examined, it is not beyond the range estimated in several studies and commonly viewed as reasonable.

The principal changes that we adopted in 2011 were the sources of income data to which these proportions are applied. We use data exclusively from Federal government sources and median income values whenever possible, considering them more representative of the incomes of typical travelers than the means. We present separate VTTS estimates for different categories of transportation vehicle operators, which can be used together with passenger VTTS to derive the benefits to vehicle occupants or combined with estimates of freight time value from other sources to derive the benefits of time savings in freight shipment. We also calculate hourly values as annual values divided by 2,080, rather than 2,000, for the sake of consistency with the wage figures published by the Bureau of Labor Statistics (BLS).

<u>Categories of VTTS</u>

The ratios of VTTS to hourly incomes in Tables 1 and 2, expressed as percentages, must be multiplied by appropriate income estimates to convert them to dollar values. These estimates are shown in Table 3, and the resulting VTTS estimates appear in Table 4. The appropriate ranges of VTTS for comparison of alternative estimates are shown in Table 5.

The tables present additional rows of "all purposes" values; these are weighted averages of the values prescribed for personal and business travel with weights derived from the 2001 NHTS. Although person-miles of travel are used to weight the surface modes, person-trips are more appropriate for air travel because many government actions that change air travel time will be independent of trip length.
The distributions so derived are:

- Local travel by surface modes: 95.4% personal, 4.6% business;
- Intercity travel by surface modes: 78.6% personal, 21.4% business;

- Intercity travel by air: 59.6% personal, 40.4% business.

Business travel

For "on-the-clock" business travelers over all distances and by every surface mode, VTTS is assumed to be equal to a nationwide median gross compensation, defined as the sum of the median hourly wage and an estimate of hourly benefits.

Median wages are obtained from the BLS National Occupational Employment and Wage Estimates. The updated (May 2015) value for this figure is $17.40 per hour. Median benefits are not available from this source; instead, they are approximated by taking the ratio of average total compensation (including fringe benefits) to average wages in the Employer Costs for Employee Compensation series and applying it to median wages. Based on BLS data for June 2015, this ratio is 1.46. This extrapolation is performed for business travelers on all modes, using the share of benefits for all workers. This procedure generates a VTTS estimate of $25.40 for general business travel.

For vehicle operators (including truck drivers, bus drivers, transit rail operators, locomotive engineers, and airline pilots and engineers), the benefit share applied is derived from the series for transportation and material moving occupations; the ratio derived from BLS data for these occupations is 1.54 in June 2015. Truck drivers' wages are estimated for a weighted average of heavy and light truck drivers from the National Occupational Employment and Wage Estimates.

In the case of air and high-speed rail travel, high-cost modes used for fast trips over long distances, we conclude that use of a distinct wage is justified. The best source for incomes of air travelers is the BTS National Household Travel Survey of 2001 (no long-distance travel survey has been conducted since then), which permits estimation of distributions of household money income by trip purpose. The ratio of 2001 median household income of business air travelers (approximately $105,000) to the U.S. Census Bureau 2001 median household income ($42,228) yield a factor of 2.5 to be multiplied by the gross median compensation estimate for surface business travelers. Recent confidential survey data suggest that income levels for high-speed rail travelers are similar to those for air travelers, so we apply the same VTTS to high-speed rail travelers. Applying the 2.5 factor to the value for general business travel yields a VTTS for air and high-speed rail travel of $63.20.

Personal travel

For local personal travel, VTTS is estimated at 50 percent of hourly median household income. The nationwide median annual household income, $56,516 in 2015, is divided by 2,080 to yield an income of $27.20 per hour. The local VTTS is thus $13.60. We distinguish local from intercity personal travel, estimating a VTTS that rises with distance. For the latter purpose, we have adopted a ratio of VTTS to hourly income of 70 percent. The VTTS for intercity personal surface travel is then $19.00 per hour.

For personal travel by air or high-speed rail, the above estimate of VTTS for personal intercity surface travel is multiplied by 1.9, the ratio from the NHTS of the 2001 median household income of air travelers on personal business to the nationwide median household income in

2001. Updating median household income with 2015 information from the US Census Bureau yields a VTTS estimate of $36.10.

Special issues

In application, vehicle-hours are to be converted to person-hours by multiplying by average passenger occupancy of vehicles. Although riders may be a family with a joint VTTS or passengers in a car pool or transit vehicle with independent values, these circumstances can seldom be distinguished. Therefore, all individuals are assumed to have independent values.

Except for specific distinctions, we consider it inappropriate to use different income levels or sources for different categories of traveler. Neither the incomes associated with published research nor the stability of the relationship between income and VTTS are certain enough to imply that fine adjustments would yield more realistic estimates. The first distinction we recognize is that between personal and business (on-the-clock) travel; the second is that between surface travel by conventional modes and travel by air or high-speed rail. While VTTS for business travel is correlated with an estimate of passengers' employment compensation, for vehicle operators on several modes we have provided VTTS estimates based on median compensation data by employment category as reported by the Bureau of Labor Statistics. The scale of income levels developed here is applicable nationwide, and analysts should not attempt to substitute incomes for particular modes or locations. Nevertheless, estimates derived by reliable and focused research may be superior for predicting behavioral responses in specific cases.

Personal time spent walking or waiting outside of vehicles, as well as time spent standing in vehicles or bicycling, should be evaluated at 100 percent of hourly income, with a range of 80 to 120 percent to reflect uncertainty. As stated above, reducing the time during which uncomfortable conditions are experienced provides a benefit equal to the product of this VTTS and the reduction in time, while the benefit of improved travel conditions (such as additional seating) is equal to the product of the difference in VTTS (50 percent of hourly income) and the total time during which discomfort would have been experienced.

Uncertainty in the recommended values

The ratios in Table 1 represent the best single figures for defining VTTS as a fraction of hourly income. These figures, like all parameters of travel behavior, are subject to uncertainty. Table 2 summarizes a plausible range for each trip category, not necessarily symmetric about the point estimates in Table 1. The corresponding high and low dollar estimates are shown in Table 5. In addition to evaluations based on the most likely estimates, alternative calculations using these ranges should be presented to test the sensitivity of analyses to potential errors in estimation.

Updating the estimated values

The Office of the Assistant Secretary for Transportation Policy will publish annual updates of VTTS to reflect growth in hourly incomes, using the data sources cited above. No updating of the percentages developed in Tables 1 and 2 is required. We will monitor and interpret available research on travel behavior and issue new guidance as appropriate.

Table 1 (Revision 2 – 2016 Update)

Recommended Values of Travel Time Savings (per person-hour as a percentage of total earnings)		
Category	**Surface Modes*** **(except High-Speed Rail)**	**Air and High-Speed Rail Travel**
Local Travel -		
Personal	50%	--
Business	100%	--
Intercity Travel -		
Personal	70%	70%
Business	100%	100%

Vehicle operators- 100% on all modes

* Surface figures apply to all combinations of in-vehicle and other time. Walk access, waiting, and transfer time should be valued at 100% of hourly income when actions affect only those elements of travel time.

Table 2 (Revision 2 – 2016 Update)

Plausible Ranges for Values of Travel Time Savings (per person-hour as a percentage of total earnings)		
Category	**Surface Modes* (except High-Speed Rail)**	**Air and High-Speed Rail Travel**
Local Travel -		
Personal	35% - 60%	--
Business	80% - 120%	--
Intercity Travel-		
Personal	60% - 90%	60% - 90%
Business	80% - 120%	80% - 120%

Vehicle operators- 80%-120% on all modes

* Surface figures apply to all combinations of in-vehicle and other transit time. Walk access, waiting, and transfer time should be valued at 80%-120% of hourly income when actions affect only those elements of travel time.

Table 3 (Revision 2 – 2016 Update)

Recommended Hourly Earnings Rates for Determining Values of Travel Time Savings (2015 U.S. $ per person-hour)		
Category	**Surface Modes (except High-Speed Rail)**	**Air and High-Speed Rail Travel**
Local Travel -		
Personal	$27.20	
Business	$25.40	
Intercity Travel -		
Personal	$27.20	$36.10
Business	$25.40	$63.20

Truck Drivers	$27.20
Bus Drivers	$28.30
Transit Rail Operators	$46.10
Locomotive engineers	$41.60
Airline Pilots and Engineers	$86.70

Table 3 (Revision 2, continued)

Sources:

(1) Local and intercity personal travel by conventional surface modes: median income for all U.S. households in 2015 ($56,516), reported in U.S. Census Bureau, Table H-8. Median Household Income by State: 1984 to 2015, divided by 2,080 hours per year.
http://www.census.gov/hhes/www/income/data/historical/household/

(2) Local and intercity business travel by conventional surface modes: Bureau of Labor Statistics, May 2015 Occupational Employment and Wage Estimates, median wage for all occupations, http://www.bls.gov/oes/current/oes_nat.htm multiplied by the ratio of mean total compensation to mean wage from BLS Employer Costs for Employee Compensation, 2nd Quarter 2015,
http://www.bls.gov/ncs/ect/sp/ececqrtn.pdf

(3) Intercity personal travel by air or high-speed rail: median hourly household income from (1), multiplied by 1.9.
Intercity business travel by air or high-speed rail: median hourly household income from (1), multiplied by 2.5 and by the ratio of median national employee compensation to median household income.

(4) Truck Drivers: weighted average of May 2015 median hourly wages of heavy- and light-truck drivers ($17.71) from BLS National Occupational Employment and Wage Estimates; expanded to total compensation by the ratio of total compensation to wages for transportation and material moving occupations from the 2015 Employer Cost for Employee Compensation series.
http://stats.bls.gov/oes/current/oes_nat.htm#b53-0000

Other vehicle operators: May 2015 median hourly wages from BLS National Occupational Employment and Wage Estimates; expanded to total compensation by the ratio of total compensation to wages for transportation and material moving occupations from the 2015 Employer Cost for Employee Compensation series.

Table 4 (Revision 2 – 2016 Update)

Recommended Hourly Values of Travel Time Savings (2015 U.S. $ per person-hour)		
Category	**Surface Modes*** **(except High-Speed Rail)**	**Air and High-Speed Rail Travel**
Local Travel-		
Personal	$13.60	
Business	$25.40	
All Purposes **	$14.10	
Intercity Travel -		
Personal	$19.00	$36.10
Business	$25.40	$63.20
All Purposes **	$20.40	$47.10

Truck Drivers	$27.20
Bus Drivers	$28.30
Transit Rail Operators	$46.10
Locomotive engineers	$41.60
Airline Pilots and Engineers	$86.70

Table 4 (Revision 2, continued)

* Surface figures apply to all combinations of in-vehicle and other time. Walk access, waiting, transfer, and standing time should be valued at $27.20 per hour for personal travel when actions affect only those elements of travel time.

** Weighted averages, using distributions of travel by trip purpose on various modes. Distribution for local travel by surface modes: 95.4% personal, 4.6% business. Distribution for intercity travel by conventional surface modes: 78.6% personal, 21.4% business. Distribution for intercity travel by air or high-speed rail: 59.6% personal, 40.4% business. Surface figures derived using annual person-mile (PMT) data from the 2001 National Household Travel Survey. http://nhts.ornl.gov/. Air figures use person-trip data.

Table 5 (Revision 2 - corrected)

Plausible Ranges for Hourly Values of Travel Time Savings (2015 U.S. $ per person-hour)				
Category	**Surface Modes*** **(except High-Speed Rail)**		**Air and High-Speed Rail Travel**	
	Low	High	Low	High
Local Travel-				
Personal	$9.50	$16.30	--	--
Business	$20.30	$30.50	--	--
All Purposes **	$10.00	$17.00	--	--
Intercity Travel -				
Personal	$16.30	$24.50	$31.00	$46.50
Business	$20.30	$30.50	$50.60	$75.80
All Purposes **	$17.20	$25.80	$38.90	$58.30

	Low	High
Truck Drivers	$21.80	$32.70
Bus Drivers	$22.70	$34.00
Transit Rail Operators	$36.90	$55.30
Locomotive engineers	$33.30	$49.90
Airline Pilots and Engineers	$69.40	$104.10

Table 5 (Revision 2, continued)

* Surface figures apply to all combinations of in-vehicle and other transit time. Walk access, waiting, and transfer time in personal travel should be valued at $21.70 - $32.60 per hour when actions affect only those elements of travel time.

** Weighted averages, using distributions of travel by trip purpose on various modes. Distribution for local travel by surface modes: 95.4% personal, 4.6% business. Distribution for intercity travel by conventional surface modes: 78.6% personal, 21.4% business. Distribution for intercity travel by air or high-speed rail: 59.6% personal, 40.4% business. Surface figures derived using annual person-mile (PMT) data from the 2001 National Household Travel Survey. http://nhts.ornl.gov/. Air figures use person-trip data.

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BRIDGE REHABILITATION STUDY REPORT

Prepared For:

New Hampshire DOT

Interstate 89 over the Connecticut River

Bridge No. 044/104 (N.B.)
Bridge No. 044/103 (S.B.)

Lebanon, NH – Hartford, VT

Bridge Rehabilitation Study Report

Prepared By:

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53 Regional Drive • Concord, NH 03301

State Project No. 16148

July 2014

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EXECUTIVE SUMMARY

Purpose and Need Statement

The Purpose and Need statement is fundamental to the analysis of the project under the National Environmental Policy Act (NEPA) and other environmental regulations.

Purpose

The purpose of the proposed project is to improve highway safety and preserve the structural integrity of the existing bridges, while maintaining this vital, high-volume transportation link between New Hampshire and Vermont.

Need

The need for the project is as follows:

- ☼ The SB Bridge is currently on the State's Red List and is considered structurally deficient based on its deteriorated superstructure.
- ☼ The NB Bridge is currently on the State's Red List and is considered structurally deficient based on its deteriorated deck.
- ☼ The existing inside and outside shoulder widths on both bridges are non-standard at only 3'-0" wide.
- ☼ The on-ramp from northbound Interstate 91 (I-91) to southbound Interstate 89 (I-89) has an insufficient merge distance.
- ☼ There is less than the desirable 2,000 feet between the southbound on-ramp from I-91 and the off-ramp to Exit 20.
- ☼ There are crashes occurring on the southbound on-ramp from I-91 as a result of the above mentioned geometric deficiencies.

Project Description

State Project No. 16148 evaluates the rehabilitation of State Bridge Nos. 044/104 & 044/103. The bridges carry northbound and southbound traffic on I-89 over the Connecticut River and the New England Central Railroad between Lebanon, NH and Hartford, VT. The primary purpose of the project is to correct structural deficiencies and improve traffic safety between the I-91 interchange in Vermont and the Exit 20 interchange in New Hampshire. The project proposes to widen the existing bridges and rehabilitate the existing substructures.

Project Decisions

Key project decisions have been made by the NHDOT Front Office and VTrans Executive Staff based on the conducted evaluations and analyses. The following project decisions were approved by the NHDOT Front Office at the dates noted below and by VTrans Executive Staff at the October 7, 2013 meeting. The key project decisions include:

- Widen bridges to the inside. Two widening alternatives were reviewed; widen the bridges to the outside or widen to the inside gap between the bridges. The decision to widen to the inside was based on several factors including highway alignment, proximity of adjacent interchanges, environmental permitting, and traffic control/construction phasing.

- In-Fill the existing gap between the bridges. The final lane configurations on the bridge would not require a full in-fill of the gap between the existing bridges (see Appendix F). However, a full in-fill of the deck would provide significant benefits related to traffic control during construction and foundation alternatives. The decision to widen the deck to provide one full-width bridge deck was approved at the August 12, 2013 NHDOT Front Office meeting.
- Provide a southbound auxiliary lane. The traffic analysis conducted for the project recommended that an auxiliary lane be provided on southbound I-89 between the on-ramp from I-91 and the off-ramp at Exit 20. The analysis also indicated that an auxiliary lane should be considered for northbound, but the need was not as compelling. The decision to provide a six-lane bridge, four through lanes and two auxiliary lanes, was approved at the August 12, 2013 NHDOT Front Office meeting.
- Replace existing superstructure structural steel. The original scope for the bridge widening included rehabilitating and repainting the existing structural steel and providing new steel girders for the in-fill widening. A load rating analysis and fatigue evaluation of the existing structural steel was completed. The load rating used current AASHTO HL-93 live loading, but was based on the original girder section properties without consideration of structural steel deterioration. The fatigue evaluation was performed with the same criteria. The load rating indicated the design condition had sufficient capacity at most locations for current loading, and the remaining locations could be modified to comply. The fatigue evaluation indentified several details with a finite life remaining, which was less than the proposed service life. The decision to replace the existing steel was based on concerns with the condition of the existing steel, the numerous details that would need to be rehabilitated to conform to fatigue requirements, and the significant cost associated with the rehabilitation and repainting the existing structural steel. The decision to replace the existing superstructure steel was approved at the August 12, 2013 NHDOT Front Office meeting.
- Construct full-height in-fill piers. Two pier options were evaluated for support of the proposed in-fill superstructure widening; an in-fill pier and a connected existing pier option (see Appendix F). The in-fill pier option would construct a new pier between the existing piers matching the basic geometry of the adjacent existing piers. This option requires a deep foundation (piles) and associated construction access and environmental impacts. The connected existing pier option would connect the existing pier caps to support the new in-filled superstructure. This option would use top-down construction and eliminate the environmental impacts associated with work in the river. Both options were evaluated for capacity of existing piers with proposed loading conditions. Evaluation of the connected existing pier option determined that the piles and upper portion of the pier stem would be significantly overstressed due to the induced frame action inherent with this option. The effort associated with retrofitting the piers to accommodate the loads from the connected pier option negates any benefit from the option. The decision to progress the in-fill pier option was approved at the March 31, 2014 NHDOT Front Office Meeting.

EXISTING CONDITIONS

Roadway

Figure RD1 is an aerial photo of the project area. I-89 connects smaller cities and rural areas within New Hampshire and Vermont, and maintains two lanes of traffic in each direction throughout the route. The Connecticut River bridges are located along I-89 between two interchanges approximately one mile apart. On the west side in Hartford, Vermont is the I-91 system interchange. On the east side is Lebanon, a major NH population center, where the final exit in NH (Exit 20), provides access to West Lebanon's large retail district along NH Route 12A. I-89 is one of Vermont's most important roads, as it is the only Interstate highway to directly serve both Vermont's capital city (Montpelier) and largest city (Burlington).

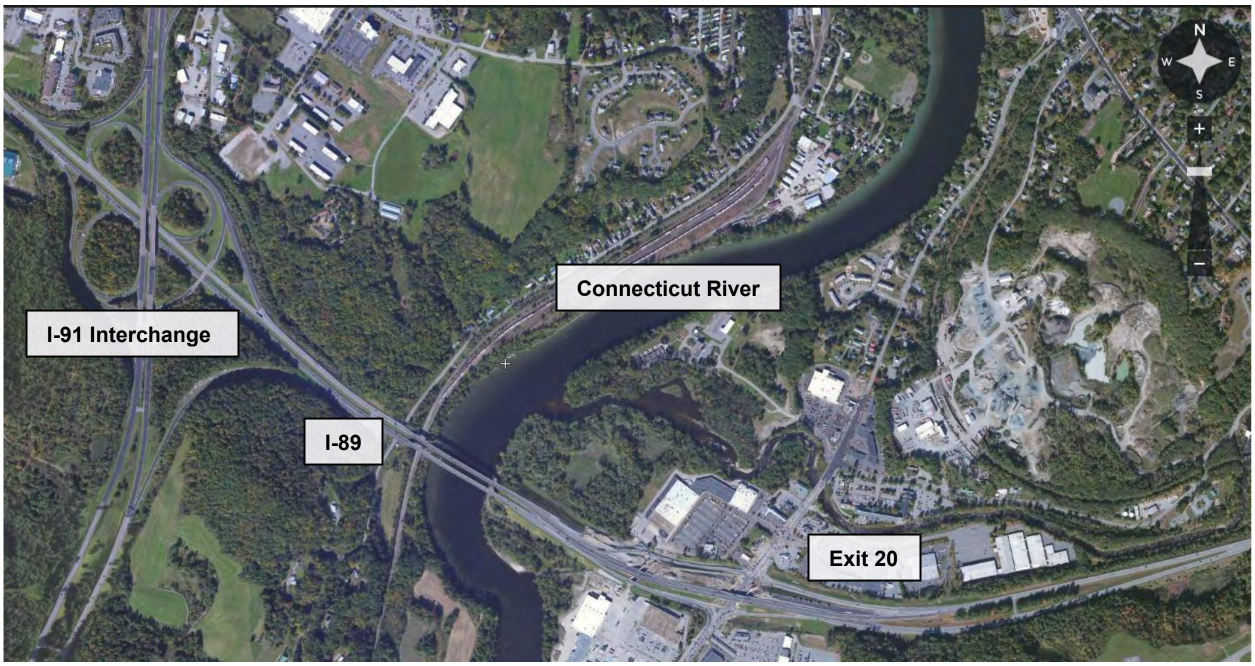


Figure RD1: Project Study Area

Within the project limits I-89 is a four-lane (two northbound and two southbound) divided urban principal arterial highway with full access control. The normal posted speed limit on the bridge is 65 miles per hour. The most recent Average Annual Daily Traffic (AADT) from 2013 indicates approximately 38,048 vehicles per day (vpd) use these bridges between Vermont and New Hampshire.

The lanes on both bridges are all 12-feet wide, however, the inside and outside shoulders are all 3-feet wide. The shoulders on all approaches are wider.

Northwest of the project is the I-89/I-91 Interchange, which is a partial cloverleaf with three loop ramps. Southeast of the bridges is Exit 20, which is a recently reconstructed diamond interchange.

Waterway & Scour

The Connecticut River is a rural, sinuous waterway that flows in an overall north-south direction from its headwaters at the Fourth Connecticut Lake in Pittsburg, NH, and defines the border between New Hampshire and Vermont. The Connecticut River ultimately discharges into Long Island Sound in southern Connecticut. In the immediate bridge reach, the channel bed is comprised primarily of sand and gravel. The valley setting generally provides low to moderate relief with narrow flood plains. The river is incised with alluvial channel boundaries, and trees generally cover 50 to 90 percent of the bank.

The river generally does not anabranch, but is locally braided within immediate reaches, in particular downstream at Johnston Island. The Mascoma River outlets into the Connecticut River immediately upstream (~700 feet) of the bridge. The White River outlets into the Connecticut River approximately 7,000 feet upstream of the bridge.

The NHDOT Bridge Inspection Reports indicate that light erosion exists along the riverbanks in the vicinity of the SB bridge, and heavy riverbank erosion exists upstream of the NB bridge. There is lateral movement (drift) of the river in addition to slumping of the stone rip rap slope in front of the abutments on the NH embankment.

The NHDOT underwater inspection reports document exposed abutment and pier footings, as well as localized scour holes at the piers.

The NHDOT commissioned a waterway and scour assessment of the bridges. In a June 2010 report, the waterway ratings of both bridges were determined, and both bridges were classified as scour critical, as highlighted in Tables WS-1 and WS-2.

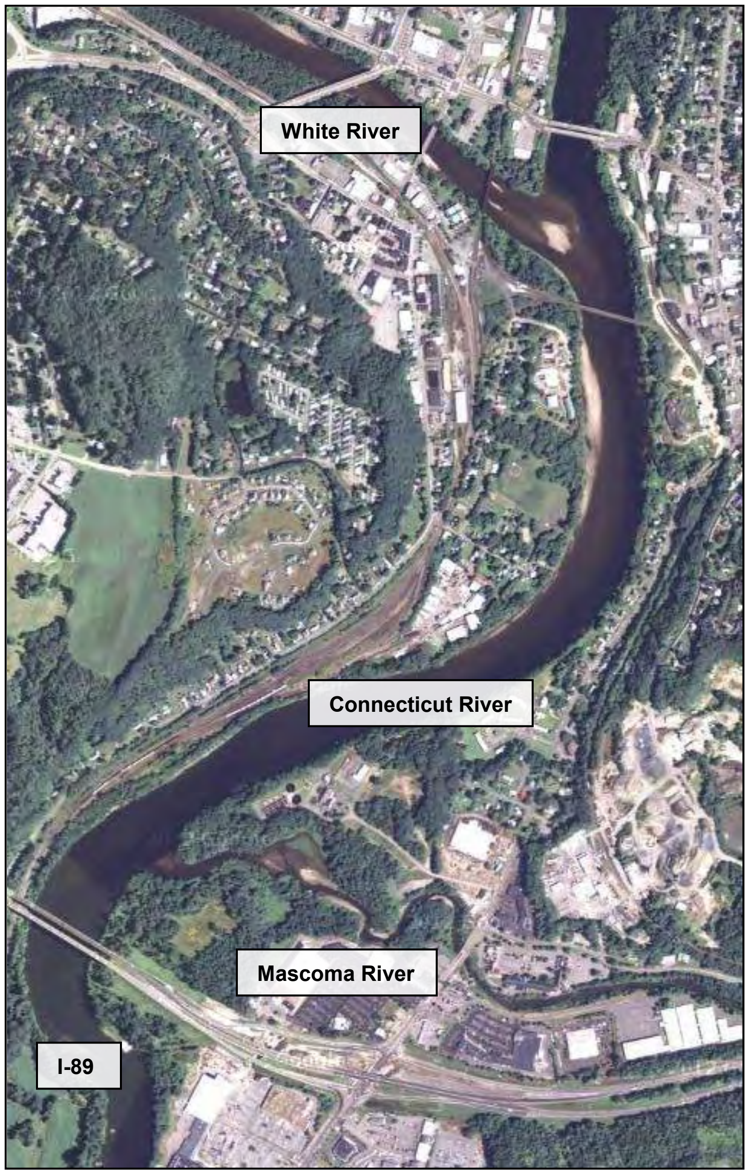


Figure WS-1: Aerial of Connecticut River in project area

Table WS-1: NBIS Waterway Ratings (044/104 I89 NB)			
Item	**Description**	**Rating**	**Description**
61	Channel & Channel Protection	7	Bank protection is in need of minor repairs. River control devices and embankment protection have a little minor damage. Banks and/or channel have minor amounts of drift.
71	Waterway Adequacy	9	Superior to present desirable criteria
113	Scour Critical Bridges	3	Bridge is scour critical; bridge foundations determined to be unstable for calculated scour conditions.
			Depth of Potential Scour (100-year) = 20 feet at Pier 2 (Undermining of pile cap would occur)

Table WS-2: NBIS Waterway Ratings (044/103 I89 SB)			
Item	**Description**	**Rating**	**Description**
61	Channel & Channel Protection	7	Bank protection is in need of minor repairs. River control devices and embankment protection have a little minor damage. Banks and/or channel have minor amounts of drift.
71	Waterway Adequacy	9	Superior to present desirable criteria
113	Scour Critical Bridges	3	Bridge is scour critical; bridge foundations determined to be unstable for calculated scour conditions.
			Depth of Potential Scour (100-year) = 20 feet at Pier 3 (Undermining of pile cap would occur)

Hartford and West Lebanon have a history of severe seasonal ice-jam related damage and flooding along the Connecticut River. The *Cold Regions Research Engineering Laboratory* (CRREL) Ice Jam Database and other sources record ice-related events in the project area. Data has been collected over the last 100-years in the area of the Connecticut River from its confluence with the White River at White River Junction downstream through the Johnston Island area. A recent March 2011 report recorded:

> *"An ice jam has caused the Connecticut River at West Lebanon to jump over 9 feet in less than two hours and is now approaching flood stage. The river will likely top flood stage overnight and continue to fluctuate through the night due to the unpredictable nature of ice jams."*

Bridge

General

The I-89 bridges span the Connecticut River and New England Central Railroad (NECRR) between the city of Lebanon, New Hampshire and the town of Hartford, Vermont. The NB and SB barrels each consist of two travel lanes, with direction of travel carried by separate, but identical, bridge structures. Bridge No. 044/103 carries I-89 SB traffic, while Bridge No. 044/104 carries I-89 NB traffic.

Figure BR1: Westerly Elevation View of Bridges

The six-span, 840-foot sister bridges were constructed in 1966 and consist of non-composite, haunched steel plate girders founded on cantilever abutments and hammerhead piers. The bridges are inspected and maintained by the NHDOT through a mutual agreement with the Vermont Agency of Transportation (VTrans).

The NHDOT bridge records indicate that no major rehabilitation or reconstruction of the bridge has been performed. The concrete deck was rehabilitated in 1984, with work including wearing surface replacement, deck concrete repairs, resetting the granite bridge curb, and bridge rail rehabilitation. More recently, the NHDOT Bureau of Bridge Maintenance has installed supplemental steel plates and members to repair section loss and web cracks at isolated locations.

Figure BR2: FAST Anti-Icing System Nozzle Installed in SB Bridge Pavement

In September 2006, a Fixed Automated Spray Technology (FAST) anti-icing system was installed along the centerline of the SB bridge. The system is controlled by a weather information system that uses deck sensors to detect environmental conditions and automatically apply liquid de-icing chemicals to the bridge before the deck is able to freeze. The anti-icing system was recently removed according to the 2013 Bridge Inspection Report.

Superstructure – General

The bridges are comprised of five non-composite welded steel (A36) plate girders supporting a 7-inch reinforced concrete deck protected by membrane with a bituminous concrete wearing surface. The six-span configuration consists of two 120'-0" end spans and four 150'-0" interior spans on a three percent tangent profile grade aligned on a ten degree skew. The typical section for each bridge (presented in Figure BR3) measures 35'-10" wide from the outside edge of deck and consists of symmetrically placed 3'-0" shoulders, two 12'-0" travel lanes, and reinforced concrete brush curbs measuring 2'-11" wide each. Per the original design plans, the constant clear distance between the adjacent NB and SB decks is 38'-2".

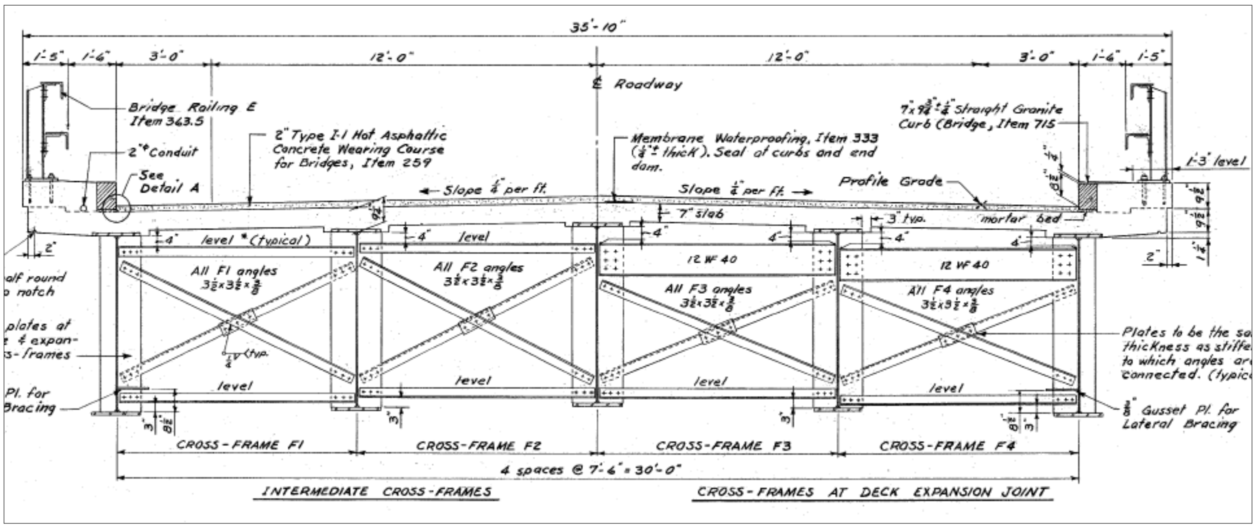


Figure BR3: Existing Bridge Section

The girder web depth is haunched at each pier (Figure BR4). Vertical web stiffeners are provided along the entire bridge length, and longitudinal web stiffeners are provided at approximately 1/5 of the clear web depth from the bottom flange within the tapered pier sections. Reference Appendix A, Existing Bridge Plans, for additional information.

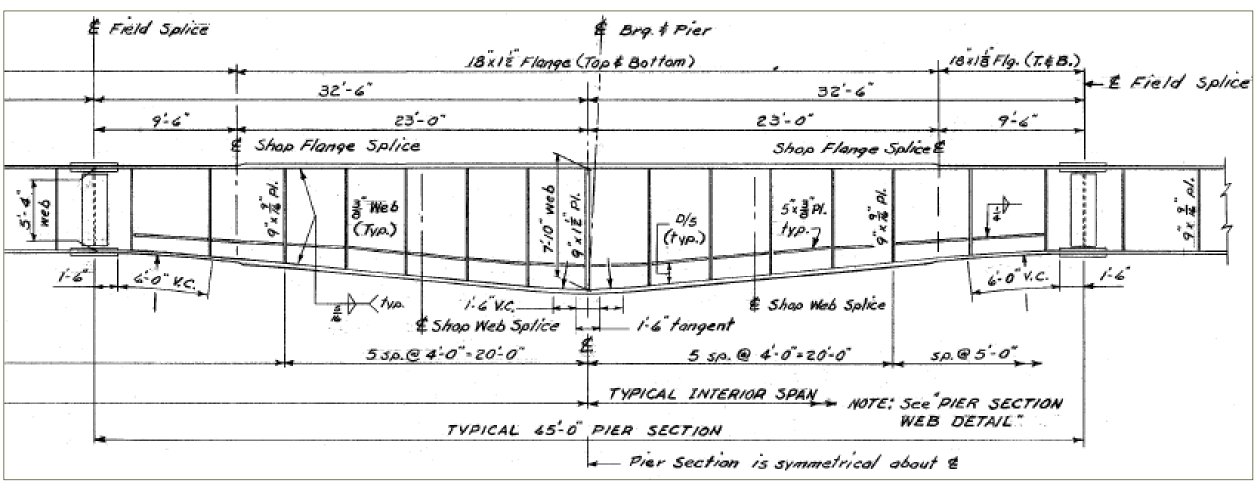


Figure BR4: Typical Girder Detailing at Intermediate Piers

Figure BR5: Typical Corrosion at Deck Expansion Joint

The concrete bridge decks exhibit signs of distress, including cracking, delamination, and efflorescence at various locations. The lead-based girder paint system is failing as evidenced by cracking, flaking, and peeling, and light rust has formed in many locations on the steel members. Section loss of the girders and bracing members has been documented, most notably near the bridge deck expansion joints where the section loss is moderate to severe (See Figure BR5).

Figure BR6: Knife-Edge. Heavy Section Loss at Stiffener & Gusset Plate

Severe pitting has occurred along the bottom flanges and at the base of the web, the girder webs exhibit holes from section loss and are nearly perforated in multiple locations, and severe section loss on transverse stiffeners has resulted in a knife edge condition (Figure BR6). Secondary lateral bracing members and their gusset plates exhibit severe section loss beneath the deck expansion joints.

Recent repairs by the NHDOT Bureau of Bridge Maintenance (BBM) have included sandblasting and recoating of corroded steel, installation of bolted plates at a large web crack, and welded plate repairs. These major deficiencies are primarily located near the leaking deck joints in Spans 3 and 4. Bridge Inspection reports also note formwork from deck repairs being left in place on the deck underside.

The condition rating of the deck and superstructure is Fair to Poor for both the northbound and southbound structures. The Northbound October 2013 and the Southbound January 2014 bridge rating reports are provided in Appendix B. Specific details regarding the condition of each superstructure are taken from the NHDOT bridge inspection reports and are outlined below:

Superstructure: Bridge No. 044/103 (I-89 SB)

- The deck exhibits moderate concrete delamination at multiple underside locations, with light leaking at the relief joints in Spans 3 and 4 where they pass through the brush curbs. Span 5 exhibits a cracked and depressed area of pavement near the roadway centerline.

Figure BR7: Bottom Flange Pitting

- Concrete brush curbs contain cracks and moderate spalls, and the granite curb stones have become dislodged.

- The girders exhibit paint coating failure and light rust throughout. Flanges of exterior girders have moderate section loss and heavy pitting near the deck relief joints. Lateral bracing members, gusset plates, and the girder web show signs of severe section loss in these areas.

- Isolated web perforations have been noted in the exterior girders, concentrated primarily near the welded gusset plate attachments for lateral bracing. There is an approximate 1 inch hole in the web of Exterior Girder #1 in Span 3, and another location exists in Span 5 where the web is nearly perforated. Section loss of up to ¼" has been measured along the middle of the exterior girder flanges near the web in this area as well.

Figure BR8: Hole and Crack in Web at Transverse Stiffener

- In December of 2011, the NHDOT repaired a large crack in the westerly exterior girder in Span 4. The crack had progressed approximately 15 inches along the toe of the weld between a vertical stiffener and the web and appeared to have initiated at a nearby hole in the girder web caused by corrosion at the leaking joint (Figure BR8). The repair consisted of removing the stiffener, drilling holes to arrest the crack, and bolting steel splice plates to the web and bottom flange of the girder. The completed repair is presented in Figure BR9.

Figure BR9: Web Crack Bolted Plate Repair by NHDOT BBM (outside face)

- Moderate corrosion and some light damage have been noted on the bridge rail.

- Roadway drainage has reduced effectiveness, because multiple deck scuppers are clogged with debris.

Figure BR10: Web Crack Bolted Plate Repair by NHDOT BBM (inside face)

Superstructure: Bridge No. 044/104 (I-89 NB)

- The concrete deck exhibits cracks, isolated light efflorescence, and water staining from leakage through the deck. Leaking is evident at the deck relief joints. Moderate to heavy delamination of the concrete has been observed throughout. Several previously patched areas in the deck are deteriorating as they lose integrity.

- Minor to light rust on the girders is evident throughout. Paint system failure characterized by cracking and flaking.

Figure BR11: Heavy Section Loss Under Deck Relief Joint

- Heavy corrosion has been observed under the deck relief joints, and on the exterior girders in the north span (Figure BR11).

- The lateral wind bracing and its gusset plate attachment located below the deck relief joint in span 3 exhibit heavy section loss from joint leakage.

- NHDOT BBM repaired severe pitting and section loss on the web of interior girder #4 in July of 2012. The repair consisted of a steel angle welded on at the intersection of a transverse stiffener and the web. Refer to Figures BR12 and BR13.

Figure BR12: Heavy Pitting on Web at Transverse Stiffener

Figure BR13: Welded Angle Web Repair by NHDOT BBM

- Loose bolts were noted at the end connections of some lateral bracing members.

- The bridge rail exhibits moderate corrosion with some observed section loss.

- The asphalt wearing surface shows signs of rutting, cracks, and delaminating.

- Granite bridge curb stones are becoming dislodged due to deterioration along the concrete brush curb.

- Roadway drainage is marginalized by plugged deck scuppers along curb lines.

Substructures

The ends of each bridge are supported on cast-in-place cantilever abutments with U-back butterfly wingwalls. The abutments and wingwalls are supported on three (3) rows of steel 12BP53 end-bearing piles driven to refusal, with the front two rows of piles battered and back row vertical. Buried approach slabs are utilized, which are twenty (20) feet long.

The piers are cast-in-place concrete hammerhead piers with tapered solid shafts. The footing for Piers I, II, and III are supported on six rows of 14BP73 steel end-bearing piles driven to refusal. Piles battered at a 4:12 slope are used to resist lateral forces in both orthogonal directions. Pier IV, located near the Vermont riverbank, has a spread footing foundation bearing on a concrete seal which bears directly on bedrock. Pier V, situated on top of the Vermont riverbank adjacent to the NECRR, is founded on four rows of 12BP53 steel end-bearing piles driven to refusal. Piles around the perimeter of the group are battered on a 2:12 vertical slope to resist lateral loads in both orthogonal directions. Piers I, II, III, and IV have similar heights ranging between approximately 60 ft and 80 ft tall measured from the top of footing, while Pier V extends approximately 40 ft from the top of its footing. Reference Appendix A, Existing Bridge Plans, for additional information.

Fixed bearings are provided at Pier III which lies at mid-length of the bridge. All other support locations have steel rocker expansion bearings. Finger joints are provided at the abutments to accommodate thermal displacements.

Figure BR14: North abutment on SB Bridge

The substructures generally exhibit relatively minor deterioration according to the October 2013 and January 2014 NHDOT bridge inspection reports for the Northbound and Southbound bridges respectively. Partial-depth concrete repairs on the abutments and wingwalls from the 1984 rehabilitation exhibit cracking. Minor to moderate concrete spalls along the abutment backwalls were also noted, and moderate spalling of the north abutment footing for the NB bridge has been observed. Steel fingers are missing from the abutment expansion joints, presumably from snow plowing operations, weld repairs are present, and the steel plates exhibit corrosion. Heavy debris buildup is present on the abutment seats. The girder bearings are heavily corroded, with heavy section loss noted on the anchor rods in some locations. Pack rust has lifted the interior bearings at the north abutment of the NB superstructure.

The NHDOT inspection reports found the piers to be in overall good condition, with some fine cracking and minor spalling. For the SB bridge, fine cracks have been observed in the cap of Pier II. For the NB bridge, a light crack has been noted in the downstream (south) end of the cap for Pier V and minor spalls were detected on top of the cap of Pier IV.

NATURAL & CULTURAL RESOURCES

Environmental resources were identified using GIS and other mapping resources and through a brief field visit. A summary of existing resources and permits that may be involved with the proposed project follows. The referenced figures can be found in Appendix C.

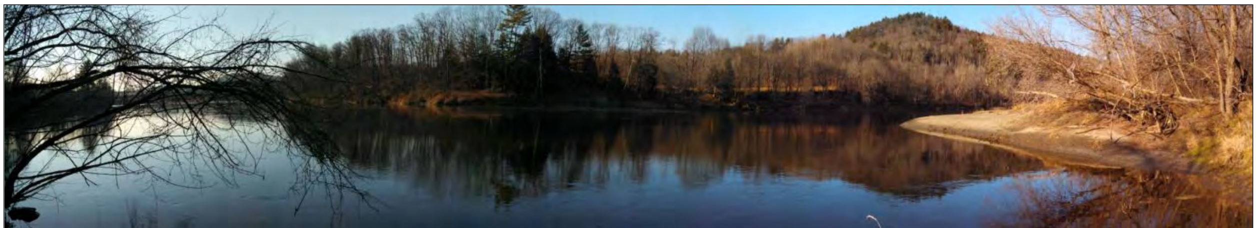


Figure ENV1: New Hampshire side - view north, south of bridge

Landscape Setting

Bridges 044/104 and 044/103 carry I-89 across the Connecticut River, which forms the border between New Hampshire and Vermont. The river has a width of approximately 550 feet at the bridge location, and is a 7th order river with a watershed (from the project area) measuring 4,286 square miles, extending north into Canada.

On the Vermont side, under the bridge, the riverbank is armored with stone from the train track down to a low floodplain that parallels the river. Vegetation on either side of the bridge includes hemlock, poplar, white birch, elm, and box elder. The low floodplain supports green ash, elm, and honeysuckle.

The land on the New Hampshire side of the river is generally lower and supports tree species including white pine, sycamore, and elm along with invasive species such as knotweed, honeysuckle, and barberry. The riverbanks on both sides show evidence of past disturbance.

Water Resources

Wetlands

Wetlands have not yet been delineated for this project. Jurisdictional limits for wetlands and waterways on the New Hampshire side will extend to the top of the riverbank, in keeping with New Hampshire wetland regulations, and on the Vermont side to the Ordinary High Water Line. The Cowardin classification for the Connecticut River at the project location is R2UBH, or riverine, lower perennial, with an unconsolidated bottom, permanently flooded. The river lies mostly in New Hampshire, since the state line was set at the low water line on the Vermont side as it existed in the 1930’s (decided by the U.S. Supreme Court in 1934). Army Corps of Engineers jurisdiction extends to the ordinary high water line on both sides. Jurisdictional limits for the Shoreland Water Quality Protection Act extend 250 feet from the ordinary high water line on the New Hampshire side. The project will likely involve a New Hampshire Standard Dredge and

Fill Wetland Permit from the NH Department of Environmental Services for work in the river and/or on the river bank, and a Shoreland Water Quality Protection Act permit for work in the protected shoreland area on the New Hampshire side. The river is also a Designated River under NH RSA 482, so wetland and shoreland permit applications would be reviewed by the Connecticut Joint River Commission. The project may also require coordination with the Vermont Agency of Natural Resources River Management Engineers to satisfy Title 19 of Vermont Statutes.

Floodplains

The floodplain of the Connecticut River extends east into New Hampshire and west into Vermont on either side of the river. There is also a regulatory floodway spanning the river. Filling within the floodplain could necessitate the creation of equivalent flood storage capacity, under Executive Order 11988. (See Appendix C-1, Floodplains.)

Navigable Waters

The Connecticut River is regulated as a Navigable Water under both the US Coast Guard Bridge Permit program and the Army Corps of Engineers Section 10 and 404 permit programs. The proposed bridge rehabilitation will require coordination with the US Coast Guard or a US Coast Guard Bridge Permit. Under the Army Corps of Engineers' Programmatic General Permit, any navigable waterway or wetland impacts in excess of one acre would require an Individual Permit from the Army Corps of Engineers. (In Vermont, the Army Corps' threshold for requiring an individual permit is 5,000 square feet of impact in navigable waters, However, the state line is on the Vermont side of the river, and all wetland impacts would probably be in New Hampshire, other than impacts between the low water line and the ordinary high water line, if any.) It is anticipated that the proposed bridge rehabilitation will involve well under an acre of work in the water, so it will probably be permitted under New Hampshire's Programmatic General Permit with the Army Corps.

Impaired Waters

The NHDES 2010 List of All Impaired Waters (most recent available) identifies this segment of the Connecticut River as being impaired for primary contact recreation by combined sewer overflows. Vermont's 2012 List of Priority Surface Waters identifies this portion of the river as impaired for aquatic life support by flow alteration caused by fluctuating flows associated with hydropower production from the Wilder Dam upstream. The proposed project is not anticipated to have any effect on the pollutants or conditions responsible for these impairments.

Figure ENV2: Beaver work, New Hampshire side, north of bridge.

<u>Wildlife Habitat</u>

Wildlife habitat in New Hampshire has been mapped in the 2010 New Hampshire Wildlife Action Plan (Appendix C-2). Habitat in the immediate vicinity of the bridge is mapped as "Tier 2, top-ranked in region." Although the area surrounding Route 12 in Lebanon is developed and unlikely to provide valuable wildlife habitat, the area along the river is well vegetated and likely provides habitat for a variety of mammals, including deer, coyote, beaver, otter, raccoons, and other mammals (See Figure ENV2).

The Vermont side of the river is dominated by farmland and mixed hardwood and conifer (hemlock and pine) forest. Farmland in the vicinity likely provides habitat for a variety of mammals, songbirds, and birds of prey. Forested land likely provides habitat typical of the area for large and small mammals, songbirds, and birds of prey. Vermont roadkill records (which are not comprehensive) include three records of moose kills on Route I-91 and I-89 west of the project location. The New Hampshire Fish and Game Fisheries Department was contacted to request information about fisheries in the Connecticut River. NHF&G's response, attached to this report, indicated that there were a variety of warm water fish inhabiting the river (Appendix C-3). No specific recommendations or restrictions regarding construction were provided. Vermont's Agency of Natural Resources considers all rivers and streams to be cold water fish habitat. The Connecticut River is designated as Essential Fish Habitat for Atlantic Salmon, so work in the water will require an Essential Fish Habitat Assessment and coordination with the National Marine Fisheries Service, as required under the Magnuson-Stevens Fishery Conservation and Management Act.

Recreational fishing and boating is common in this area of the Connecticut River. Consideration should be given during construction planning to accommodate these activities.

Rare Species

Project review requests were submitted to both the State of Vermont and the State of New Hampshire Natural Heritage Programs in April 2013. Both programs will need to be contacted for updated rare species records during the next phase of the project. New Hampshire Natural Heritage responded that there were records of the following species in the vicinity of the project:

Invertebrate Species

- Cobblestone Tiger Beetle (*Cicindela marginipennis*) (State endangered)
- Dwarf Wedge Mussel (*Alasmidonta heterodon*) (State and federally endangered)
- Tule Bluet (*Enallagma carunculatum*) (State tracked)

Correspondence with the US Fish and Wildlife Service indicated that the records for the dwarf wedge mussel were over a mile away from the project, and indicated that they had no further concerns about this species (see e-mail correspondence in Appendix C-7). No further guidance was provided on the cobblestone tiger beetle or tule bluet.

Plant Species

- Mudflat spikesedge (*Eleocharis intermedia*) (State endangered)

New Hampshire Natural Heritage Bureau indicated that appropriate habitat in the vicinity of the project should by surveyed for *Eleocharis intermedia* prior to construction.

Vertebrate species

- Bald Eagle (*Haliaeetus leucocephalus*) (State threatened)

New Hampshire Fish and Game responded that the eagle population is increasing in the vicinity of the bridge, and requested that there be additional coordination as the construction date approaches.

Vermont Natural Heritage responded that there were two species (Siberian chives [*Allium schoenoprasum]* and musk flower [*Mimulus moschatus]*) that occurred on a rock outcrop approximately 500 feet downstream of the project, but said that unless there was a direct impact to the outcrop they would not be affected (see e-mail correspondence in Appendix C-6).

Historical Resources

The bridge was constructed in 1966. By agreement with the Advisory Council of Historic Preservation, federal actions on elements of the interstate highway system are exempt from the requirements of Section 106 review unless specifically excluded from the exemption. The Lebanon-Hartford bridge is not excluded from the exemption. Therefore, although the bridge itself is almost fifty years old, it will not be subject to Section 106 or 4(f) review.

Archaeological Resources

The area surrounding the bridge was the subject of a Phase 1A Preliminary Archaeological study in 1994 ("Lebanon IM-89-1(177)60 / 11700 Exit 20") that found no areas of archaeological sensitivity within the New Hampshire study area. One area of sensitivity in New Hampshire, south of the Exit 20 interchange on I-89, is outside of this project's Area of Potential Effect. The project was discussed with NHDOT's cultural resource staff and it was agreed that no further archaeological survey would be needed in New Hampshire for the project (see response from New Hampshire Division of Historical Resources in Appendix C-9). An archaeological subconsultant was retained to perform a Phase 1A study for the Vermont portion of the Area of Potential Effect. Results of the study indicate that there are three areas of sensitivity within the Area of Potential Effect. Additional coordination with the Vermont State Historic Preservation Officer will occur as the project proceeds to determine if these areas will be affected by the project.

Hazardous Materials

The Vermont and New Hampshire GIS databases were reviewed for records of hazardous materials or hazardous waste remediation in the immediate vicinity of the bridge. There were several remediation sites on Route 12 in Lebanon, including leaking underground storage tanks, but the files are closed and the sites are not within the project area. There are no records of hazardous materials on the Vermont side.

TRAFFIC EVALUATION

Traffic Analysis Summary

A Traffic Assessment Memorandum was prepared for the project by Resource Systems Group (RSG) which is included as Appendix D. The assessment included a design standard review, traffic analysis, safety analysis and conclusions.

The Design Standard Review concluded that there are several geometric deficiencies associated with the existing bridge, these are:

- Non Standard shoulder widths on I-89.
- Non Standard ramp merge on the on ramp from northbound I-91 to southbound I-89.
- No auxiliary lane on southbound I-89 between I-91 and Exit 20.

The Traffic Analysis was performed to determine the future capacity needs on the bridge. Traffic volumes projected for the future indicate that the existing four lanes are sufficient for I-89. However, the close proximity of Exit 20 in New Hampshire and the I-91 Interchange in Vermont required further analysis to determine if auxiliary lanes are warranted. An Origin-Destination (O-D) study was conducted using blue tooth sensors to determine the volume of traffic that uses the bridge to travel between I-91 and Exit 20. See below for the recommendation.

The safety analysis was conducted to determine if any of the existing deficiencies contribute to the crashes in the area. One area in particular, the on-ramp from northbound I-91 to southbound I-89, indicates that the poor geometry likely contributes to the high number of multiple vehicle crashes.

Recommended Configuration

The Traffic Assessment recommended that an auxiliary lane be provided on the southbound bridge between I-91 and Exit 20 to address geometric, safety, and operational deficiencies. The case for a northbound auxiliary lane was not as compelling; however, it would have operational benefits. The recently completed Exit 20 project provided standard ramp geometry and the distance between the ramps is sufficient. However, there is a noticeable decrease in vehicle speeds for northbound traffic due to the steep grade (5%) north of the bridge.

The final configuration for northbound I-89 will be determined during final design. Both two and three lane configurations of I-89 will be developed so that the costs and impacts of each can be determined. Also, the public will be engaged to determine their configuration preference.

EXISTING BRIDGE EVALUATION

Load Rating Analysis

Introduction

A load rating analysis of the existing interior and exterior plate girders was performed in accordance with the provisions of the *AASHTO Manual for Bridge Evaluation, 2nd Edition* (AASHTO MBE) including the 2010 interim revisions, and the *AASHTO LRFD Bridge Design Specifications, 6th Edition* (AASHTO LRFD), using the HL-93 notional live load model. The load rating utilized “As-Designed” girder section properties (no section loss) and details obtained from the original design plans. Deterioration which has developed on the structure since the 1966 construction, as well as the repairs undertaken by the NHDOT Bureau of Bridge Maintenance (BBM), was not considered.

The intent of the rating was to establish a baseline load rating for the structure according to current design standards. NHDOT and AASHTO legal load configurations were not evaluated at this time. The “sister bridges” are identical and were originally designed for the AASHO H20-S16 live load, including the alternate military loading, in accordance with the *AASHO 1961 Specifications for the Design of Highway Bridges*.

The existing bridges consist of five (5) continuous non-composite welded plate girders with a concrete deck. The girders are stiffened both transversely and longitudinally and have haunched webs near the intermediate piers. Detailed girder elevation views from the original construction drawings are shown below in Figure LR1.

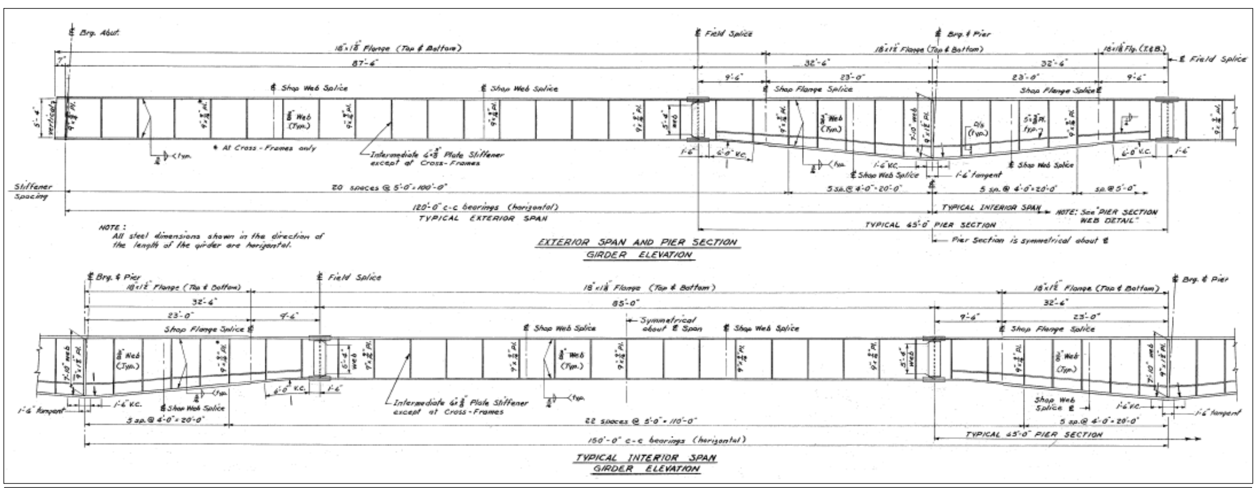


Figure LR1 – Girder Elevation Views from Original Design Plans

Load Rating Procedure and Methodology

The non-composite interior and exterior girders were modeled using the Merlin-DASH software program. Dead loads were manually computed and input for each girder. Live load distribution factors were computed by hand using the approximate formulas in AASHTO LRFD Article 4.6.2.2, and compared to those computed by Merlin Dash. Since the distribution factors calculated by hand and calculated by Merlin Dash were not in compliance, the hand calculated values were manually input into Merlin Dash.

Based on the values provided by Merlin Dash, the program is not accounting for the portion of the equations in AASHTO LRFD table 4.6.2.2.2b-1 related to the longitudinal stiffness parameter, K_g.

Per AASHTO MBE (Article 6A.6.9.3), the load rating considered the top flange of the girders to be continuously braced by the concrete deck in areas of positive flexure, despite a lack of shear connectors joining the girders and deck. The top flange lateral support mechanism for this bridge is twofold: friction between the deck and the top flange (provided there are no visible gaps), and the original plans show the top flange embedded in the deck haunch which provides additional lateral support. Refer to Figure LR2.

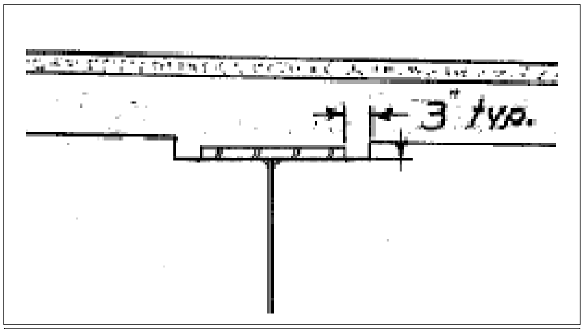


Figure LR2 –: Deck Haunch Detail

Results

The controlling flexure and shear LRFR Rating Factors were developed for the abutments, piers, and within each span, and are tabulated below.

Table LR-1: Exterior Girder Controlling LRFR Rating Factors (HL-93 Loading)

	Abutments	**Spans 1 & 6**	**Piers 1 & 5**	**Spans 2 & 5**	**Piers 2 & 4**	**Spans 3 & 4**	**Pier 3**
Flexure							
Inventory	N/A	**0.97**	1.05	1.08	1.06	1.04	1.03
Operating	N/A	1.26	1.36	1.4	1.37	1.35	1.34
Shear							
Inventory	**1.06**	2.6	2.99	2.5	2.97	2.48	2.96
Operating	1.38	3.37	3.87	3.25	3.85	3.22	3.84

Table LR-2: Interior Girder Controlling LRFR Rating Factors (HL-93 Loading)

	Abutments	**Spans 1 & 6**	**Piers 1 & 5**	**Spans 2 & 5**	**Piers 2 & 4**	**Spans 3 & 4**	**Pier 3**
Flexure							
Inventory	N/A	**1.09**	1.14	1.27	1.18	1.22	1.15
Operating	N/A	1.42	1.48	1.64	1.52	1.58	1.49
Shear							
Inventory	**0.88**	2.11	2.42	2.03	2.41	2.01	2.4
Operating	1.14	2.73	3.14	2.63	3.12	2.6	3.11

Summary of Findings

- ☼ The governing Inventory Rating Factor of 0.97 (flexure) for the exterior girder is associated with the compression flange factored flexural resistance for positive bending within the end spans (Spans 1 and 6).
- ☼ Inventory Rating Factors for positive and negative flexure for the exterior girder in the other spans (Spans 2 - 5) and at the piers were relatively uniform, ranging from 1.03 to 1.08.
- ☼ The controlling exterior girder Inventory Rating Factor for shear is 1.06 at the abutments. The stiffened end panels at the abutments are the only web panels for which shear capacity does not include tension-field action, hence, a reduced shear resistance results in reduced rating factors. Minimum rating factors for shear at other locations along the bridge were approximately 2.5 times greater than at the abutments.
- ☼ The governing Inventory Rating factor for the interior girder of 0.88 is associated with shear at the abutments. Consistent with the behavior noted for the exterior girders, the shear ratings factors elsewhere along the bridge are significantly higher.
- ☼ The controlling Inventory Rating Factor of 1.09 for the interior girder is associated with the compression flange factored flexural resistance for positive bending within the end spans (Spans 1 and 6).
- ☼ Minimum Inventory Rating Factors for the interior girder in positive flexure in other spans range from 1.22 to 1.27, and rating factors for negative flexure at the piers vary between 1.14 and 1.18.

Fatigue Analysis

Introduction

The existing bridge was reviewed for fatigue-prone details to determine whether additional members should be retrofitted or replaced as part of the proposed rehabilitation, and to estimate the remaining fatigue life of the fatigue prone details. The fatigue life analysis of the bridge utilized "As-Designed" girder section properties and details obtained from the original design plans. Deterioration which has developed on the structure since the 1966 construction, as well as the repairs undertaken by the NHDOT Bureau of Bridge Maintenance (BBM), was not considered in this analysis.

The fatigue life analysis was conducted in accordance with the *AASHTO Manual for Bridge Evaluation, First Edition* (AASHTO MBE) including the 2010 interim revisions, with reference to the *AASHTO LRFD Bridge Design Specifications, 6th Edition* as appropriate. Fatigue of steel is comprised of two mechanisms:

1. *Load-induced fatigue* is produced by cyclical tensile stresses acting on a local defect that serves to initiate and propagate a crack over time. Compressive stresses do not propagate cracks.
2. *Distortion-induced fatigue* is caused by repeated deformation of a member, many times a result of out-of-plane bending, and often occurs in girder webs.

Load-Induced Fatigue

Load-induced fatigue is the result of net tensile stresses induced by the repeated passage of trucks across the structure. Details sensitive to load-induced fatigue are currently grouped into eight detail categories (A through E') which consider fatigue resistance derived from a constant amplitude fatigue threshold.

In evaluating estimated fatigue life, the life expectancy falls into one of two categories: *infinite fatigue life* or *finite fatigue life*. When the maximum anticipated stress range at a fatigue-prone detail is less than the fatigue threshold, the detail will theoretically have *infinite fatigue life*. For details with a stress range that exceeds the fatigue threshold, there is an associated estimated *finite fatigue life* for the detail.

For details classified as having *finite fatigue life*, further analysis was conducted to estimate the expected lifespan and remaining fatigue life. Finite fatigue life is dependent upon traffic volume, specifically the number of load cycles produced by trucks. NHDOT traffic data was incorporated into the fatigue analysis. A summary of the traffic data used is presented in Table FA-1.

The bridge was modeled using the Merlin-DASH software program and live load fatigue stress ranges for the details of concern for a typical interior and exterior girder were estimated. The fatigue evaluation was based on the SB bridge (NHDOT Bridge No. 044/103), since a higher volume of truck traffic crosses that structure. Tables FA-2 and FA-3 summarize the load-induced fatigue-prone details identified on the superstructure and the results of the fatigue analysis for an exterior and interior girder, respectively. Illustrative Example figures from the *AASHTO LRFD Bridge Design Specifications* have been included for reference (See Figures F1 to F6).

Table FA-1: Traffic Data Used For Finite Fatigue Life Analysis

1965 Estimated AADT (both directions)[1]	4,920 vehicles per day
2010 AADT (both directions)[2]	38,000 vehicles per day
Estimated Annual Growth Rates[3]	4.65% (1965-2010)
	4.65% (post-2010, Assumed)
Percentage of Trucks in Traffic[4]	9% (SB Bridge)
	6% (NB Bridge)

[1] Original Design Plans

[2] NHDOT Bureau of Traffic

[3] Uniform growth rate calculated based on 1965 and 2010 traffic counts

[4] NHDOT Bridge Inspection Reports

Table FA-2: Summary of Exterior Girder Fatigue Analysis (Load-Induced)							
Detail of Concern	**Det Cat** [1]	**Fig. No.**	**Quantity per Girder**	**Constant Amplitude Fatigue Threshold**[2]	**Maximum Fatigue Stress Range**	**Finite/ Infinite Life**	**Estimated Remaining Fatigue Life**
Bolted Field Splice	B	F1	10	16.0 ksi	9.2 ksi	Infinite	N/A
Longitudinal Flange-to-Web Welds	B	F2	2	16.0 ksi	10.4 ksi	Infinite	N/A
Transverse Stiffener Welds	C'	F3	179	12.0 ksi	10.4 ksi	Infinite	N/A
Longitudinal Stiffener Weld Terminations	E	F4	75	4.5 ksi	5.1 ksi	Finite	37 years
Welded Flange Transition	B	F5	20	16.0 ksi	7.2 ksi	Infinite	N/A
Girder Web Base Metal at Wind Bracing Gussets	E	F6	90	4.5 ksi	7.6 ksi	Finite	12 years

[1] Per AASHTO LRFD Table 6.6.1.2.3-1

[2] Per AASHTO LRFD Table 6.6.1.2.5-3

Table FA-3: Summary of Interior Girder Fatigue Analysis (Load-Induced)

Detail of Concern	Det Cat [1]	Fig. No.	Quantity per Girder	Constant Amplitude Fatigue Threshold[2]	Maximum Fatigue Stress Range	Finite/ Infinite Life	Estimated Remaining Fatigue Life
Bolted Field Splice	B	F1	10	16.0 ksi	6.9 ksi	Infinite	N/A
Longitudinal Flange-to-Web Welds	B	F2	2	16.0 ksi	7.4 ksi	Infinite	N/A
Transverse Stiffener Welds	C'	F3	179	12.0 ksi	7.4 ksi	Infinite	N/A
Longitudinal Stiffener Weld Terminations	E	F4	75	4.5 ksi	3.7 ksi	Infinite	N/A
Welded Flange Transition	B	F5	20	16.0 ksi	5.4 ksi	Infinite	N/A
Girder Web Base Metal at Wind Bracing Gussets	E	F6	89	4.5 ksi	5.8 ksi	Finite	29 years

[1] Per AASHTO LRFD Table 6.6.1.2.3-1

[2] Per AASHTO LRFD Table 6.6.1.2.5-3

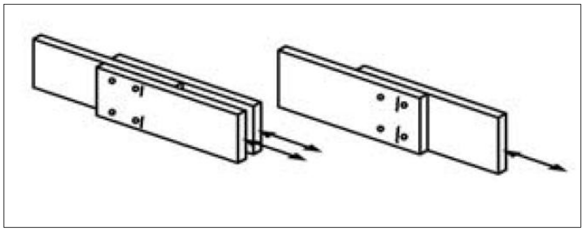


Figure F1 – Bolted Field Splice (Illustrative Example)

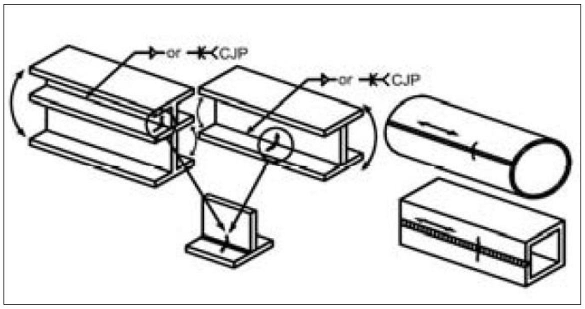


Figure F2 – Longitudinal Flange-to-Web Welds (Illustrative Example)

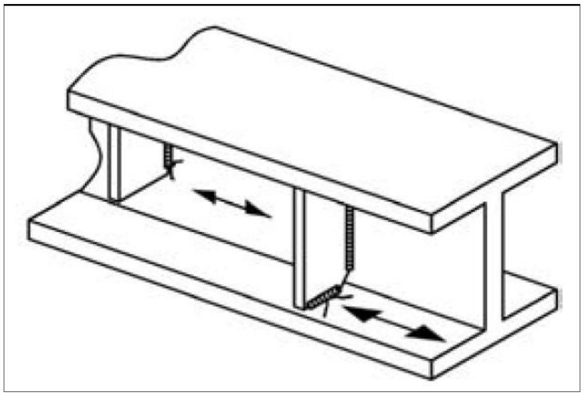


Figure F3 – Transverse Stiffener Welds (Illustrative Example)

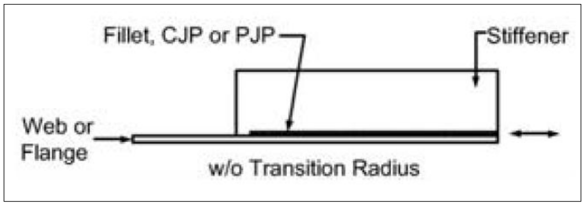


Figure F4 – Longitudinal Stiffener Weld Termination (Illustrative Example)

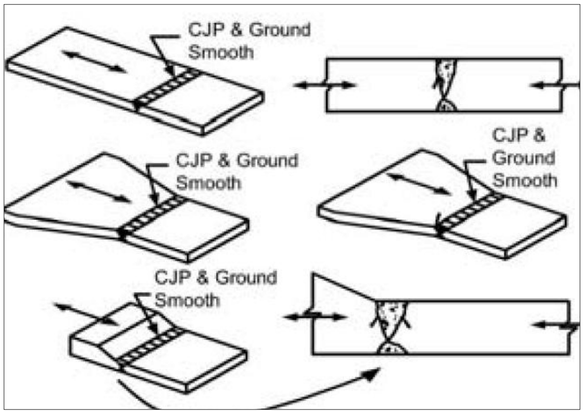


Figure F5 – Welded Flange Transition (Butt Splice) (Illustrative Example)

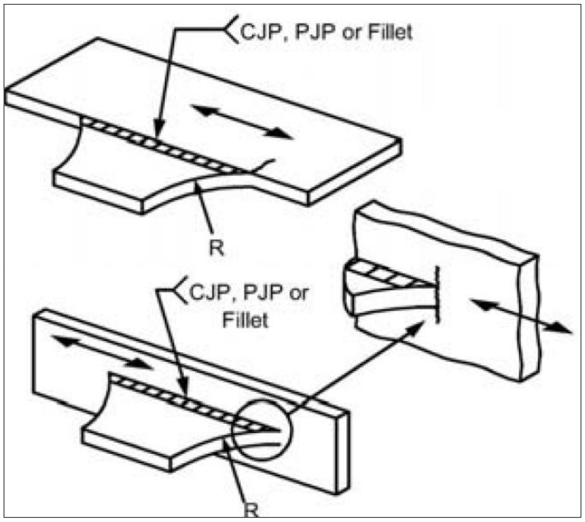


Figure F6 – Gusset Attached at Horizontal Lateral Bracing (Illustrative Example)

Distortion-Induced Fatigue

Distortion-induced fatigue is where localized stress concentrations (cracks) develop from out-of-plane distortions between members. A preliminary assessment of distortion-induced fatigue was investigated based on guidelines provided in the *AASHTO MBE* and *AASHTO LRFD* Design Specifications. Concerns regarding distortion-induced fatigue are typically minimized through proper detailing to provide sufficient rigidity or flexibility at details. This approach reduces the secondary stresses (out-of-plane bending) to non-destructive levels to prevent cracks from forming. The *AASHTO LRFD* Specifications present detailing requirements in Articles 6.6.1.3.1 and 6.6.1.3.2 to discourage the use of susceptible details. Details in violation of these modern requirements were identified on the girders and include the following:

- Connection plates at cross frames are welded to one flange only, but AASHTO presently requires welded or bolted attachment to both flanges.
- Horizontal bracing gusset plates welded to the girder webs do not meet current AASHTO requirements for required offset from the girder flanges.
- The clear distance provided between the ends of horizontal bracing members and the web and vertical stiffeners does not meet the minimum 4-inch requirement.

Summary of Findings

The results of this analysis include:

- Six superstructure load-induced fatigue-prone details were identified.
- Four of the six load-induced fatigue-prone details on the exterior girder and five of the six load-induced fatigue-prone details on the interior girder were found to have theoretically infinite life based on the calculated stress levels.
- The minimum remaining fatigue life calculated for the load-induced fatigue-prone details was estimated to be 12 years at the location where gusset plates for the horizontal wind bracing are welded to the exterior girder webs in the mid-span positive moment regions. The remaining fatigue life for the same load-induced fatigue-prone detail on the interior girder was estimated to be 29 years.
- Several details were identified that violate current AASHTO steel detailing requirements intended to prevent distortion-induced fatigue issues.
- Fracture toughness of the A36 steel used to fabricate the girders is unknown, since these bridges were constructed prior to adoption of the *AASHTO Guide Specifications for Fracture-Critical Nonredundant Steel Bridge Members* in 1978.

PROPOSED CONDITIONS

The proposed conditions must satisfy the purpose and need of the overall project. The focus of the purpose and need is to improve highway safety and the structural integrity of the bridges.

Rehabilitation vs. Replacement

Rehabilitation alternatives were compared to complete bridge replacement at a conceptual level. The rehabilitation alternatives would require deck replacement, structural steel rehabilitation or replacement, and associated substructure rehabilitation. The existing piers are in good condition and are expected to have adequate capacity to accommodate the rehabilitation alternatives. The comparison of the rehabilitation and replacement alternatives did not specifically look at construction phasing, noting only that each would need to be completed with similar constraints. The replacement bridge concept was based on the construction of a segmental concrete 3-span bridge or a steel plate girder 4-span bridge, both with new foundations. Conceptual costs were prepared for two rehabilitation alternatives (shoulder widening and filling in between the bridges (full widening)) and a replacement structure. The results of the conceptual cost analysis are presented in Table RvR-1 and indicate a 50% increase in cost for a replacement structure versus bridge rehabilitation. Based on the significant cost increase for a replacement structure, the project focus was directed towards rehabilitation alternatives.

Table RvR-1: Conceptual Construction Cost Break Down

Cost Item (2013 Costs)	Rehabilitated Bridge (Shoulder Widening)	Rehabilitated Bridge (Full Widening)	Complete Bridge Replacement
Permanent Bridge Cost	$17.0 M	$24.0 M	$37.5 M
Bridge Demolition Cost	$1.5 M	$1.5 M	$3.0 M
Temporary Bridge Cost	$6.5 M	N/A	N/A
Approach Roadway Cost	$3.0 M	$5.5 M	$5.5 M
Total Estimated Construction Cost	**$28 M**	**$31 M**	**$46 M**

See Appendix E for further details on cost analysis

Proposed Roadway

Improvement of highway safety is a primary need of the project. The proximity of the I-91 interchange in Vermont to the Exit 20 interchange in New Hampshire combined with two travel lanes on the bridge and limited shoulder width create a less than desirable safety condition. There are no auxiliary lanes and the existing shoulder widths create a safety hazard for disabled vehicles. RSG was sub-consulted to provide traffic analyses and recommendations (see Appendix D for Report). The report discussed various improvements including shoulder widening and the addition of travel lanes or auxiliary lanes.

A widening of the existing bridges to provide standard shoulder widths is the minimum option to improve highway safety. However, this would not provide improvements to the interstate between the I-91 interchange and the exit 20 interchange (southbound) or provide a climbing lane on the northbound interstate. Widening the bridge to accommodate up to three lanes in each direction (auxiliary lanes included) and standard shoulder widths would increase highway safety and alleviate highway congestion.

Traffic control and phasing during construction are significant design considerations. A requirement of the project is to maintain two lanes of traffic in each direction throughout construction. There are two primary options available to maintain the required traffic: a temporary bridge or widening the bridge to a sufficient width to accommodate traffic control. A temporary bridge could be constructed between the existing bridges while maintaining traffic. This option would require construction of temporary supports on the existing piers and temporary abutment units. The temporary bridge would encompass the majority of the opening between the existing bridges, forcing any widening alternatives to the outside of the existing bridges.

Bridge widening could be constructed to the inside or outside of the existing bridges. A combination of widening to the inside and outside is impractical due to constraints associated with construction phasing. Widening to the outside would require major rehabilitation of the existing piers to support the widening. The outside widening would also create undesirable highway alignments through this section of Interstate 89.

Two options were considered for widening to the inside: widening the minimum to achieve the desired lane and shoulders or widening to completely fill in the gap between the existing bridges. Widening the minimum amount would require major rehabilitation of the existing piers and create challenging construction phasing scenarios. A complete in-fill of the gap between the existing bridges would require major modifications to the existing piers or construction of new piers, but would provide flexibility with construction phasing and traffic control operations.

Conceptual costs were prepared for the shoulder widening option (requiring a temporary bridge) and the in-fill widening option. The results of the conceptual cost analyses presented in Table RvR-1 indicate only a $3 million savings in the shoulder widening versus the in-fill widening. Based on the greater benefits of the in-fill widening (improved highway safety and construction phasing/traffic control opportunities), combined with the minimal cost increase, the full widening alternative is recommended. The full widening alternative was presented to the NHDOT Front Office on August 12, 2013 and to the VTrans Executive Staff on October 7, 2013 and was approved by both parties.

Bridge Rehabilitation

The condition of the bridge decks and superstructures is rated as Fair to Poor; requiring rehabilitation or replacement to improve the structural integrity of the bridges to remove them from the NHDOT red-list. The existing concrete decks will be replaced with new concrete decks removing them as a factor in the low condition rating of the bridges. The existing steel can be rehabilitated or replaced. Both options were evaluated for cost efficiency.

The rehabilitation of the steel would include repairing areas of corrosion, strengthening members to meet load rating requirements, improving fatigue details to provide a 75 year life, and repainting the structural steel. The replacement of the steel would include removal of the existing structural steel and replacement with weathering steel plate girders and new bearings. Costs associated with steel rehabilitation and replacement were prepared and presented in Table BRR-1. Given the potential toughness issues with the existing steel, the large number of fatigue details to improve, and the high cost associated with repainting the steel, the replacement of the steel is desirable. The cost differential is $0.8 million with the new steel providing 75 years of service life with significantly less maintenance and potential safety concerns expected. The decision to replace the existing structural steel was presented to the NHDOT Front Office on August 12, 2013 and to the VTrans Executive Staff on October 7, 2013 and was approved by both parties.

Table BRR-1: Cost Analysis for Steel Replacement vs. Rehabilitation

Work Item	Steel Rehabilitation Fatigue Retrofits and Complete Repainting	Steel Replacement Constant Depth Weathering Steel Plate Girders
Existing Steel Girder Fatigue Retrofits	$0.9 M	N/A
Existing Steel Girder Repairs	$1.2 M	N/A
Clean & Paint Existing Steel Girders	$4.0 M	N/A
Removal of Existing Steel Girders	N/A	$1.5 M
New Steel Plate Girders	N/A	$4.5 M
Bridge Seat Modifications	N/A	$1.0 M
Estimated Initial Steel Costs (2015)	**$6.1 M**	**$7.0 M**
Estimated Remaining Service Life	50 Years	75 Years
Bridge Life Cycle Cost Analysis (Base Year = 2015)	**$10.2 M**	**$9.4 M**

See Appendix E for further details on cost analysis

Substructure Evaluation

Introduction

An analysis of the existing substructure was conducted in accordance with the appropriate provisions from the *AASHTO LRFD Bridge Design Specifications, 6th Edition with 2013 Revisions* (AASHTO LRFD) and the *NHDOT Bridge Design Manual*, 2000 Edition. The analyses were based on the "As-Designed" substructures and details obtained from the original 1964 design plans. Changes to the condition and/or strength of the concrete, which may have occurred since the construction of the bridges in 1966, was not considered in the analyses.

The intent of these analyses was to determine if the existing substructure units are adequate for reuse to carry the proposed superstructure replacement as well as meet the current AASHTO design specifications and live loading requirements. The original bridges were designed for the AASHO H20-S16 live load, including the alternate military loading, in accordance with the *AASHO 1961 Specifications for the Design of Highway Bridges.*

The existing substructure of each bridge is comprised of two cast-in-place cantilever abutments with U-back butterfly wingwalls and five cast-in-place concrete hammerhead piers with tapered solid shafts. All abutments are supported on three rows of steel 12BP53 end bearing piles driven to refusal, with the front two rows battered and the back row vertical. Piers I, II, III, and V are founded on six rows of steel 14BP73 end bearing piles driven to refusal. The remaining pier, Pier IV, is supported by a spread footing founded on a concrete cofferdam seal bearing directly on bedrock. Fixed bearings are currently provided at Pier III, located at mid span of each bridge.

The preliminary analysis of the existing substructure consisted of the investigation of one typical pier with fixed bearings founded on piles (Pier III), one typical pier supported by a spread footing on bedrock (Pier IV), one typical pier with expansion bearings founded on piles (Pier I), and one typical Abutment founded on piles (Abutment A). Abutment A was analyzed as it was similar to Abutment B, but slightly taller and with longer piles. Pier I was selected over Pier II and Pier V for the typical pier founded on piles because it was taller than Pier V, and further than Pier II from the fixed bearing pier (larger induced thermal loading).

As part of this preliminary investigation, two pier configurations were considered to accommodate the proposed bridge widening. One alternative was to connect each pair of existing pier caps forming a frame to carry the proposed superstructure (Connected Pier option, see Appendix F). This was the more desirable option as it would allow for top down construction; keeping all construction out of the river thereby providing significant cost savings and reducing environmental impact. The second alternative was to build new full height piers down the middle to support the new bridge section (In-Fill Pier option, see Appendix F). This option requires conventional construction to occur in the waterway increasing construction time and costs. The sections to follow detail the analysis results and the factors that show the In-Fill Pier Option to be the preferred foundation solution for this bridge widening and superstructure replacement project.

Summary of Initial Analysis Loading Conditions

Prior to determining which pier configuration would be more optimal for the proposed improvements, a base line analysis was completed for a typical abutment, Pier I, Pier III, and Pier IV. This base line analysis assumed that the original bridge width would be replaced (ignoring any widening) with new steel girders and proposed 8½ inch reinforced concrete deck. The purpose of this analysis was to uncover deficiencies per current AASHTO and NHDOT standards, and to determine if modifications would need to be made in the application of loads from the superstructure to the substructure before considering the different pier configurations (i.e. could elastomeric bearings be used or would a non-traditional bearing type be required).

Lead core seismic isolation bearings were utilized in the initial analysis. Seismic isolation bearings were chosen to mitigate the amount of load transfer from the superstructure to the substructure during a seismic event. Lead core seismic isolation bearings are essentially a conventional elastomeric bearing with a solid lead core in the middle. During a seismic event the lead core dissipates energy through plastic deformation, and the rubber accommodates these deformations while providing a restoring force to re-center the bridge when the event has concluded. During seismic events this seismic isolation bearing system has a stiffness ideally equal to a similarly sized conventional elastomeric bearing. Under service load conditions, the lead core stiffens the bearing as compared to a conventional elastomeric bearing; therefore increasing the service loading transferred to the substructure. The preliminary lead core bearing assembly used in this initial analysis was determined through the technical specification sheets provided by Dynamic Isolation Systems. The chosen geometry of the bearing was based on a balance of minimizing the service load transfer, while providing adequate seismic energy dissipation (i.e. an adequately sized lead core). The stiffness of this assumed system was used to determine the service loads transferred to the substructure, and the preliminary assumptions set in the NHDOT Bridge Design Manual were followed for the seismic loading.

The loads considered in the initial analysis are as follows:

- Dead loads due to the proposed superstructure including steel girders, 8½” deck, 2⅝” wearing surface, brush curbs, and metal bridge rail.
- Current design vehicular loading (HL-93) as defined in AASHTO LRFD Article 3.6.1.2.
- Live Load Surcharge according to AASHTO LRFD Article 3.11.6.4.
- Wind loading applied directly to the substructure according to Article 3.8.1.2.3.
- Thermal forces due to expansion and contraction of the superstructure, Article 3.12 AASHTO LRFD.
- Ice loading due to ice drifts found in the Connecticut River, Article 3.9 AASHTO LRFD.
- Braking force due to vehicles on the superstructure, Article 3.6.4 AASHTO LRFD.

- Seismic forces in soil pressure by a Mononobe-Okabe Analysis (abutment only).
- Seismic reactions resulting from the superstructure according to the preliminary design requirements for seismic isolation bearings defined in section 603.5.1 of the NHDOT Bridge Design Manual. In accordance with section 603.5.1, the seismic force from the superstructure was estimated at 12% of the superstructure dead load.

Summary of Initial Analysis

To conduct the initial analysis three software packages were utilized: ABLRFD, RC-Pier, and LPILE. ABLRFD is a software package produced by the Pennsylvania Department of Transportation that was used to analyze a typical existing abutment. The Bentley RC-Pier software was used to analyze piers I, III, and IV. Lastly, LPILE was used to approximate the lateral pile capacity due to the soil-pile interaction. One LPILE run was conducted using a typical abutment pile. The results from the abutment pile were also used for the piers. This was assumed to be a conservative approximation for the lateral geotechnical capacity of the piles supporting the piers because the pier piles are larger than the abutment piles.

Preliminary results of the initial analysis suggest that the reinforcement in all of the Piers is insufficient to meet current code standards for crack control, and the abutment reinforcement is insufficient to meet current code standards for temperature and shrinkage requirements. The abutments fail to meet the requirements of section AASHTO LRFD 5.10.8 for temperature and shrinkage steel. This is largely due to the 40 ksi steel that was used for the reinforcement. The piers do not comply with limits for compression member reinforcement set in section 5.7.4.2 of AASHTO LRFD. Similar to the abutments, this code requirement is significantly impacted by the 40ksi rebar in the existing piers.

Along with the identified code deficiencies, the substructure elements exhibited inadequacies in their respective supporting elements (piles or spread footing). The deficiencies identified in the abutments were minor as compared to the piers. Tables SSE-1 and SSE-2 below summarize the results of the initial abutment analysis. The lateral loads calculated in the bridge longitudinal direction show the piles as being slightly over stressed when compared the available preliminary lateral resistance. At the time of these analyses there was relatively little known about the geotechnical properties of the rock and soil present at the site other than what was provided with the original plan set. Therefore, for these preliminary analyses the axial pile stresses will be compared to the original design axial pile stresses. When compared to the original design stresses the results of the analysis suggest that the proposed axial loading will overstress the existing piles axially.

Table SSE-1: Initial Abutment Pile Lateral Load Summary (Bridge Longitudinal Direction)			
	Total Lateral Load (Kips)	Total Available Lateral Capacity From Piles (Kips)	Performance Ratio
Service I	673	653	0.971
Strength I	828	759	0.917
Strength III	738	726	0.983
Strength V	811	753	0.929
Extreme I	563	781	1.39

Table SSE-2: Initial Abutment Pile Axial Load Summary	
	Total Axial Load (ksi)
Original Design Stress	5.8
Service I	8.8
Strength I	9.9
Strength III	7.6
Strength V	9.4
Extreme I	6.8

Pier I displayed the least favorable results of the three piers analyzed. The poor performance of Pier I can be attributed to its height and distance from the fixed support (resulting in higher thermal loading). Lateral pile capacity was not an issue for Pier I as the applied lateral loads were accommodated with the batter component of the piles without considering any geotechnical capacity of the piles. Conversely, the axial stress in the piles greatly exceeded the original design stress (more than doubled). The high axial pile loads are a product of the higher modern longitudinal bridge loads combined with the height of the pier structure. Table SSE-3 summarizes the axial stress calculated in the Pier I piles.

Table SSE-3: Pier I Pile Axial Stress Summary	
	Total Axial Stress (ksi)
Original Design Stress	5.6
Service Stress	11.4
Factored Stress	12.2

Pier III exhibited similar results to Pier I; however the axial pile stress for the Pier III piles were much closer to the original design pile stress. Like Pier I, lateral resistance of the pile batter was sufficient to handle the proposed lateral loads. Table SSE-4 summarizes the axial stresses in the piles at Pier III.

Table SSE-4: Pier III Pile Axial Load Summary	
	Total Axial Load (ksi)
Original Design Stress	5.6
Service Stress	6.2
Factored Stress	10.1

The third pier assessed during the initial analysis was Pier IV which is founded on a spread footing supported by rock. The spread footing was found to be adequate for sliding and overturning calculations. The issue noted with Pier IV was the bearing pressure. Without geotechnical information on the integrity of the rock which the pier is bearing on, original design bearing force was all the analysis could be based on. The resulting bearing pressure from the current code loading condition was significantly higher than the original design bearing force. Table SSE-5 summarizes the bearing pressures determined as part of the initial analysis.

Table SSE-5: Pier IV Spread Footing Bearing Pressure Summary	
	Bearing Pressure (ksi)
Original Design Stress	5.6
Service Stress	15.2
Factored Stress	20.7

It was evident at the conclusion of the initial analyses that the applied loads would be too large to allow for the reuse of the existing substructure elements. In order to accommodate the modern loading conditions provisions were made to reduce the applied loading and another bearing system was selected to further reduce the transfer of load to the substructure.

Revised Loading Conditions

Based on the findings of the initial substructure analysis, it was evident that reduction in the proposed longitudinal loads would be necessary for reuse of the existing substructure. The controlling factored load case for all piers was Extreme Event I. The seismic load used in Extreme Event I was based on the 12% of the superstructure dead load assumption set in section 603.5.1 of the NHDOT Bridge Manual. The provisions of this assumption allow the designer to reduce this percentage to as low as 7% of the superstructure dead load. Doing so provided much more favorable results for the

Extreme Event I load case; however this assumption does not help to address the other remaining service load cases. Since the start of the preliminary analysis there has been discussion in the T-3 Technical AASHTO Subcommittee on Bridges and Structures for Seismic to reduce the seismic loading requirements for bridges such as this one found in Zone 1. The proposed amendment would eliminate the requirement to carry the design connection force from the point of application through the substructure to the foundation elements. In their June 2014 meeting, the Subcommittee on Bridges and Structures voted in favor of this amendment to the AASHTO LRFD section 3.10.9.2. This amendment allows for the dismissal of superstructure seismic forces from the evaluation of the existing substructure, and subsequently eliminates the need for seismic isolation bearings. Without the need for seismic isolation bearings, low friction bearing systems could be utilized to reduce the applied longitudinal service loads transferred to the substructure.

The revised loads considered for the investigation of a typical abutment and the existing piers associated with both the In-Fill Pier and Connected Pier configurations were as follows:

- Dead loads due the proposed superstructure including steel girders, 8½” deck, 2⅝” wearing surface, and metal bridge rail.
- Current design vehicle (HL-93) as defined in AASHTO LRFD Article 3.6.1.2.
- Live Load Surcharge according to AASHTO LRFD Article 3.11.6.4.
- Wind loading applied directly to the substructure according to Article 3.8.1.2.3.
- Seismic forces in soil pressure by a Mononobe-Okabe Analysis (abutment only).
- Ice loading due to ice drifts found in the Connecticut River, Article 3.9 AASHTO LRFD.
- Frictional loads applied to each bearing location equal to 7% of the superstructure dead load. A value of 7% was chosen because it was assumed to be a conservative value and that the true percentage transmitted by a low friction bearing could be lower.

Revised Abutment Analysis Results

The use of low friction bearings for the abutment analysis reduced the pile reactions much closer to compliance with the original design loads and preliminary capacity predictions. Tables SSE-6 and SSE-7 summarize the pile performance with the use of low friction bearings. It should be noted that under service conditions the existing piles now have sufficient resistance to support the proposed lateral loads. Also, the predicted axial pile stress now matches the original design pile stress. The remaining load cases exhibit minor deficiencies; however, these can be rectified in the final design calculations and through the connection of the existing abutment footings with the proposed in-fill abutment footing.

Table SSE-6: Abutment Pile Lateral Load Summary with Low Friction Bearings			
	Total Lateral Load (Kips)	**Total Available Lateral Capacity From Piles (Kips)**	**Performance Ratio**
Service I	503	548	1.09
Strength I	753	721	0.95
Strength III	655	670	1.02
Strength V	732	710	0.97

Table SSE-7: Abutment Pile Axial Stress Summary with Low Friction Bearings	
	Total Axial Load (ksi)
Original Design Stress	5.8
Service I	5.8
Strength I	8.6
Strength III	6.9
Strength V	8.1

In-Fill Pier vs. Connected Pier Analysis Under the Revised Loading Condition

For the analysis of the In-Fill Pier and Connected Pier configurations, Pier I was the only pier location considered. The Pier I location was chosen because the majority of the piers are founded on piles with similar pile configurations. Pier I also exhibited the most deficiencies during the initial analysis when compared to the original design loads. Pier IV, the spread footing, was not considered because the lack of current geotechnical data at this preliminary stage would have made the analysis of the Connected Pier option difficult.

The original assumption with this analysis was that the Connected Pier option would not be able to sustain the longitudinal loads with only the existing supporting elements. Through the use of low friction bearings this proved to not be the case, and that existing foundation elements could satisfactorily carry the proposed longitudinal loads. What was not initially considered was the effect that the frame action, caused by connecting the two piers, would have on the substructure elements in the transverse direction. The frame action of the connected piers greatly increased the transverse lateral loads in the piles when compared to the In-Fill pier option. Table SSE-8 summarizes the calculated loads associated with the In-Fill and Connected existing pier options.

Table SSE-8: Pier I Lateral Pile Loads in the Transverse and Longitudinal Direction			
Substructure Configuration	**Lateral Load (Kips)**	**Resistance From Pile Batter (Kips)**	**Performance Ratio**
New In-Fill Pier Option (Longitudinal to the Bridge)	160	219	1.3
Connected Existing Pier Option (Longitudinal to the Bridge)	220	302	1.3
New In-Fill Pier Option (Transverse to the Bridge)	23	155	6.7
Connected Existing Pier Option (Transverse to the Bridge)	733	387	0.52

The use of low friction bearing systems made the axial stresses for the In-Fill Pier option more compliant with the original design axial pile stresses. An increase in axial pile performance was calculated for the In-Fill Pier option through a reduction in the applied longitudinal loads due to a subsequent reduction in the overturning force applied to the piles. The low friction bearings apply the same benefit to the Connected Pier option, just not to the same degree as the In-Fill Pier option due to the frame action experienced by the Connected Pier option. Table SSE-9 summarizes the axial pile stresses observed in each pier configuration compared to the original design stress.

Table SSE-9: Pier I Pile Axial Load Summary	
	Total Axial Load (ksi)
Original Design Stress	5.6
In-Fill Pier Option	7.3
Connected Existing Pier Option	11.2

In conclusion, it is recommended that low friction bearings and the In-Fill Pier Option be pursued in final design. The frame action effects experienced by the Connected Pier option are too severe to consider connecting the existing piers as an economically viable solution.

TRAFFIC DATA

Continuous Traffic Counter
Grouping Study and Regression Analysis
Based on 2014 Traffic Data

Vermont Agency of Transportation
Highway Division
Traffic Research Unit
March 2015

A: Interstate Highways

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
					Short Term Growth				2009	to	2014	0.99
					20 Year Growth				2014	to	2034	1.09
2009	1.00											
2010	1.00	1.00										
2011	1.00	1.00	1.00									
2012	0.99	1.00	1.00	1.00								
2013	0.99	0.99	1.00	1.00	1.00							
2014	0.99	0.99	0.99	1.00	1.00	1.00						
2015						1.00	1.00					
2016						1.01	1.00	1.00				
2017						1.01	1.01	1.00	1.00			
2018						1.02	1.01	1.01	1.00	1.00		
2019						1.02	1.02	1.01	1.01	1.00	1.00	
2020						1.03	1.02	1.02	1.01	1.01	1.00	1.00
2021						1.03	1.03	1.02	1.02	1.01	1.01	1.00
2022						1.04	1.03	1.03	1.02	1.02	1.01	1.01
2023						1.04	1.04	1.03	1.03	1.02	1.02	1.01
2024						1.05	1.04	1.04	1.03	1.03	1.02	1.02
2025						1.05	1.04	1.04	1.04	1.03	1.03	1.02
2026						1.05	1.05	1.04	1.04	1.04	1.03	1.03
2027						1.06	1.05	1.05	1.04	1.04	1.04	1.03
2028						1.06	1.06	1.05	1.05	1.04	1.04	1.04
2029						1.07	1.06	1.06	1.05	1.05	1.04	1.04
2030						1.07	1.07	1.06	1.06	1.05	1.05	1.04
2031						1.08	1.07	1.07	1.06	1.06	1.05	1.05
2032						1.08	1.08	1.07	1.07	1.06	1.06	1.05
2033						1.09	1.08	1.08	1.07	1.07	1.06	1.06
2034						1.09	1.09	1.08	1.08	1.07	1.07	1.06
2035						1.09	1.09	1.08	1.08	1.08	1.07	1.07
2036						1.10	1.09	1.09	1.08	1.08	1.07	1.07
2037						1.10	1.10	1.09	1.09	1.08	1.08	1.07
2038						1.11	1.10	1.10	1.09	1.09	1.08	1.08
2039						1.11	1.11	1.10	1.10	1.09	1.09	1.08
2040						1.12	1.11	1.11	1.10	1.10	1.09	1.09
2041						1.12	1.12	1.11	1.11	1.10	1.10	1.09
2042						1.13	1.12	1.12	1.11	1.11	1.10	1.10
2043						1.13	1.13	1.12	1.12	1.11	1.11	1.10
2044						1.14	1.13	1.12	1.12	1.11	1.11	1.11
2045						1.14	1.13	1.13	1.12	1.12	1.11	1.11
2046						1.14	1.14	1.13	1.13	1.12	1.12	1.11
2047						1.15	1.14	1.14	1.13	1.13	1.12	1.12
2048						1.15	1.15	1.14	1.14	1.13	1.13	1.12
2049						1.16	1.15	1.15	1.14	1.14	1.13	1.13
2050						1.16	1.16	1.15	1.15	1.14	1.14	1.13
2051						1.17	1.16	1.16	1.15	1.15	1.14	1.14
2052						1.17	1.17	1.16	1.16	1.15	1.15	1.14
2053						1.18	1.17	1.17	1.16	1.15	1.15	1.14
2054						1.18	1.17	1.17	1.16	1.16	1.15	1.15
2055						1.18	1.18	1.17	1.17	1.16	1.16	1.15
2056						1.19	1.18	1.18	1.17	1.17	1.16	1.16
2057						1.19	1.19	1.18	1.18	1.17	1.17	1.16
2058						1.20	1.19	1.19	1.18	1.18	1.17	1.17
2059						1.20	1.20	1.19	1.19	1.18	1.18	1.17

RATE OF CHANGE PER YEAR 2039 - 2059

$\frac{1.18 - 1.09}{20} = 0.0045/\text{YR}$

$0.0045/\text{YR} \times 10\text{YR} = 0.05$

THEREFORE GROWTH FACTOR FOR 2019 - 2069 SHALL BE

$\underset{2059}{1.18} + \underset{10\text{YR AVG}}{0.05} = \underline{\underline{1.23}}$

CONTINUOUS TRAFFIC COUNTER REPORT
(The Redbook)
Based on 2016 Traffic Data

VERMONT AGENCY OF TRANSPORTATION
Highway Division
Traffic Research Unit
August 2017

2016 AADT GROWTH FACTORS

The factors in the table below may be used to project current year AADTs to a future year. They are applicable on all routes statewide.

The factors are based on a 2016 to 2036 20-year AADT growth factor of 1.09 which was developed from Vermont economic and labor statistics.

	FROM CURRENT YEAR		
TO FUTURE YEAR	2016	2017	2018
2016	1.00		
2017	1.00	1.00	
2018	1.01	1.00	1.00
2019	1.01	1.01	1.00
2020	1.02	1.01	1.01
2021	1.02	1.02	1.01
2022	1.03	1.02	1.02
2023	1.03	1.03	1.02
2024	1.04	1.03	1.03
2025	1.04	1.04	1.03
2026	1.05	1.04	1.04
2027	1.05	1.05	1.04
2028	1.05	1.05	1.05
2029	1.06	1.05	1.05
2030	1.06	1.06	1.05
2031	1.07	1.06	1.06
2032	1.07	1.07	1.06
2033	1.08	1.07	1.07
2034	1.08	1.08	1.07
2035	1.09	1.08	1.08
2036	1.09	1.09	1.08
2037	1.09	1.09	1.09
2038	1.10	1.09	1.09
2039	1.10	1.10	1.09
2040	1.11	1.10	1.10
2041	1.11	1.11	1.10
2042	1.12	1.11	1.11

2016
Automatic Vehicle Classification Report

Vermont Agency of Transportation
Highway Division
Traffic Research Unit
July 2017

VERMONT

Definitions

Location: Automatic Traffic Recorder Station number assigned by VTrans

FC: Functional Classification (designates road use characteristics)

1 = Interstate
2 = Principal Arterial - Other Freeways & Expressways
3 = Principal Arterial - Other
4 = Minor Arterial
5 = Major Collector
6 = Minor Collector
7 = Local

R/U: U (urban) designates a location within the Federal Aid Urban Area Boundary
R (rural) designates a location outside the Federal Aid Urban Area Boundary

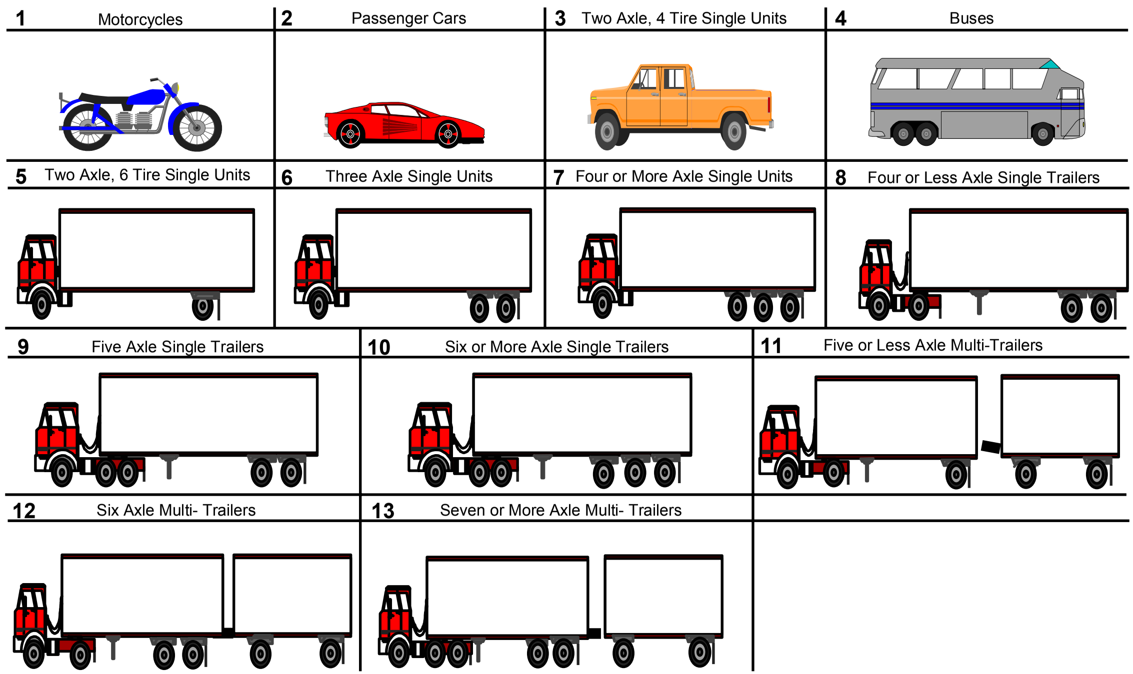
AADT: Annual Average Daily Traffic for the Year shown

FHWA Vehicle Classes

Class	Heading	Description
1	MC	motorcycle
2	PC	passenger car
3	2A 4T	pickup truck/sports utility
4	BUS	full size school and transit busses
5	2A 6T	2 axle six tire, delivery type van or heavy duty pick up
6	3A SU	3 axle single unit, short haul delivery truck, dump truck
7	4A SU	4 axle single unit, short haul delivery truck, concrete truck
8	<5A ST	< 5 axle tractor/single trailer, medium haul delivery
9	5A ST	5 axle tractor/single trailer, "18 Wheeler"
10	>5A ST	> 5 axle tractor/single trailer, tanker truck, logging truck
11	<6A MT	< 6 axle multi trailer truck
12	6A MT	6 axle multi trailer truck
13	>6A MT	> 6 axle multi trailer truck

TRUCKS	FHWA Class 4-13
MEDIUMS	Single Unit truck (FHWA Vehicle Class 4-7)
HEAVIES	Tractor-trailer truck (FHWA Vehicle Class 8-13)

FHWA VEHICLE CLASSIFICATIONS



2016 FUNCTIONAL CLASS AVERAGES

DAILY

RURAL	Class 1 MC	Class 2 Car	Class 3 Pickup	Class 4 Bus	Class 5 2A SU	Class 6 3A SU	Class 7 >3A SU	Class 8 <5A 2U	Class 9 5A 2U	Class 10 >5A 2U	Class 11 <6A >2U	Class 12 6A >2U	Class 13 >6A >2U	TRUCKS TOTAL	TRUCKS MED	TRUCKS HEAVY
FC1 AVG	1.18%	70.00%	17.22%	1.03%	4.17%	1.19%	0.17%	1.21%	2.86%	0.82%	0.06%	0.02%	0.06%	11.59%	6.56%	5.03%
FC2 AVG	2.24%	64.92%	22.78%	0.78%	4.24%	0.98%	0.27%	2.61%	0.65%	0.33%	0.08%	0.02%	0.09%	10.05%	6.27%	3.78%
FC3 AVG	1.46%	69.00%	19.40%	0.78%	3.91%	0.89%	0.17%	1.23%	2.53%	0.56%	0.01%	0.01%	0.04%	10.14%	5.75%	4.38%
FC4 AVG	2.25%	67.83%	21.48%	0.71%	4.01%	0.96%	0.15%	1.00%	1.18%	0.38%	0.01%	0.00%	0.03%	8.43%	5.83%	2.61%
FC5 AVG	2.00%	68.04%	22.93%	0.55%	3.95%	0.91%	0.15%	0.76%	0.43%	0.26%	0.01%	0.00%	0.02%	7.04%	5.55%	1.48%
FC6 AVG	1.72%	67.84%	23.05%	0.44%	4.72%	1.13%	0.14%	0.48%	0.17%	0.27%	0.00%	0.01%	0.02%	7.40%	6.44%	0.96%
FC7 AVG	1.43%	65.87%	24.19%	0.54%	5.27%	1.37%	0.08%	0.74%	0.44%	0.07%	0.00%	0.00%	0.00%	8.51%	7.26%	1.25%

URBAN	Class 1 MC	Class 2 Car	Class 3 Pickup	Class 4 Bus	Class 5 2A SU	Class 6 3A SU	Class 7 >3A SU	Class 8 <5A 2U	Class 9 5A 2U	Class 10 >5A 2U	Class 11 <6A >2U	Class 12 6A >2U	Class 13 >6A >2U	TRUCKS TOTAL	TRUCKS MED	TRUCKS HEAVY
FC1 AVG	0.73%	72.17%	16.89%	1.01%	3.84%	1.16%	0.28%	1.04%	2.19%	0.48%	0.08%	0.04%	0.07%	10.20%	6.30%	3.90%
FC2 AVG	0.88%	76.28%	16.73%	0.66%	2.96%	0.52%	0.12%	0.76%	0.83%	0.18%	0.02%	0.01%	0.04%	6.11%	4.26%	1.85%
FC3 AVG	1.38%	73.93%	17.47%	0.67%	3.67%	0.69%	0.13%	0.72%	1.03%	0.24%	0.01%	0.01%	0.04%	7.21%	5.16%	2.05%
FC4 AVG	1.41%	74.21%	18.57%	0.56%	3.49%	0.60%	0.12%	0.56%	0.31%	0.11%	0.01%	0.01%	0.04%	5.81%	4.77%	1.04%
FC5 AVG	1.02%	74.53%	19.50%	0.42%	3.43%	0.38%	0.06%	0.47%	0.14%	0.03%	0.00%	0.01%	0.02%	4.96%	4.28%	0.67%
FC6 AVG	0.67%	76.06%	17.88%	0.37%	4.07%	0.47%	0.04%	0.33%	0.09%	0.02%	0.00%	0.00%	0.00%	5.39%	4.95%	0.44%
FC7 AVG	1.14%	72.20%	18.67%	1.26%	5.30%	0.79%	0.03%	0.36%	0.24%	0.02%	0.00%	0.00%	0.00%	8.00%	7.39%	0.61%

PEAK HOUR

RURAL	Class 1 MC	Class 2 Car	Class 3 Pickup	Class 4 Bus	Class 5 2A SU	Class 6 3A SU	Class 7 >3A SU	Class 8 <5A 2U	Class 9 5A 2U	Class 10 >5A 2U	Class 11 <6A >2U	Class 12 6A >2U	Class 13 >6A >2U	TRUCKS TOTAL	TRUCKS MED	TRUCKS HEAVY
FC1 AVG	1.01%	73.01%	17.44%	0.72%	3.59%	0.96%	0.16%	0.74%	1.80%	0.52%	0.00%	0.00%	0.05%	8.54%	5.43%	3.11%
FC2 AVG	2.55%	65.07%	23.17%	0.70%	4.01%	0.98%	0.35%	2.38%	0.30%	0.11%	0.14%	0.08%	0.16%	9.21%	6.04%	3.17%
FC3 AVG	1.30%	70.58%	19.05%	0.67%	4.17%	0.87%	0.18%	1.12%	1.67%	0.33%	0.00%	0.00%	0.04%	9.07%	5.90%	3.17%
FC4 AVG	1.64%	69.13%	21.85%	0.61%	3.89%	0.86%	0.13%	0.77%	0.85%	0.24%	0.01%	0.00%	0.02%	7.38%	5.49%	1.89%
FC5 AVG	1.71%	68.71%	22.81%	0.63%	3.87%	0.81%	0.12%	0.76%	0.35%	0.20%	0.00%	0.01%	0.02%	6.77%	5.44%	1.33%
FC6 AVG	1.58%	68.36%	22.14%	0.60%	5.28%	1.17%	0.18%	0.50%	0.07%	0.13%	0.00%	0.00%	0.00%	7.93%	7.22%	0.70%
FC7 AVG	1.41%	66.63%	23.85%	0.61%	5.27%	1.09%	0.11%	0.49%	0.47%	0.07%	0.00%	0.00%	0.00%	8.12%	7.08%	1.04%

URBAN	Class 1 MC	Class 2 Car	Class 3 Pickup	Class 4 Bus	Class 5 2A SU	Class 6 3A SU	Class 7 >3A SU	Class 8 <5A 2U	Class 9 5A 2U	Class 10 >5A 2U	Class 11 <6A >2U	Class 12 6A >2U	Class 13 >6A >2U	TRUCKS TOTAL	TRUCKS MED	TRUCKS HEAVY
FC1 AVG	0.67%	76.35%	15.73%	0.76%	3.03%	1.03%	0.15%	0.63%	1.20%	0.28%	0.04%	0.10%	0.03%	7.24%	4.97%	2.28%
FC2 AVG	0.97%	78.48%	15.89%	0.37%	2.57%	0.32%	0.08%	0.66%	0.47%	0.12%	0.01%	0.02%	0.04%	4.65%	3.34%	1.31%
FC3 AVG	1.34%	76.10%	16.46%	0.48%	3.41%	0.57%	0.12%	0.67%	0.61%	0.14%	0.01%	0.02%	0.07%	6.09%	4.58%	1.51%
FC4 AVG	1.37%	76.10%	17.45%	0.51%	3.14%	0.48%	0.08%	0.51%	0.21%	0.07%	0.01%	0.01%	0.06%	5.08%	4.20%	0.88%
FC5 AVG	1.07%	75.42%	18.73%	0.50%	3.21%	0.30%	0.05%	0.52%	0.10%	0.04%	0.01%	0.01%	0.03%	4.78%	4.07%	0.71%
FC6 AVG	0.67%	76.54%	17.60%	0.32%	3.98%	0.46%	0.02%	0.37%	0.04%	0.00%	0.00%	0.00%	0.00%	5.19%	4.78%	0.41%
FC7 AVG	1.24%	74.62%	17.50%	1.02%	4.68%	0.49%	0.02%	0.33%	0.11%	0.00%	0.00%	0.00%	0.00%	6.65%	6.21%	0.44%

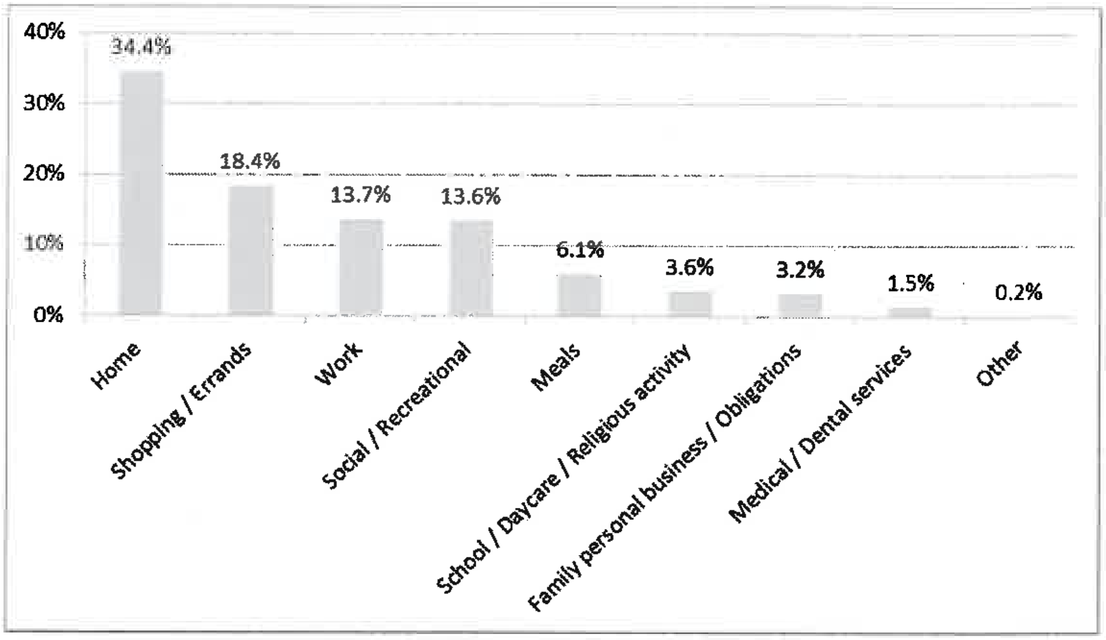


Figure 4. Distribution of Trip Purpose or Destination for Vermonters, 2009 (USDOT, 2010)

Definition

A trip is defined in the NHTS as a single leg of a journey, with a discrete beginning and end. The trip destination reveals the primary purpose of the trip. For example, work destinations reveal commuter trips while commercial destinations reveal shopping trips. An overall reduction in home destinations generally indicates a higher degree of efficiency of trip-chaining behavior, with single trips accounting for multiple purposes/tasks. Reductions in the share of home-destination trips, largely completed by passenger vehicle, may also serve as an indicator of higher occupancy rates, with multiple household members or other travelers being served by a single vehicle.

Current Data

The distribution of trip destinations by Vermonters for all modes is shown in Figure 4. Home-destined trips are the predominant trip type (34.4%), followed by shopping (18.4%), employment (13.7%), and social/recreational (13.6%). The home destined trip share indicates trip chaining with an average of approximately 2 destinations before returning home.

3.4 Vehicle Occupancy

- Trips within Vermont averaged 1.51 occupants per vehicle while those between Vermont and another state or Canada averaged 1.75 occupants per vehicle.
- Occupancy of vehicles used for work trips was significantly lower (1.16 occupants per vehicle) than the average for all trip types (1.51 occupants per vehicle)
- The 2009 Vermont carpool rate, 11.7%, was almost equal to the 12% national rate.
- Currently, there are 1,690 park-and-ride parking spaces in Vermont with an average annual growth rate of 100 spaces.

Definition

Vehicle occupancy is defined as the number of people travelling in a single vehicle typically measured for private passenger vehicles.

http://nhdot.ms2soft.com/tcds/tsearch.asp?loc=Nhdot&mod=

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New Hampshire DOT Department of Transportation

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Transportation Data Management System

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Location ID	02253090	MPO ID	
Type	SPOT	HPMS ID	
On NHS	Yes	On HPMS	No
LRS ID	I0000089_S	LRS Loc Pt.	
SF Group	03	Route Type	
AF Group	03	Route	I-89 SB
GF Group	C	Active	Yes
Class Dist Grp	Default	Category	1
WIM Group	Default		
QC Group	Perm		
Fnct'l Class	Interstate	Milepost	
Located On	Interstate 89 S		
Loc On Alias	I-89 AT CROSSOVER SOUTH OF VERMONT SL (SB-NB) (01253001-01253002)		

PR	MP	PT

More Detail

STATION DATA Show Data

Directions: 2-WAY NB SB 1 2 1 2 3

AADT

Year	AADT	DHV-30	K %	D %	PA	BC	Src
2016	40,979	4,456	11	58	37,372 (91%)	3,607 (9%)	
2015	40,866						
2014	38,726		11	59			
2013	38,048		11				
2012	39,000						

|<< < > >>| 1-5 of 49

Travel Demand Model

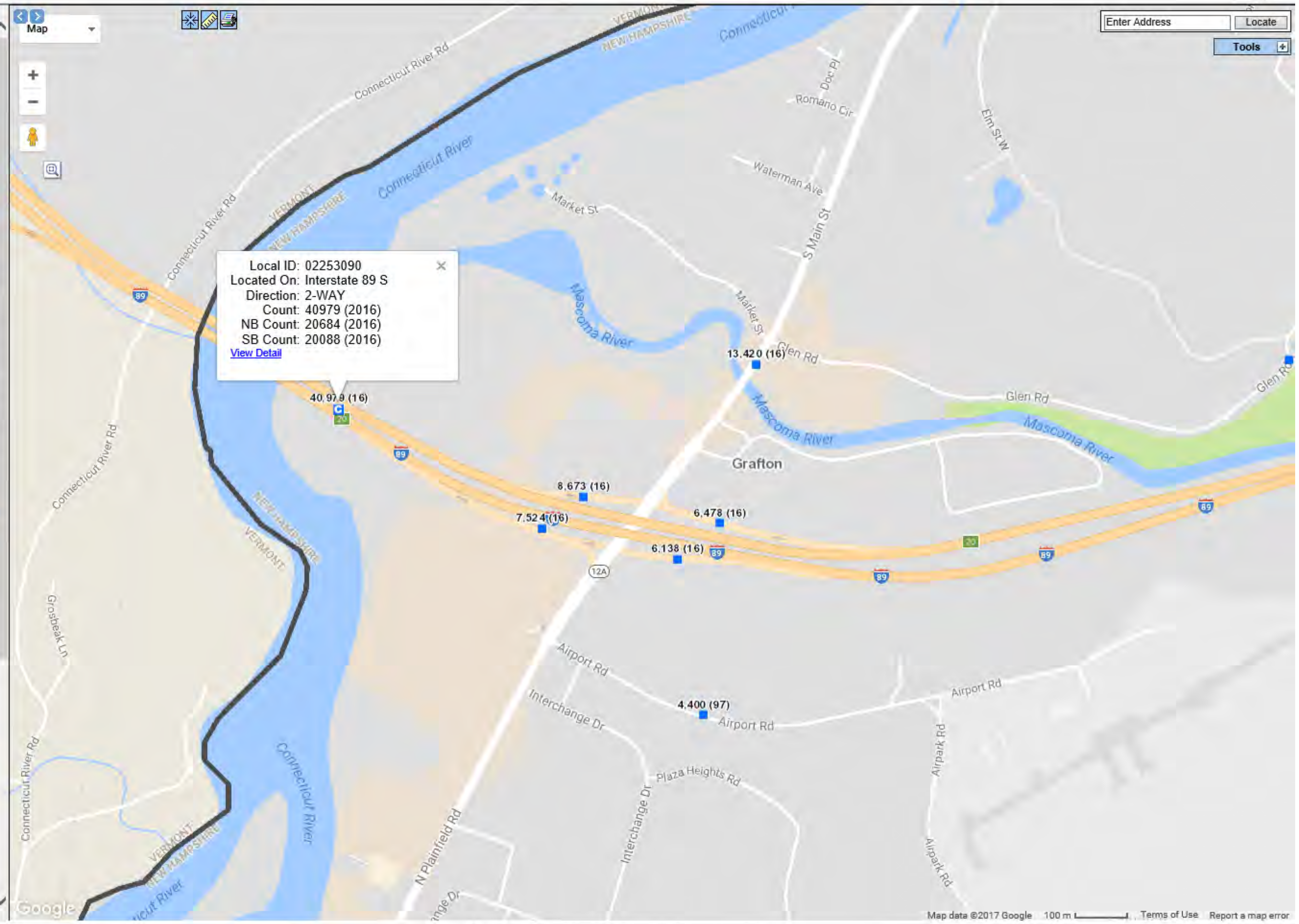
Model Year	Model AADT	AM PHV	AM PPV	MD PHV	MD PPV	PM PHV	PM PPV	NT PHV	NT PPV

VOLUME COUNT

	Date	Int	Total
	Tue 9/5/2017	60	43,365
	Mon 9/4/2017	60	42,352
	Sun 9/3/2017	60	34,510
	Sat 9/2/2017	60	39,945
	Fri 9/1/2017	60	56,724
	Thu 8/31/2017	60	46,503
	Wed 8/30/2017	60	42,960

VOLUME TREND

Year	Annual Growth
2016	0%
2015	6%
2014	2%
2013	-2%
2012	1%
2010	-1%
2009	2%



GUIDANCE ON THE TREATMENT OF ECONOMIC VALUE OF STATISTICAL LIFE

U.S. Department of Transportation
Office of the Secretary Of Transportation

1200 New Jersey Ave., S.E.
Washington, DC 20590

August 8, 2016

MEMORANDUM TO: SECRETARIAL OFFICERS
MODAL ADMINISTRATORS

From: Molly J. Moran
Acting General Counsel, x64702

Carlos Monje
Assistant Secretary for Transportation Policy, x60396

Subject: Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses – 2016 Adjustment

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Departmental guidance on valuing the reduction of fatalities and injuries by regulations or investments has been published periodically by this office since 1993. We issued a thorough revision of our guidance in 2013 and indicated that we planned to issue annual updates to adjust for changes in prices and real incomes since then.

Our 2013 revision indicated a VSL of $9.1 million in current dollars for analyses using a base year of 2012, which was updated to $9.4 million in the 2015 guidance for analyses using a base year of 2014. Using the 2015 value as a baseline, and taking into account both changes in prices and changes in real incomes, we now find that these changes over the past year result in an increased VSL of $9.6 million for analyses prepared in 2016. The procedure for adjusting VSL for changes in prices and real incomes is described on pages 8-9 of the guidance.

This guidance also includes a table of the relative values of preventing injuries of varied severity as a fraction of the VSL; these fractions remain unchanged since the 2013 guidance. We also prescribe a sensitivity analysis of the effects of using alternative VSL values. Instead of treating alternative values in terms of a probability distribution, analysts should apply only a test of low and high alternative values of $5.4 million and $13.4 million (in 2015 dollars).

This guidance and other relevant documents will be posted on the Office of Transportation Policy website, http://www.dot.gov/policy/transportation-policy/economy , and on the General Counsel's regulatory information website, http://www.transportation.gov/regulations. Questions should be addressed to Darren Timothy, (202) 366-4051 or darren.timothy@dot.gov.

cc: Regulations officers and liaison officers

Revised Departmental Guidance 2016:

Treatment of the Value of Preventing Fatalities and Injuries in Preparing Economic Analyses

On the basis of the best available evidence, this guidance identifies **$9.6 million as the value of a statistical life to be used for Department of Transportation analyses assessing the benefits of preventing fatalities and using a base year of 2015**. It also establishes policies for assigning comparable values to prevention of injuries.

Background

Prevention of injury, illness, and loss of life is a significant factor in many private economic decisions, including job choices and consumer product purchases. When government makes direct investments or controls external market impacts by regulation, it also pursues these benefits, often while also imposing costs on society. The Office of the Secretary of Transportation and other DOT administrations are required by Executive Order 13563, Executive Order 12866, Executive Order 12893, OMB Circular A-4, and DOT Order 2100.5 to evaluate in monetary terms the costs and benefits of their regulations, investments, and administrative actions, in order to demonstrate the faithful execution of their responsibilities to the public. Since 1993, the Office of the Secretary of Transportation has periodically reviewed the published research on the value of safety and updated guidance for all administrations. Our previous guidance revision, issued on February 28, 2013, stated that we planned to update our guidance annually to adjust for changes in prices and real incomes. This guidance updates our values based on 2015 prices and real incomes.

The benefit of preventing a fatality is measured by what is conventionally called the Value of a Statistical Life (VSL), defined as the additional cost that individuals would be willing to bear for improvements in safety (that is, reductions in risks) that, in the aggregate, reduce the expected number of fatalities by one. This conventional terminology has often provoked misunderstanding on the part of both the public and decision-makers. What is involved is not the valuation of life as such, but the valuation of reductions in risks. While new terms have been proposed to avoid misunderstanding, we will maintain the common usage of the research literature and OMB Circular A-4 in referring to VSL.

Most regulatory actions involve the reduction of risks of low probability (as in, for example, a one-in-10,000 annual chance of dying in an automobile crash). For these low-probability risks, we shall assume that the willingness to pay to avoid the risk of a fatal injury increases proportionately with growing risk. That is, when an individual is willing to pay $1,000 to reduce the annual risk of death by one in 10,000, she is said to have a VSL of $10 million. The assumption of a linear relationship between risk and willingness to pay therefore implies that she would be willing to pay $2,000 to reduce risk by two in 10,000 or $5,000 to reduce risk by five in 10,000. The assumption of a linear relationship between risk and willingness to pay (WTP) breaks down when the annual WTP becomes a substantial portion of annual income, so the assumption of a constant VSL is not appropriate for substantially larger risks.

When first applied to benefit-cost analysis in the 1960s and 1970s, the value of saving a life was measured by the potential victim's expected earnings, measuring the additional product society might have lost. These lost earnings were widely believed to understate the real costs of loss of life, because the value that we place on the continued life of our family and friends is not based entirely, or even principally, on their earning capacity. In recent decades, studies based on estimates of individuals' willingness to pay for improved safety have become widespread, and offer a way of measuring the value of reduced risk in a more comprehensive way. These estimates of the individual's value of safety are then treated as the ratio of the individual marginal utility of safety to the marginal utility of wealth. These estimates of the individual values of changes in safety can then be aggregated to produce estimates of social benefits of changes in safety, which can then be compared with the costs of these changes.

Studies estimating the willingness to pay for safety fall into two categories. Some analyze subjects' responses in real markets, and are referred to as revealed preference (RP) studies, while others analyze subjects' responses in hypothetical markets, and are described as stated preference (SP) studies. Revealed preference studies in turn can be divided into studies based on consumer purchase decisions and studies based on employment decisions (usually referred to as hedonic wage studies). Even in revealed preference studies, safety is not purchased directly, so the value that consumers place upon it cannot be measured directly. Instead, the value of safety can be inferred from market decisions that people make in which safety is one factor in their decisions. In the case of consumer purchase decisions, since goods and services usually display multiple attributes, and are purchased for a variety of reasons, there is no guarantee that safety will be the conclusive factor in any purchasing decision (note that even products like bicycle helmets, which are purchased primarily for safety, also vary in style, comfort, and durability). Similarly, in employment decisions, safety is one of many considerations in the decision of which job offer to accept. Statistical techniques must therefore be used to identify the relative influence of price (or wage), safety, and other qualitative characteristics of the product or job on the consumer's or worker's decision on which product to buy or which job to accept.

An additional complication in RP studies is that, even if the real risks confronted by individuals can be estimated accurately by the analyst, the consumer or employee may not estimate these risks accurately. It is possible for individuals, through lack of relevant information or limited ability to analyze risks, to assign an excessively low or high probability to fatal risks. Alternatively, detailed familiarity with the hazards they face and their own skills may allow individuals to form more accurate estimates of risk at, for example, a particular job-site than those derived by researchers, which inevitably are based on more aggregate data.

In the SP approach, market alternatives incorporating hypothetical risks are presented to test subjects, who respond with what they believe would be their choices. Answers to hypothetical questions may provide helpful information, but they remain hypothetical. Although great pains are usually taken to communicate probabilities and measure the subjects' understanding, there is no assurance that individuals' predictions of their own behavior would be observed in practice. Against this weakness, the SP method can evaluate many more alternatives than those for which market data are available, and it can guarantee that risks are described objectively to subjects. With indefinitely large potential variations in cost and risk and no uncontrolled variation in any other dimension, some of the objections to RP models are obviated. Despite procedural safeguards, however, SP studies have not proven consistently successful in estimating measures of WTP that increase proportionally with greater risks.

RP studies involving decisions to buy and/or use various consumer products have focused on decisions such as buying cars with better safety equipment, wearing seat belts or helmets, or buying and installing smoke detectors. These studies often lack a continuum of price-risk opportunities, so that the price paid for a safety feature (such as a bicycle helmet) does not necessarily represent the value that the consumer places on the improvement in safety that the helmet provides. In the case of decisions to use a product (like a seatbelt) rather than to buy the product, the "price" paid by the consumer must be inferred from the amount of time and degree of inconvenience involved in using the product, rather than the directly observable price of buying the product. The necessity of making these inferences introduces possible sources of error. Studies of purchases of automobiles probably are less subject to these problems than studies of other consumer decisions, because the price of the safety equipment is directly observable, and there are usually a variety of more or less expensive safety features that provide more of a range of price-risk trade-offs for consumers to make.

While there are many examples of SP studies and RP studies involving consumer product purchases, the most widely cited body of research comprises hedonic wage studies, which estimate the wage differential that employers must pay workers to accept riskier jobs, taking other factors into account. Besides the problem of identifying and quantifying these factors, researchers must have a reliable source of data on fatality and injury risks and also assume that workers' psychological risk assessment conforms to the objective data. The accuracy of hedonic wage studies has improved over the last decade with the availability of more complete data from the Bureau of Labor Statistics' (BLS) Census of Fatal Occupational Injuries (CFOI), supported by advances in econometric modeling, including the use of panel data from the Panel Study of Income Dynamics (PSID). The CFOI data are, first of all, a complete census of occupational fatalities, rather than a sample, so they allow more robust statistical estimation. Second, they classify occupational fatalities by both industry and occupation, allowing variations in fatalities across both dimensions to be compared with corresponding variations in wage rates. Some of the new studies use panel data to analyze the behavior of workers who switch from one job to another, where the analysis can safely assume that any trade-off between wage levels and risk reflects the preferences of a single individual, and not differences in preferences among individuals.

VSL estimates are based on studies of groups of individuals that are covered by the study, but those VSL estimates are then applied to other groups of individuals who were not the subjects of the original studies. This process is called benefit transfer. One issue that has arisen in studies of VSL is whether this benefit transfer process should be applied broadly over the general population of people that are affected by a rulemaking, or whether VSL should be estimated for particular subgroups, such as workers in particular industries, and people of particular ages, races, and genders. Advances in data and econometric techniques have allowed specialized estimates of VSL for these population subgroups. Safety regulations issued by the Department of Transportation typically affect a broad cross-section of people, rather than more narrowly defined subgroups. For that, and other policy reasons, we do not consider variations in VSL among different population groups in this guidance.

Principles and policies of DOT guidance

This guidance for the conduct of Department of Transportation analyses is a synthesis of empirical estimates, practical adaptations, and social policies. We continue to explore new empirical literature as it appears and to give further consideration to the policy resolutions embodied in this guidance. Although our current approach is unchanged from previous guidance, the numbers and their sources are new, consistent with OMB guidance in Circular A-4 and with the use of the best available evidence. The methods we adopt are:

1. Prevention of an expected fatality is assigned a single, nationwide value in each year, regardless of the age, income, or other distinct characteristics of the affected population, the mode of travel, or the nature of the risk. When Departmental actions have distinct impacts on infants, disabled passengers, or the elderly, no adjustment to VSL should be made, but analysts should call the attention of decision-makers to the special character of the beneficiaries.
2. The value to be used by all DOT administrations will be published annually by the Office of the Secretary of Transportation.
3. Alternative high and low benefit estimates should be prepared, using a range of VSLs prescribed on pages 11-12 of this guidance

2008 VSL Guidance Update

In Circular A-4 (2003), the Office of Management and Budget endorsed VSL values between $1 million and $10 million[1], drawing on two then recently completed VSL meta-analyses.[2] . The basis for our 2008 guidance comprised five studies, four of which were meta-analyses that synthesized many primary studies, identifying their sources of variation and estimating the most likely common parameters. These studies were written by Ted R. Miller;[3] Ikuho Kochi, Bryan Hubbell, and Randall Kramer;[4] W. Kip Viscusi;[5] Janusz R. Mrozek and Laura O. Taylor;[6] and W. Kip Viscusi and Joseph Aldy.[7] They narrowed VSL estimates to the $2 million to $7 million range in dollar values of the original data, between 1995 and 2000 (about $3 million to

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[1] In 2015 dollars, these values would be between $1.3 million and $13 million.
[2] Viscusi, W. K. and J.E. Aldy (2003). "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World." *Journal of Risk and Uncertainty*, 27(1): 5-76; and Mrozek, J.R. and L. O. Taylor (2002). "What Determines the Value of a Life? A Meta-Analysis." *Journal of Policy Analysis and Management*. 21(2).
[3]Miller, T. R. (2000). "Variations between Countries in Values of Statistical Life." *Journal of Transport Economics and Policy*. 34(2): 169-188. http://www.bath.ac.uk/e-journals/jtep/pdf/Volume_34_Part_2_169-188.pdf
[4]Kochi, I., B. Hubbell, and R. Kramer (2006). "An Empirical Bayes Approach to Combining and Comparing Estimates of the Value of a Statistical Life for Environmental Policy Analysis." *Environmental and Resource Economics.* 34(3): 385-406.
[5]Viscusi, W. K. (2004). "The Value of Life: Estimates with Risks by Occupation and Industry." *Economic Inquiry.* 42(1): 29-48.
[6] Mrozek, J. R., and L. O. Taylor (2002). "What Determines the Value of Life? A Meta-Analysis." *Journal of Policy Analysis and Management.* 21(2).
[7] Viscusi, W. K. and J. E. Aldy (2003). "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World." *Journal of Risk and Uncertainty*. 27(1): 5-76.

$9 million at current prices). Miller and Viscusi and Aldy also estimated income elasticities for VSL (the percent increase in VSL per one percent increase in income). Miller's estimates were close to 1.0, while Viscusi and Aldy estimated the elasticity to be between 0.5 and 0.6. DOT used the Viscusi and Aldy elasticity estimate (averaged to 0.55), along with the Wages and Salaries component of the Employer Cost for Employee Compensation, as well as price levels represented by the Consumer Price Index, to project these estimates to a 2007 VSL estimate of $5.8 million.

2013 VSL Guidance Update

Since these studies were published, the credibility of these meta-analyses has been qualified by recognition of weaknesses in the data used by the earlier primary studies whose results are synthesized in the meta-analyses. We now believe that the most recent primary research, using improved data (particularly the CFOI data discussed above) and specifications, provides more reliable results. This conclusion is based in part on the advice of a panel of expert economists that we convened to advise us on this issue. The panel consisted of Maureen Cropper (University of Maryland), Alan Krupnick (Resources for the Future), Al McGartland (Environmental Protection Agency), Lisa Robinson (independent consultant), and W. Kip Viscusi (Vanderbilt University). The Panel unanimously concluded that we should base our guidance only on hedonic wage studies completed within the past 10 years that made use of the CFOI database and used appropriate econometric techniques.

A White Paper prepared for the U.S. Environmental Protection Agency (EPA) in 2010 identified eight hedonic wage studies using the CFOI data;[8] we also identified seven additional studies, including five published since the EPA White Paper was issued (see Table 1). Some of these studies focus on estimating VSL values for narrowly defined economic, demographic, or occupational categories, or use inappropriate econometric techniques, resulting in implausibly high VSL estimates. We therefore focused on nine studies that we think are useful for informing an appropriate estimate of VSL. There is broad agreement among researchers that these newer hedonic wage studies provide an improved basis for policy-making.[9]

The 15 hedonic wage studies we have identified that make use of the CFOI database to estimate VSL are listed in Table 1. Several of these studies focus on estimating how VSL varies for different categories of people, such as males and females,[10] older workers and younger workers,[11] blacks and whites,[12] immigrants and non-immigrants,[13] and smokers and non-

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[8] U.S. Environmental Protection Agency (2010), *Valuing Mortality Risk Reductions for Environmental Policy: A White Paper (Review Draft)*. Prepared by the National Center for Environmental Economics for consultation with the Science Advisory Board – Environmental Economics Advisory Committee.

[9] A current survey of theoretical and empirical research on VSL may be found in: Cropper, M., J.K. Hammitt, and L.A. Robinson (2011). "Valuing Mortality Risk Reductions: Progress and Challenges." *Annual Review of Resource Economics.* 3: 313-336. http://www.annualreviews.org/doi/abs/10.1146/annurev.resource.012809.103949

[10] Leeth, J.D. and J. Ruser (2003). "Compensating Wage Differentials for Fatal and Nonfatal Injury Risks by Gender and Race." *Journal of Risk and Uncertainty*, 27(3): 257-277.

[11] Kniesner, T.J., W.K. Viscusi, and J.P. Ziliak (2006). "Life-Cycle Consumption and the Age-Adjusted Value of Life." *Contributions to Economic Analysis and Policy*. 5(1): 1-34; Viscusi, W.K. and J.E. Aldy (2007). "Labor Market Estimates of the Senior Discount for the Value of Statistical Life." *Journal of Environmental Economics and Management*. 53: 377-392; Aldy, J.E. and W.K. Viscusi (2008). "Adjusting the Value of a Statistical Life for

smokers,[14] as well as for different types of fatality risks.[15] Some of these studies do not estimate an overall "full-sample" VSL, instead estimating VSL values only for specific categories of people. Some of the studies, as the authors themselves sometimes acknowledge, arrive at implausibly high values of VSL, because of econometric specifications which appear to bias the results, or because of a focus on a narrowly-defined occupational group. Moreover, these papers generally offer multiple model specifications, and it is often not clear (even to the authors) which specification most accurately represents the actual VSL. We have generally chosen the specification that the author seems to believe is best. In cases where the author does not express a clear preference, we have had to average estimates based on alternative models within the paper to get a representative estimate for the paper as a whole.

Table 1: VSL Studies Using CFOI Database

(VSLs in millions of dollars)

	Study	Year of Study $	VSL in Study-Year $	VSL in 2012$	Comments
1.	Viscusi (2003) *	1997	$14.185M	$21.65M	Implausibly high; industry-only risk measure
2.	Leeth and Ruser (2003) *	2002	$7.04M	$8.90M	Occupation-only risk measure
3.	Viscusi (2004)	1997	$4.7M	$7.17M	Industry/occupation risk measure
4.	Kniesner and Viscusi (2005)	1997	$4.74M	$7.23M	Industry/occupation risk measure
5.	Kniesner *et al*. (2006) *	1997	$23.70M	$36.17M	Implausibly high; industry/occupation risk measure
6.	Viscusi and Aldy (2007) *	2000			Industry-only risk measure; no full-sample VSL estimate
7.	Aldy and Viscusi (2008) *	2000			Industry-only risk measure, no full-sample VSL estimate
8.	Evans and Smith (2008)	2000	$9.6M	$12.84M	Industry-only risk measure

Age and Cohort Effects." *Review of Economics and Statistics*. 90(3): 573-581; and Evans, M.F. and G. Schaur (2010). "A Quantile Estimation Approach to Identify Income and Age Variation in the Value of a Statistical Life." *Journal of Environmental Economics and Management*. 59: 260-270.

[12] Viscusi, W.K. (2003). "Racial Differences in Labor Market Values of a Statistical Life." *Journal of Risk and Uncertainty*. 27(3): 239-256, and Leeth, J.D. and J. Ruser (2003), *op. cit*.

[13] Hersch, J. and W.K. Viscusi (2010). "Immigrant Status and the Value of Statistical Life." *Journal of Human Resources*. 45(3): 749-771.

[14] Viscusi, W.K. and J. Hersch (2008). "The Mortality Cost to Smokers." *Journal of Health Economics*. 27: 943-958.

[15] Scotton, C.R. and L.O. Taylor. "Valuing Risk Reductions: Incorporating Risk Heterogrneity into a Revealed Preference Framework." *Resource and Energy Economics*. 33 and Kochi, I and L.O. Taylor (2011). "Risk Heterogeneity and the Value of Reducing Fatal Risks: Further Market-Based Evidence." *Journal of Benefit-Cost Analysis*. 2(3): 381-397.

9.	Viscusi and Hersch (2008)	2000	$7.37M	$9.86M	Industry-only risk measure
10.	Evans and Schaur (2010)	1998	$6.7M	$9.85M	Industry-only risk measure
11.	Hersch and Viscusi (2010)	2003	$6.8M	$8.43M	Industry/occupation risk measure
12.	Kniesner *et al*. (2010)	2001	$7.55M	$9.76M	Industry/occupation risk measure
13.	Kochi and Taylor (2011)*	2004			VSL estimated only for occupational drivers
14.	Scotton and Taylor (2011)	1997	$5.27M	$8.04M	Industry/occupation risk measure; VSL is mean of estimates from three preferred specifications
15.	Kniesner *et al*. (2012)	2001	$4M - $10M	$5.17M - $12.93M	Industry/occupation risk measure; mean VSL estimate is $9.05M

* Studies shown in grayed-out rows were not used in determining the VSL Guidance value.

We found that nine of these studies provided usable estimates of VSL for a broad cross-section of the population.[16] We excluded Viscusi (2003) and Kniesner *et al*. (2006) on the grounds that their estimates of VSL were implausibly high (Viscusi acknowledges that the estimated VSLs in his study are very high). We excluded Leeth and Ruser (2003) because it used only variations in occupation for estimating variation in risk (the occupational classifications are generally regarded as less accurate than the industry classifications). We excluded Viscusi and Aldy (2007) and Aldy and Viscusi (2008) because they did not estimate overall "full-sample" VSLs (they focused instead on estimating VSLs for various subgroups). We excluded Kochi and Taylor (2011) because it estimated VSL only for a narrow occupational group (occupational drivers). For Scotton and Taylor (2011) and Kniesner *et al*. (2012) we calculated average values for VSL from what appeared to be the preferred model specifications. For our 2013 guidance, we adopted the average of the VSLs estimated in the remaining nine studies, updated to 2012 dollars (based both on changes in the price level and changes in real incomes from the year for which the VSL was originally estimated). This average was $9.14 million, which we rounded to $9.1 million for purposes of that guidance.

[16] In addition to Viscusi (2004) [cited in footnote 4], Viscusi and Hersch (2008) [cited in footnote 13], Evans and Schaur (2010) [cited in footnote 10], Hersch and Viscusi (2010) [cited in footnote 12], and Scotton and Taylor (2011) [cited in footnote 14], these include Kniesner, T.J. and W.K. Viscusi (2005). "Value of a Statistical Life: Relative Position vs. Relative Age." *AEA Papers and Proceedings*. 95(2): 142-146; Evans, M.F. and V.K. Smith (2008). "Complementarity and the Measurement of Individual Risk Tradeoffs: Accounting for Quantity and Quality of Life Effects." National Bureau of Economic Research Working Paper 13722; Kniesner, T.J., W.K. Viscusi, and J.P. Ziliak (2010). "Policy Relevant Heterogeneity in the Value of Statistical Life: New Evidence from Panel Data Quantile Regressions." *Journal of Risk and Uncertainty*. 40: 15-31; and Kniesner, T.J., W.K. Viscusi, C. Woock, and J.P. Ziliak (2012). "The Value of a Statistical; Life: Evidence from Panel Data." *Review of Economics and Statistics*. 94(1): 74-87.

Adjustments for Inflation and Real Income Growth

Updating the VSL from the original base year to a new base year involves adjusting for inflation and real incomes over the intervening years. Specifically, the formula used is:

$$VSL_T = VSL_0 * (P_T / P_0) * (I_T / I_0)^{\varepsilon}$$

where

0 = Original Base Year
T = Updated Base Year
P_t = Price Index in Year t
I_t = Real Incomes in Year t
ε = Income Elasticity of VSL.

Inflation. This guidance uses the Consumer Price Index for All Urban Consumers Current Series (CPI) to adjust for inflation over time, as this price index is deemed to be representative of changes in the value of money that would be considered by a typical worker making decisions corresponding to his income level. This index grew by 3.23 percent from 2012 to 2015.

Real Incomes. The index we use to measure real income growth as it affects VSL is the Median Usual Weekly Earnings (MUWE), in constant (1982-84) dollars, derived by BLS from the Current Population Survey (Series LEU0252881600 – not seasonally adjusted). This series is more appropriate than the Wages and Salaries component of the Employment Cost Index (ECI), which we used previously, because the ECI applies fixed weights to employment categories, while the weekly earnings series uses a median employment cost for wage and salary workers over the age of 16. A median value is preferred because it should better reflect the factors influencing a typical traveler affected by DOT actions (very high incomes would cause an increase in the mean, but not affect the median). In contrast to a median, an average value over all income levels might be unduly sensitive to factors that are less prevalent among actual travelers. Similarly, we do not take into account changes in non-wage income, on the grounds that this non-wage income is not likely to be significant for the average person affected by our rules. While the constant dollar MUWE has been relatively flat over the past two decades, it grew by 1.79 percent from 2012 to 2015.

Income Elasticity. The VSL literature is generally in agreement that VSL increases with real incomes, but the exact rate at which it does so is subject to some debate. In our 2011 guidance, we cited research by Viscusi and Aldy (2003) that estimated the elasticity of VSL with respect to increases in real income as being between 0.5 and 0.6 (i.e., a one-percent increase in real income results in an increase in VSL of 0.5 to 0.6 percent). We accordingly increased VSL by 0.55 percent for every one-percent increase in real income. More recent research by Kniesner, Viscusi, and Ziliak (2010) has derived more refined income elasticity estimates ranging from 2.24 at low incomes to 1.23 at high incomes, with an overall figure of 1.44.[17] An alternative specification yielded an overall elasticity of 1.32. Similarly, Costa and Kahn (2004) estimated

[17] Kniesner, T.J., W.K. Viscusi, and J.P. Ziliak (2010). "Policy Relevant Heterogeneity in the Value of Statistical Life: New Evidence from Panel Data Quantile Regressions." *Journal of Risk and Uncertainty.* 40(1):15–31.

the income-elasticity of VSL to be between 1.5 and 1.6.[18] These empirical results are consistent with theoretical arguments suggesting that the income-elasticity of VSL should be greater than 1.0.[19]

In view of the large increase in the income elasticity of VSL that would be suggested by these empirical results, and because the literature seems somewhat unsettled, we decided in our 2013 guidance to increase our suggested income-elasticity figure only to 1.0. While this figure is lower than the elasticity estimates of Kniesner *et al.* and Costa and Kahn, it is higher than that of Viscusi and Aldy, the basis for our previous guidance. It is difficult to state with confidence whether a cross-sectional income elasticity (such as those estimated in these empirical analyses), representing the difference in sensitivity to fatality risks between low-income and high-income workers in a given population, corresponds to a longitudinal elasticity, representing the way in which VSL is affected by growth in income over time for an overall population. Consequently, we adopt this more moderate figure, pending more comprehensive documentation.

This VSL guidance is updated each year to take into account both the changes in price levels and changes in real incomes. Applying the procedure above for updating the overall VSL value yields an increased VSL of $9.6 million for analyses prepared in 2016 using a 2015 base year. For analyses using base years prior to 2015, the appropriate VSL are found below in Table 2.

Table 2: Prior Year VSL

Guidance Year	Value (million$)	Base year
2015	9.4	2014
2014	9.2	2013
2013	9.1	2012

Value of Preventing Injuries

Nonfatal injuries are far more common than fatalities and vary widely in severity, as well as probability. In principle, the resulting losses in quality of life, including both pain and suffering and reduced income, should be estimated by potential victims' WTP for personal safety. While estimates of WTP to avoid injury are available, often as part of a broader analysis of factors influencing VSL, these estimates are generally only available for an average injury resulting in a lost workday, and not for a range of injuries varying in severity. Because detailed WTP

[18] Costa, D.L. and M.E. Kahn (2004). "Changes in the Value of Life, 1940-1980." *Journal of Risk and Uncertainty*. 29(2): 159-180.
[19] Eeckhoudt, L.R. and J.K. Hammitt (2001). "Background Risks and the Value of a Statistical Life." *Journal of Risk and Uncertainty*. 23(3): 261-279; Kaplow, L. (2005). "The Value of a Statistical Life and the Coefficient of Relative Risk Aversion." *Journal of Risk and Uncertainty*, 31(1); Murphy, K.M. and R.H. Topel (2006). "The Value of Health and Longevity." *Journal of Political Economy*. 114(5): 871-904; and Hammitt, J.K. and L.A. Robinson (2011). "The Income Elasticity of the Value per Statistical Life: Transferring Estimates between High and Low Income Populations." *Journal of Benefit-Cost Analysis*. 2(1): 1-27.

estimates covering the entire range of potential disabilities are unobtainable, we use an alternative standardized method to interpolate values of expected outcomes, scaled in proportion to VSL. Each type of accidental injury is rated (in terms of severity and duration) on a scale of quality-adjusted life years (QALYs), in comparison with the alternative of perfect health. These scores are grouped, according to the Maximum Abbreviated Injury Scale (MAIS), yielding coefficients that can be applied to VSL to assign each injury class a value corresponding to a fraction of a fatality.

In our 2011 guidance, the values of preventing injuries were updated by new estimates from a study by Spicer and Miller.[20] The measure adopted was the quality-adjusted percentage of remaining life lost for median utility weights, based on QALY research considered "best," as presented in Table 9 of the cited study. The rate at which disability is discounted over a victim's lifespan causes these percentages to vary slightly, and the study shows estimates for 0, 3, 4, 7, and 10 percent discount rates. These differences are minor in comparison with other sources of variation and uncertainty, which we recognize by sensitivity analysis. Since OMB recommends the use of alternative discount rates of 3 and 7 percent, we present the scale corresponding to an intermediate rate of 4 percent for use in all analyses. The fractions shown should be multiplied by the current VSL to obtain the values of preventing injuries of the types affected by the government action being analyzed.

Table 3: Relative Disutility Factors by Injury Severity Level (MAIS)
For Use with 3% or 7% Discount Rate

MAIS Level	Severity	Fraction of VSL
MAIS 1	Minor	0.003
MAIS 2	Moderate	0.047
MAIS 3	Serious	0.105
MAIS 4	Severe	0.266
MAIS 5	Critical	0.593
MAIS 6	Unsurvivable	1.000

Note that these factors represent an average disutility of all injuries sustained by persons with a given MAIS. Although injured persons normally have multiple injuries, only one disutility factor should be applied to each injured person. For example, if the analyst were seeking to estimate the value for an injured person whose highest level injury was rated "serious" (MAIS 3), he or she would multiply the Fraction of VSL for a serious injury (0.105) by the VSL ($9.6 million) to calculate the value of the serious injury ($1.01 million).

[20] Rebecca S. Spicer and Ted R. Miller. "Final Report to the National Highway Traffic Safety Administration: Uncertainty Analysis of Quality Adjusted Life Years Lost." Pacific Institute for Research and Evaluation. February 5, 2010. http://ostpxweb.dot.gov/policy/reports/QALY Injury Revision_PDF Final Report 02-05-10.pdf.

These factors have two direct applications in analyses. The first application is as a basis for establishing the value of preventing nonfatal injuries in benefit-cost analysis. The total value of preventing injuries and fatalities can be combined with the value of other economic benefits not measured by VSLs, and then compared to costs to determine either a benefit/cost ratio or an estimate of net benefits.

The second application stems from the requirement in OMB Circular A-4 that evaluations of major regulations for which safety is the primary outcome include cost-effectiveness analysis, in which the cost of a government action is compared with a non-monetary measure of benefit. The values in the above table may be used to translate nonfatal injuries into fatality equivalents which, when added to fatalities, can be divided into costs to determine the cost per equivalent fatality. This ratio may also be seen as a "break-even" VSL, the value that would have to be assumed if benefits of a proposed action were to equal its costs. It would illustrate whether the costs of the action can be justified by a VSL that is well within the accepted range or, instead, would require a VSL approaching the upper limit of plausibility. Because the values assigned to prevention of injuries and fatalities are derived in part by using different methodologies, it is useful to understand their relative importance in drawing conclusions. Consequently, in analyses where benefits from reducing both injuries and fatalities are present, the estimated values of injuries and fatalities prevented should be stated separately, as well as in the aggregate.

Recognizing Uncertainty

Regulatory and investment decisions must be made by officials informed of the limitations of their information. The values we adopt here do not establish a threshold dividing justifiable from unjustifiable actions; they only suggest a region where officials making these decisions can have relatively greater or lesser confidence that their decisions will generate positive net benefits. To convey the sensitivity of this confidence to changes in assumptions, OMB Circular A-4 and Departmental policy require analysts to prepare estimates using alternative values. We have previously encouraged the use of probabilistic methods such as Monte Carlo analysis to synthesize the many uncertain quantities determining net benefits.

While the individual estimates of VSL reported in the studies cited above are often accompanied by estimates of confidence intervals, we do not, at this time, have any reliable method for estimating the overall probability distribution of the average VSL that we have calculated from these various studies. Consequently, alternative VSL values can only illustrate the conclusions that would result if the true VSL actually equaled the higher or lower alternative values. Analysts should not imply a known probability that the true VSL would exceed or fall short of either the primary VSL figure or the alternative values used for sensitivity analysis. Kniesner *et al*. (2012) suggest that a reasonable range of values for VSL is between $4 million and $10 million (in 2001 dollars), or about $5.4 million to $13.4 million in 2015 dollars. This range of values includes all the estimates from the eight other studies on which this guidance is based. For illustrative purposes, analysts should calculate high and low alternative estimates of the values of fatalities and injuries by using alternative VSLs of $5.4 million and $13.4 million.

Because the relative costs and benefits of different provisions of a rule can vary greatly, it is important to disaggregate the provisions of a rule, displaying the expected costs and benefits of each provision, together with estimates of costs and benefits of reasonable alternatives to each provision.

This guidance and other relevant documents will be posted on the Office of Transportation Policy website, http://www.dot.gov/policy/transportation-policy/economy. Questions should be addressed to Darren Timothy, (202) 366-4051, or darren.timothy@dot.gov.

CRASH MODIFICATION FACTORS

CRASH MODIFICATION FACTORS CLEARINGHOUSE

CMF / CRF Details

CMF ID: 3898

Provide an auxiliary lane between an entrance ramp and exit ramp

Description: Provide an auxiliary lane between an entrance ramp and exit ramp

Prior Condition: directional freeway segment containing a combination of an entrance ramp and an exit ramp without an auxiliary lane between the entrance ramp and exit ramp

Category: Interchange design

Study: *NCHRP Report 169: Determining Guidelines for Ramp and Interchange Spacing*, Ray et al., 2010

Star Quality Rating:	[View score details]

Crash Modification Factor (CMF)	
Value:	0.8
Adjusted Standard Error:	
Unadjusted Standard Error:	

Crash Reduction Factor (CRF)	
Value:	20 *(This value indicates a **decrease** in crashes)*
Adjusted Standard Error:	
Unadjusted Standard Error:	

Applicability	
Crash Type:	All
Crash Severity:	All
Roadway Types:	Principal Arterial Interstate
Number of Lanes:	
Road Division Type:	
Speed Limit:	
Area Type:	Not specified
Traffic Volume:	
Time of Day:	All
If countermeasure is intersection-based	
Intersection Type:	Roadway/roadway (interchange ramp terminal)
Intersection Geometry:	
Traffic Control:	

Major Road Traffic Volume:	15928 to 104079 Average Daily Traffic (ADT)
Minor Road Traffic Volume:	84 to 31495 Average Daily Traffic (ADT)

Development Details

Date Range of Data Used:	2005 to 2007
Municipality:	
State:	WA
Country:	U.S.A.
Type of Methodology Used:	Regression cross-section
Sample Size Used:	5177 Crashes

Other Details

Included in Highway Safety Manual?	No
Date Added to Clearinghouse:	
Comments:	This CMF was obtained from Exhibit 3-35 for the variable AuxLn for total crashes: e^(-.2283)=0.8 Note that this analysis was based on one direction of travel. The sample size was computed from Exhibit 3-33 as 33.4 crashes per segment * 155 segments = 5,177 crashes. The sites are comprised of multiple roadway types, primarily of interstates and freeways but also of routes with lower functional classifications (p. 3-45). Interchange-related is not available so intersection-related was selected. The traffic volumes

	were obtained from Exhibit 3-31. The minimum minor traffic volume was the lesser of the entrance and exit minimum ADTs. Similarly, the maximum minor traffic volumes was the greater of the entrance and exit maximum ADTs. The average minor traffic volume was computed as the average of the averages.

This site is funded by the U.S. Department of Transportation Federal Highway Administration and maintained by the University of North Carolina Highway Safety Research Center

CMF / CRF Details

CMF ID: 6758

Widen shoulder

Description:

Prior Condition: Narrower paved shoulder than after condition

Category: Shoulder treatments

Study: *Safety Impacts of Highway Shoulder Attributes in Illinois*, Bamzai et al., 2011

Star Quality Rating:	★★★☆☆ [View score details]

Crash Modification Factor (CMF)	
Value:	0.96
Adjusted Standard Error:	
Unadjusted Standard Error:	

Crash Reduction Factor (CRF)

Value:	4 *(This value indicates a **decrease** in crashes)*
Adjusted Standard Error:	
Unadjusted Standard Error:	

Applicability

Crash Type:	Fixed object,Head on,Run off road,Sideswipe
Crash Severity:	Fatal
Roadway Types:	Principal Arterial Interstate
Number of Lanes:	
Road Division Type:	Divided by Median
Speed Limit:	45-65
Area Type:	Urban
Traffic Volume:	
Time of Day:	All
If countermeasure is intersection-based	
Intersection Type:	
Intersection Geometry:	
Traffic Control:	
Major Road Traffic Volume:	

Minor Road Traffic Volume:	

Development Details

Date Range of Data Used:	2000 to 2006
Municipality:	
State:	IL
Country:	USA
Type of Methodology Used:	Before/after using empirical Bayes or full Bayes
Sample Size Used:	

Other Details

Included in Highway Safety Manual?	No
Date Added to Clearinghouse:	Jun-22-2015
Comments:	This CMF applies to urban interstates with an outside paved shoulder width greater than 8 ft. This CMF applies to shoulder related crashes, defined as head-on, fixed object, sideswipe opposite direction, and run-off-road.

This site is funded by the U.S. Department of Transportation Federal Highway Administration and maintained by the University of North Carolina Highway Safety Research Center

CMF / CRF Details

CMF ID: 6759

Widen shoulder

Description:

Prior Condition: Narrower paved shoulder than after condition

Category: Shoulder treatments

Study: *Safety Impacts of Highway Shoulder Attributes in Illinois*, Bamzai et al., 2011

Star Quality Rating:	[View score details]

Crash Modification Factor (CMF)	
Value:	0.76
Adjusted Standard Error:	
Unadjusted Standard Error:	

Crash Reduction Factor (CRF)

Value:	24 *(This value indicates a **decrease** in crashes)*
Adjusted Standard Error:	
Unadjusted Standard Error:	

Applicability

Crash Type:	Fixed object,Head on,Run off road,Sideswipe
Crash Severity:	Serious injury,Minor injury
Roadway Types:	Principal Arterial Interstate
Number of Lanes:	
Road Division Type:	Divided by Median
Speed Limit:	45-65
Area Type:	Urban
Traffic Volume:	
Time of Day:	All
If countermeasure is intersection-based	
Intersection Type:	
Intersection Geometry:	
Traffic Control:	
Major Road Traffic Volume:	

Minor Road Traffic Volume:	

Development Details

Date Range of Data Used:	2000 to 2006
Municipality:	
State:	IL
Country:	USA
Type of Methodology Used:	Before/after using empirical Bayes or full Bayes
Sample Size Used:	

Other Details

Included in Highway Safety Manual?	No
Date Added to Clearinghouse:	Jun-22-2015
Comments:	This CMF applies to urban interstates with an outside paved shoulder width greater than 8 ft. This CMF applies to shoulder related crashes, defined as head-on, fixed object, sideswipe opposite direction, and run-off-road.

This site is funded by the U.S. Department of Transportation Federal Highway Administration and maintained by the University of North Carolina Highway Safety Research Center

CMF / CRF Details

CMF ID: 6706

Widen shoulder

Description:

Prior Condition: Narrower paved shoulder than after condition

Category: Shoulder treatments

Study: *Safety Impacts of Highway Shoulder Attributes in Illinois*, Bamzai et al., 2011

Star Quality Rating:	[View score details]

Crash Modification Factor (CMF)	
Value:	0.83
Adjusted Standard Error:	
Unadjusted Standard Error:	

Crash Reduction Factor (CRF)

Value:	17 *(This value indicates a **decrease** in crashes)*
Adjusted Standard Error:	
Unadjusted Standard Error:	

Applicability

Crash Type:	Fixed object,Head on,Run off road,Sideswipe
Crash Severity:	Property damage only (PDO)
Roadway Types:	Principal Arterial Interstate
Number of Lanes:	
Road Division Type:	Divided by Median
Speed Limit:	45-65
Area Type:	Urban
Traffic Volume:	30000 *Annual Average Daily Traffic (AADT)*
Time of Day:	All
If countermeasure is intersection-based	
Intersection Type:	
Intersection Geometry:	
Traffic Control:	
Major Road Traffic Volume:	

Minor Road Traffic Volume:	

Development Details

Date Range of Data Used:	2000 to 2006
Municipality:	
State:	IL
Country:	USA
Type of Methodology Used:	Before/after using empirical Bayes or full Bayes
Sample Size Used:	

Other Details

Included in Highway Safety Manual?	No
Date Added to Clearinghouse:	Jun-22-2015
Comments:	This CMF applies to urban interstates with daily traffic less than or equal to 30,000 vehicles per day. This CMF applies to shoulder related crashes, defined as head-on, fixed object, sideswipe opposite direction, and run-off-road.

This site is funded by the U.S. Department of Transportation Federal Highway Administration and maintained by the University of North Carolina Highway Safety Research Center

BENEFIT COST ANALYSIS WORKSHEETS

Implicit Priced Delator from Gross Domestic Product

Base Year	Multiplier to Adjust to Real $2016[1]
2013	1.0424
2014	1.0240
2015	1.1032
2016	1.0000

1. Source: Bureau of Economic Analysis, National Income and Product Accounts Table 1.1.9 "Implicit Deflators for Gross Domestic Prodcut" (March 2016)

Calendar Year	Total Traffic Volumes	Automobile Traffic Volumes 93.99%	Truck Traffic Volumes 6.01%	Volume of Business Travel (21.4% of Auto) 21.40%	Volume of Personal Travel (78.6% of Auto) 78.60%	Volume of Truck Travel (100% of Truck)
2016						
2017						
2018						
2019	41389	38902	2487	8325	30577	2487
2020	41572	39074	2499	8362	30712	2499
2021	41756	39246	2510	8399	30848	2510
2022	41939	39419	2521	8436	30983	2521
2023	42123	39591	2532	8473	31119	2532
2024	42306	39764	2543	8509	31254	2543
2025	42490	39936	2554	8546	31390	2554
2026	42673	40109	2565	8583	31525	2565
2027	42857	40281	2576	8620	31661	2576
2028	43040	40453	2587	8657	31796	2587
2029	43224	40626	2598	8694	31932	2598
2030	43407	40798	2609	8731	32067	2609
2031	43591	40971	2620	8768	32203	2620
2032	43774	41143	2631	8805	32339	2631
2033	43957	41316	2642	8842	32474	2642
2034	44141	41488	2653	8878	32610	2653
2035	44324	41660	2664	8915	32745	2664
2036	44508	41833	2675	8952	32881	2675
2037	44691	42005	2686	8989	33016	2686
2038	44875	42178	2697	9026	33152	2697
2039	45058	42350	2708	9063	33287	2708
2040	45242	42523	2719	9100	33423	2719
2041	45425	42695	2730	9137	33558	2730
2042	45609	42868	2741	9174	33694	2741
2043	45792	43040	2752	9211	33829	2752
2044	45976	43212	2763	9247	33965	2763
2045	46159	43385	2774	9284	34100	2774
2046	46342	43557	2785	9321	34236	2785
2047	46526	43730	2796	9358	34372	2796
2048	46709	43902	2807	9395	34507	2807
2049	46893	44075	2818	9432	34643	2818
2050	47076	44247	2829	9469	34778	2829
2051	47260	44419	2840	9506	34914	2840
2052	47443	44592	2851	9543	35049	2851
2053	47627	44764	2862	9580	35185	2862
2054	47810	44937	2873	9616	35320	2873
2055	47994	45109	2884	9653	35456	2884
2056	48177	45282	2895	9690	35591	2895
2057	48360	45454	2906	9727	35727	2906
2058	48544	45626	2917	9764	35862	2917
2059	48727	45799	2929	9801	35998	2929
2060	48911	45971	2940	9838	36133	2940
2061	49094	46144	2951	9875	36269	2951
2062	49278	46316	2962	9912	36405	2962
2063	49461	46489	2973	9949	36540	2973
2064	49645	46661	2984	9985	36676	2984
2065	49828	46833	2995	10022	36811	2995
2066	50012	47006	3006	10059	36947	3006
2067	50195	47178	3017	10096	37082	3017
2068	50379	47351	3028	10133	37218	3028
2069	50562	47523	3039	10170	37353	3039
2070	50745	47696	3050	10207	37489	3050
2071	50929	47868	3061	10244	37624	3061
2072	51112	48041	3072	10281	37760	3072
2073	51296	48213	3083	10318	37895	3083

Value of Travel Time

Calendar Year	Project Year	Affected Population[1]	Total Travel Time Saved[2]	Business Travel Time Saved	Personal Travel Time Saved	Truck Travel Time Saved	Value of Time Saved ($2016)
2016							
2017							
2018							
2019	1	58315	0.0	$0	$0	$0	$0
2020	2	58574	0.0	$0	$0	$0	$0
2021	3	58832	116.7	$736	$2,632	$191	$3,559
2022	4	59091	117.2	$739	$2,644	$192	$3,575
2023	5	59349	117.8	$742	$2,655	$192	$3,590
2024	6	59607	118.3	$746	$2,667	$193	$3,606
2025	7	59866	118.8	$749	$2,679	$194	$3,622
2026	8	60124	119.3	$752	$2,690	$195	$3,637
2027	9	60383	119.8	$755	$2,702	$196	$3,653
2028	10	60641	120.3	$759	$2,713	$197	$3,669
2029	11	60900	120.8	$762	$2,725	$198	$3,684
2030	12	61158	121.3	$765	$2,736	$198	$3,700
2031	13	61417	121.9	$768	$2,748	$199	$3,716
2032	14	61675	122.4	$772	$2,760	$200	$3,731
2033	15	61934	122.9	$775	$2,771	$201	$3,747
2034	16	62192	123.4	$778	$2,783	$202	$3,762
2035	17	62451	123.9	$781	$2,794	$203	$3,778
2036	18	62709	124.4	$785	$2,806	$203	$3,794
2037	19	62968	124.9	$788	$2,817	$204	$3,809
2038	20	63226	125.4	$791	$2,829	$205	$3,825
2039	21	63485	126.0	$794	$2,840	$206	$3,841
2040	22	63743	126.5	$797	$2,852	$207	$3,856
2041	23	64002	127.0	$801	$2,864	$208	$3,872
2042	24	64260	127.5	$804	$2,875	$208	$3,888
2043	25	64519	128.0	$807	$2,887	$209	$3,903
2044	26	64777	128.5	$810	$2,898	$210	$3,919
2045	27	65036	129.0	$814	$2,910	$211	$3,934
2046	28	65294	129.6	$817	$2,921	$212	$3,950
2047	29	65553	130.1	$820	$2,933	$213	$3,966
2048	30	65811	130.6	$823	$2,945	$213	$3,981
2049	31	66070	131.1	$827	$2,956	$214	$3,997
2050	32	66328	131.6	$830	$2,968	$215	$4,013
2051	33	66587	132.1	$833	$2,979	$216	$4,028
2052	34	66845	132.6	$836	$2,991	$217	$4,044
2053	35	67104	133.1	$839	$3,002	$218	$4,060
2054	36	67362	133.7	$843	$3,014	$218	$4,075
2055	37	67621	134.2	$846	$3,026	$219	$4,091
2056	38	67879	134.7	$849	$3,037	$220	$4,106
2057	39	68138	135.2	$852	$3,049	$221	$4,122
2058	40	68396	135.7	$856	$3,060	$222	$4,138
2059	41	68654	136.2	$859	$3,072	$223	$4,153
2060	42	68913	136.7	$862	$3,083	$224	$4,169
2061	43	69171	137.2	$865	$3,095	$224	$4,185
2062	44	69430	137.8	$869	$3,106	$225	$4,200
2063	45	69688	138.3	$872	$3,118	$226	$4,216
2064	46	69947	138.8	$875	$3,130	$227	$4,232
2065	47	70205	139.3	$878	$3,141	$228	$4,247
2066	48	70464	139.8	$882	$3,153	$229	$4,263
2067	49	70722	140.3	$885	$3,164	$229	$4,278
2068	50	70981	140.8	$888	$3,176	$230	$4,294
2069	51	71239	141.3	$891	$3,187	$231	$4,310
2070	52	71498	141.9	$894	$3,199	$232	$4,325
2071	53	71756	142.4	$898	$3,211	$233	$4,341
2072	54	72015	142.9	$901	$3,222	$234	$4,357
2073	55	72273	143.4	$904	$3,234	$234	$4,372
		Totals	**6893.4**				**$210,183**

Recommended Hourly Values of Travel Time Savings		
Category - Intercity Travel	Surface Modes ($2016)	Surface Modes ($2016)
Personal	$19.00	$19.00
Business	$25.40	$25.40
Truck	$27.20	$27.20

Estimated Percentage of Personal and Business Travel	
Business	21.40%
Personal	78.60%

Source: Intercity Travel All purposes - Based on "The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2016 Update) - US DOT 2015 monetized to $2016

Notes

1. Assuming average occupancy rate of 1.51 people per vehicle based for personal use and 1.16 people per vehicle for business use * volume of traffic
Source: "The Vermont Tranportation Energy Profile" - VTrans August 2013 and 2015

2. Assumes increase in travel speed of 7 mph over 1 mile project length per vehicle per day

Value of Travel Time - Work Zone Related

Calendar Year	Project Year	Type of Work	Affected Population (Daily)[1]	Affected Population (Off Peak Speed Reduction)[2]	Average Number of Days Closed per Year (Total both bridges)	Total Travel Time Saved[3]	Business Travel Time Saved	Personal Travel Time Saved	Truck Travel Time Saved	Value of Time Saved ($2016)
2016										
2017										
2018										
2019	1		58315	18078	8	0.0	$0	$0	$0	$0
2020	2		58574	18158	8	0.0	$0	$0	$0	$0
2021	3		58832	18238	9	1108.4	$6,989	$24,994	$1,812	$33,795
2022	4		59091	18318	10	1224.6	$7,721	$27,614	$2,002	$37,337
2023	5		59349	18398	11	1352.9	$8,530	$30,509	$2,212	$41,251
2024	6		59607	18478	12	1494.7	$9,424	$33,706	$2,443	$45,573
2025	7		59866	18558	13	1651.3	$10,412	$37,237	$2,699	$50,348
2026	8		60124	18639	14	1824.3	$11,502	$41,137	$2,982	$55,622
2027	9		60383	18719	16	2015.3	$12,707	$45,446	$3,294	$61,447
2028	10		60641	18799	17	2226.3	$14,038	$50,204	$3,639	$67,881
2029	11		60900	18879	19	2459.4	$15,507	$55,460	$4,020	$74,988
2030	12		61158	18959	21	2716.8	$17,130	$61,265	$4,441	$82,837
2031	13		61417	19039	23	3001.1	$18,923	$67,676	$4,906	$91,505
2032	14		61675	19119	25	3315.1	$20,903	$74,757	$5,419	$101,080
2033	15		61934	19199	28	3661.9	$23,090	$82,578	$5,986	$111,654
2034	16		62192	19280	31	4044.9	$25,505	$91,215	$6,612	$123,332
2035	17		62451	19360	34	4467.9	$28,172	$100,753	$7,304	$136,229
2036	18		62709	19440	37	4935.1	$31,117	$111,287	$8,067	$150,472
2037	19		62968	19520	41	5450.9	$34,370	$122,921	$8,911	$166,201
2038	20		63226	19600	45	6020.6	$37,962	$135,768	$9,842	$183,572
2039	21		63485	19680	45	6105.7	$38,498	$137,686	$9,981	$186,165
2040	22		63743	19760	46	6191.9	$39,042	$139,629	$10,122	$188,793
2041	23		64002	19841	46	6279.2	$39,592	$141,597	$10,265	$191,454
2042	24		64260	19921	47	6367.6	$40,149	$143,591	$10,409	$194,149
2043	25		64519	20001	8	1094.1	$6,898	$24,671	$1,788	$33,358
2044	26		64777	20081	8	1109.4	$6,995	$25,018	$1,814	$33,827
2045	27		65036	20161	8	1125.0	$7,093	$25,369	$1,839	$34,301
2046	28		65294	20241	8	1140.8	$7,193	$25,725	$1,865	$34,782
2047	29		65553	20321	8	1156.7	$7,294	$26,085	$1,891	$35,269
2048	30		65811	20401	8	1172.9	$7,396	$26,449	$1,917	$35,762
2049	31		66070	20482	8	1189.3	$7,499	$26,819	$1,944	$36,262
2050	32		66328	20562	9	1205.9	$7,603	$27,193	$1,971	$36,768
2051	33		66587	20642	9	1222.7	$7,709	$27,572	$1,999	$37,280
2052	34		66845	20722	9	1239.7	$7,817	$27,956	$2,027	$37,799
2053	35		67104	20802	9	1256.9	$7,925	$28,344	$2,055	$38,325
2054	36		67362	20882	9	1274.4	$8,035	$28,738	$2,083	$38,857
2055	37		67621	20962	9	1292.1	$8,147	$29,137	$2,112	$39,396
2056	38		67879	21043	9	1310.0	$8,260	$29,541	$2,141	$39,942
2057	39		68138	21123	9	1328.1	$8,374	$29,950	$2,171	$40,495
2058	40		68396	21203	9	1346.5	$8,490	$30,364	$2,201	$41,055
2059	41		68654	21283	9	1365.1	$8,607	$30,784	$2,232	$41,623
2060	42		68913	21363	9	1383.9	$8,726	$31,209	$2,262	$42,197
2061	43		69171	21443	10	1403.0	$8,847	$31,639	$2,294	$42,779
2062	44		69430	21523	10	1422.4	$8,968	$32,075	$2,325	$43,368
2063	45		69688	21603	10	1427.7	$9,002	$32,194	$2,334	$43,530
2064	46		69947	21684	10	1432.9	$9,035	$32,313	$2,342	$43,691
2065	47		70205	21764	10	1438.2	$9,069	$32,433	$2,351	$43,853
2066	48		70464	21844	10	1443.5	$9,102	$32,552	$2,360	$44,014
2067	49		70722	21924	10	1448.8	$9,135	$32,672	$2,368	$44,175
2068	50		70981	22004	10	1454.1	$9,169	$32,791	$2,377	$44,337
2069	51		71239	22084	10	1459.4	$9,202	$32,911	$2,386	$44,498
2070	52		71498	22164	10	1464.7	$9,235	$33,030	$2,394	$44,660
2071	53		71756	22244	10	1470.0	$9,269	$33,149	$2,403	$44,821
2072	54		72015	22325	10	1475.3	$9,302	$33,269	$2,412	$44,983
2073	55		72273	22405	10	1480.6	$9,336	$33,388	$2,420	$45,144
			Totals			**118950.3**				**$3,626,836**

Recommended Hourly Values of Travel Time Savings		
Category - Intercity Travel	Surface Modes ($2016)	Surface Modes ($2016)
Personal	$19.00	$19.00
Business	$25.40	$25.40
Truck	$27.20	$27.20

Estimated Percentage of Personal and Business Travel	
Business	21.40%
Personal	78.60%

Source: Intercity Travel All purposes - Based on "The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2016 Update) - US DOT 2015 monetized to $2016

Notes

1. Assuming average occupancy rate of 1.51 people per vehicle based for personal use and 1.16 people per vehicle for business use * volume of traffic Source: "The Vermont Tranportation Energy Profile" - VTrans August 2013 and 2015
2. Developed from AADT between 9am-3pm on an average day in the July (Approx 34% of daily)

Value of Life Crash Cost by Type

Relative Disutility oFactor by AIS for use with 3 or 7% discount rate				
AIS Level	Severity	Fraction of VSL	Cost ($2016)	Cost ($2016)
1	Minor	0.003	$28,800	$28,800.00
2	Moderate	0.047	$451,200	$451,200.00
3	Serious	0.105	$1,008,000	$1,008,000.00
4	Severe	0.266	$2,553,600	$2,553,600.00
5	Critical	0.593	$5,692,800	$5,692,800.00
6	Fatal	1	$9,600,000	$9,600,000.00

Source: TIGER Benefit-Cost Resource Guide

Kabco - AIS Data Conversion for Kabco "0" Accident (i.e. PDO)			
		Cost ($2016)	Cost ($2016)
AIS 0	0.92534	$0	$0
AIS 1	0.07257	$28,800	$2,090
AIS 2	0.00198	$451,200	$893
AIS 3	0.00008	$1,008,000	$81
AIS 4	0.00000	$2,553,600	$0
AIS 5	0.00003	$5,692,800	$171
AIS 6	0.00000	$9,600,000	$0
		Total	$3,235

Source: TIGER Benefit-Cost Resource Guide

Type	Cost ($2016)	Cost ($2016)
PDO	$4,252	$4,252
Injury	$451,200	$432,847
Fatality	$9,600,000	$9,209,517

Observed Crashes (2007-2016)[1]	Average per year
Total	114	11.4
PDO	92	9.2
Injury	21	2.1
Fatal	1	0.1

1.) Source: NHDOT and VTrans taken from Traffic Assessment prepared by RSG, 2013 for the years 2007-2011 and database query from NHDOT and VTrans for the years 2012-2016 which is the newest data available for both states.

Cost of crashes per year	
Type	Cost ($2016)
PDO	$39,118.40
Injury	$908,979.28
Fatal	$920,951.65
Total per year	$1,869,049.33

Expected Crashes per year based on % increase in traffic volume per year						Expected Reduction in crashes per year[1]			
Year	Traffic Volume	% increase in traffic volume	PDO Crashes	Injury Crashes	Fatal Crashes)	PDO Crashes	Injury Crashes	Fatal Crashes)	Cost Savings ($2016)
2019	41389	0	9.2	2.1	0.1	0	0	0	0
2020	41572	0.44%	9.3	2.2	0.2	0.0	0.0	0.046	$423,638
2021	41756	0.44%	9.4	2.3	0.2	1.6	0.4	0.046	$624,485
2022	41939	0.44%	9.5	2.4	0.2	3.2	0.9	0.046	$842,355
2023	42123	0.44%	9.6	2.5	0.2	3.2	1.0	0.046	$859,379
2024	42306	0.43%	9.7	2.6	0.2	3.3	1.0	0.046	$876,403
2025	42490	0.43%	9.8	2.7	0.2	3.3	1.1	0.046	$893,427
2026	42673	0.43%	9.9	2.8	0.2	3.3	1.1	0.046	$910,451
2027	42857	0.43%	10	2.9	0.2	3.4	1.1	0.046	$927,475
2028	43040	0.43%	10.1	3.0	0.2	3.4	1.2	0.046	$944,499
2029	43224	0.42%	10.2	3.1	0.2	3.4	1.2	0.046	$961,523
2030	43407	0.42%	10.3	3.2	0.2	3.5	1.2	0.046	$978,546
2031	43591	0.42%	10.4	3.3	0.2	3.5	1.3	0.046	$995,570
2032	43774	0.42%	10.5	3.4	0.2	3.5	1.3	0.046	$1,012,594
2033	43957	0.42%	10.6	3.5	0.2	3.6	1.4	0.046	$1,029,618
2034	44141	0.42%	10.7	3.6	0.2	3.6	1.4	0.046	$1,046,642
2035	44324	0.41%	10.8	3.7	0.2	3.6	1.4	0.046	$1,063,666
2036	44508	0.41%	10.9	3.8	0.2	3.7	1.5	0.046	$1,080,690
2037	44691	0.41%	11	3.9	0.2	3.7	1.5	0.046	$1,097,714
2038	44875	0.41%	11.1	4.0	0.2	3.7	1.6	0.046	$1,114,738
2039	45058	0.41%	11.2	4.1	0.2	3.8	1.6	0.046	$1,131,762
2040	45242	0.41%	11.3	4.2	0.2	3.8	1.6	0.046	$1,148,786
2041	45425	0.40%	11.4	4.3	0.2	3.8	1.7	0.046	$1,165,810
2042	45609	0.40%	11.5	4.4	0.2	3.9	1.7	0.046	$1,182,833
2043	45792	0.40%	11.6	4.5	0.2	3.9	1.8	0.046	$1,199,857
2044	45976	0.40%	11.7	4.6	0.2	3.9	1.8	0.046	$1,216,881
2045	46159	0.40%	11.8	4.7	0.2	4.0	1.8	0.046	$1,233,905
2046	46342	0.40%	11.9	4.8	0.2	4.0	1.9	0.046	$1,250,929
2047	46526	0.39%	12	4.9	0.2	4.0	1.9	0.046	$1,267,953
2048	46709	0.39%	12.1	5.0	0.2	4.1	2.0	0.046	$1,284,977
2049	46893	0.39%	12.2	5.1	0.2	4.1	2.0	0.046	$1,302,001
2050	47076	0.39%	12.3	5.2	0.2	4.1	2.0	0.046	$1,319,025
2051	47260	0.39%	12.4	5.3	0.2	4.2	2.1	0.046	$1,336,049
2052	47443	0.39%	12.5	5.4	0.2	4.2	2.1	0.046	$1,353,073
2053	47627	0.39%	12.6	5.5	0.2	4.2	2.1	0.046	$1,370,096
2054	47810	0.38%	12.7	5.6	0.2	4.3	2.2	0.046	$1,387,120
2055	47994	0.38%	12.8	5.7	0.2	4.3	2.2	0.046	$1,404,144
2056	48177	0.38%	12.9	5.8	0.2	4.3	2.3	0.046	$1,421,168
2057	48360	0.38%	13	5.9	0.2	4.4	2.3	0.046	$1,438,192
2058	48544	0.38%	13.1	6.0	0.2	4.4	2.3	0.046	$1,455,216
2059	48727	0.38%	13.2	6.1	0.2	4.4	2.4	0.046	$1,472,240
2060	48911	0.38%	13.3	6.2	0.2	4.5	2.4	0.046	$1,489,264
2061	49094	0.37%	13.4	6.3	0.2	4.5	2.5	0.046	$1,506,288
2062	49278	0.37%	13.5	6.4	0.2	4.5	2.5	0.046	$1,523,312
2063	49461	0.37%	13.6	6.5	0.2	4.6	2.5	0.046	$1,540,336
2064	49645	0.37%	13.7	6.6	0.2	4.6	2.6	0.046	$1,557,359
2065	49828	0.37%	13.8	6.7	0.2	4.6	2.6	0.046	$1,574,383
2066	50012	0.37%	13.9	6.8	0.2	4.7	2.7	0.046	$1,591,407
2067	50195	0.37%	14	6.9	0.2	4.7	2.7	0.046	$1,608,431
2068	50379	0.36%	14.1	7.0	0.2	4.7	2.7	0.046	$1,625,455
2069	50562	0.36%	14.2	7.1	0.2	4.8	2.8	0.046	$1,642,479
2070	50745	0.36%	14.3	7.2	0.2	4.8	2.8	0.046	$1,659,503
2071	50929	0.36%	14.4	7.3	0.2	4.8	2.8	0.046	$1,676,527
2072	51112	0.36%	14.5	7.4	0.2	4.9	2.9	0.046	$1,693,551
2073	51296	0.36%	14.6	7.5	0.2	4.9	2.9	0.046	$1,710,575
								Total	$67,424,298

1.) Based on CMF= 0.80 For all Crash Types for Adding auxilliary Lane Between Entrance and Exit Ramps CMF=0.83 For PDO Crashes, CMF=0.76 for Injury Crashes, and CMF= 0.96 for Fatalities for Widening outside shoulder. - Source: CMF Clearinghouse 2016. Values reduced by 50% for 2021 because only one new bridge will be open to traffic.

Total Expected Crashes per year with improvements		
PDO Crashes	Injury Crashes	Fatal Crashes)
10	3	1
8	2	1
7	2	1
7	2	1
7	2	1
7	2	1
7	2	1
7	2	1
7	2	1
7	2	1
7	2	1
7	3	1
7	3	1
8	3	1
8	3	1
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9	4	1
9	4	1
9	4	1
9	4	1
9	4	1
9	4	1
10	4	1
10	5	1
10	5	1
10	5	1
10	5	1
10	5	1
10	5	1
10	5	1
10	5	1
10	5	1
10	5	1

Calendar Year	Initial Construction Cost ($2016)	Bridge Operations and Maintenance Cost ($2016)	De-icing Operation and Maintenance Cost ($2016)	Total Cost ($2016)	7% Rate	Total Costs ($2016) Discounted 7%	3% Rate	Total Costs ($2016) Discounted 3%
2016								
2017								
2018								
2019	$2,947,500	-	$15,000	$2,962,500	0.82	$2,418,282	0.92	$2,711,107
2020	$4,912,500	-	$15,000	$4,927,500	0.76	$3,759,166	0.89	$4,378,020
2021	$4,912,500	$0	$15,000	$4,927,500	0.71	$3,513,239	0.86	$4,250,505
2022	$4,912,500	$0	$15,000	$4,927,500	0.67	$3,283,401	0.84	$4,126,704
2023	$1,965,000	$0	$15,000	$1,980,000	0.62	$1,233,044	0.81	$1,609,921
2024	$0	$6,048	$15,000	$21,048	0.58	$12,250	0.79	$16,615
2025	$0	$6,048	$15,000	$21,048	0.54	$11,449	0.77	$16,132
2026	$0	$6,048	$15,000	$21,048	0.51	$10,700	0.74	$15,662
2027	$0	$6,048	$15,000	$21,048	0.48	$10,000	0.72	$15,206
2028	$0	$10,282	$15,000	$25,282	0.44	$11,225	0.70	$17,732
2029	$0	$6,048	$25,000	$31,048	0.41	$12,884	0.68	$21,142
2030	$0	$6,048	$15,000	$21,048	0.39	$8,163	0.66	$13,915
2031	$0	$6,048	$15,000	$21,048	0.36	$7,629	0.64	$13,510
2032	$0	$6,048	$15,000	$21,048	0.34	$7,130	0.62	$13,116
2033	$0	$102,816	$15,000	$117,816	0.32	$37,298	0.61	$71,281
2034	$0	$6,048	$15,000	$21,048	0.30	$6,227	0.59	$12,363
2035	$0	$6,048	$15,000	$21,048	0.28	$5,820	0.57	$12,003
2036	$0	$6,048	$15,000	$21,048	0.26	$5,439	0.55	$11,654
2037	$0	$6,048	$15,000	$21,048	0.24	$5,083	0.54	$11,314
2038	$0	$48,384	$15,000	$63,384	0.23	$14,307	0.52	$33,080
2039	$0	$6,048	$25,000	$31,048	0.21	$6,549	0.51	$15,732
2040	$0	$6,048	$15,000	$21,048	0.20	$4,150	0.49	$10,354
2041	$0	$6,048	$15,000	$21,048	0.18	$3,878	0.48	$10,053
2042	$0	$6,048	$15,000	$21,048	0.17	$3,624	0.46	$9,760
2043	$0	$5,080,048	$15,000	$5,095,048	0.16	$819,948	0.45	$2,293,735
2044	$0	$6,048	$15,000	$21,048	0.15	$3,166	0.44	$9,200
2045	$0	$6,048	$15,000	$21,048	0.14	$2,959	0.42	$8,932
2046	$0	$6,048	$15,000	$21,048	0.13	$2,765	0.41	$8,671
2047	$0	$6,048	$15,000	$21,048	0.12	$2,584	0.40	$8,419
2048	$0	$10,282	$15,000	$25,282	0.11	$2,901	0.39	$9,818
2049	$0	$6,048	$25,000	$31,048	0.11	$3,329	0.38	$11,706
2050	$0	$6,048	$15,000	$21,048	0.10	$2,109	0.37	$7,705
2051	$0	$6,048	$15,000	$21,048	0.09	$1,971	0.36	$7,480
2052	$0	$6,048	$15,000	$21,048	0.09	$1,842	0.35	$7,262
2053	$0	$102,816	$15,000	$117,816	0.08	$9,638	0.33	$39,466
2054	$0	$6,048	$15,000	$21,048	0.08	$1,609	0.33	$6,845
2055	$0	$6,048	$15,000	$21,048	0.07	$1,504	0.32	$6,646
2056	$0	$6,048	$15,000	$21,048	0.07	$1,406	0.31	$6,452
2057	$0	$6,048	$15,000	$21,048	0.06	$1,314	0.30	$6,264
2058	$0	$10,282	$15,000	$25,282	0.06	$1,475	0.29	$7,305
2059	$0	$6,048	$25,000	$31,048	0.05	$1,693	0.28	$8,710
2060	$0	$6,048	$15,000	$21,048	0.05	$1,072	0.27	$5,733
2061	$0	$6,048	$15,000	$21,048	0.05	$1,002	0.26	$5,566
2062	$0	$6,048	$15,000	$21,048	0.04	$937	0.26	$5,404
2063	$0	$5,080,048	$15,000	$5,095,048	0.04	$211,890	0.25	$1,269,985
2064	$0	$6,048	$15,000	$21,048	0.04	$818	0.24	$5,094
2065	$0	$6,048	$15,000	$21,048	0.04	$765	0.23	$4,945
2066	$0	$6,048	$15,000	$21,048	0.03	$715	0.23	$4,801
2067	$0	$6,048	$15,000	$21,048	0.03	$668	0.22	$4,661
2068	$0	$48,384	$15,000	$63,384	0.03	$1,879	0.22	$13,628
2069	$0	$6,048	$25,000	$31,048	0.03	$860	0.21	$6,481
2070	$0	$6,048	$15,000	$21,048	0.03	$545	0.20	$4,266
2071	$0	$6,048	$15,000	$21,048	0.02	$509	0.20	$4,142
2072	$0	$6,048	$15,000	$21,048	0.02	$476	0.19	$4,021
2073	$0	$102,816	$15,000	$117,816	0.02	$2,491	0.19	$21,852
Total	**$19,650,000**	**$10,838,077**	**$875,000**	**$31,363,077**		**$15,477,778**		**$21,232,077**

Steel Rehabilitation		
Work Item	Fatigue Retrofits and Complete Repainting ($2015)	Fatigue Retrofits and Complete Repainting ($2016)
Existing Girder Fatigue Retrofits	$900,000	$900,000
Existing Girder Repairs	$1,200,000	$1,200,000
Clean and Paint Existing Girders	$4,000,000	$4,000,000
Concrete Deck Replacement	$6,650,000	$6,650,000
Replace Anti-Icing System	$400,000	$400,000
Temporary Bridge for Traffic		$6,500,000
Control	$6,500,000	$0
Total Rehabilitation Cost ($2016)	$19,650,000	$19,650,000

Source: Bridge Rehabilitation Study Report- NHDOT 2014

BRIDGE INSPECTION REPORTS

Bridge Inspection Report

Lebanon 044/104

Date of Inspection: 11/18/2015
Date Report Sent: 1/19/2016
☑ Picture taken during inspection
Owner: NHDOT
Bridge also in: Hartford , Vermont

I-89 NB
Over
CONNECTICUT RIVER,NECRR
Vietnam Veteran Memorial
Interstate Bridge Number: 071

Recommended Postings:

Weight: No Posting Required — ☑ Weight Sign OK

Width: Not Required — ☑ Width Sign OK

Primary Height Sign Recommendation: *None*
Optional Centerline Height Sign Rec: *None*

Clearances: (Feet) Over:
Under: 38.98
Route:

☑ Height Signs OK

Condition: State Redlist
Deck: 4 Poor
Superstructure: 5 Fair
Substructure: 5 Fair
Culvert: N N/A (NBI)

Structure Type and Materials:
Number of Spans Main Unit: 6
Number of Approach Spans: 0

Main Span Material and Design Type
Steel Continuous Multiple Beam

Sufficiency Rating: 61.8%
NBI Status: Structurally Deficient

Bridge Rail: Substandard
Rail Transition: Substandard
Bridge Approach Rail: Substandard
Approach Rail Ends: Substandard

NH Bridge Type: I Beams w/ Concrete Deck
Deck Type: Concrete, Cast in Place
Wearing Surface: Bituminous
Membrane: Other
Deck Protection: None
Pavement thickness: Not Applicable
Curb Reveal: 8.5 in
Plan Location: 17-4-1

Bridge Dimensions:
Length Maximum Span: 150.0 ft
Left Curb/Sidewalk Width: 0.7 ft
Width Curb to Curb: 30.0 ft
Approach Roadway Width (W/ Shoulders): 40.0 ft

Total Bridge Length: 847.0 ft
Right Curb/Sidewalk Width: 0.7 ft
Total Bridge Width: 35.8 ft
Median: No median
Bridge Skew: 10.00 °

Bridge Service:
Type of Service on Bridge: Highway
Type of Service under: Railroad-waterway
Lanes on bridge: 2
Lanes Under: NA

Year Built: 1966
Year Rebuilt: Not Rebuilt
Detour Length: 1.0 mi

AADT: 18363 — Percent Trucks: 6 % — Year of AADT: 2014
Future AADT: 27177 — Year of Future AADT: 2035

Federal or State Definition Bridge:	Fed. Definition Bridge
Roadway Functional Class:	Urban Interstate
New Hampshire Highway System and Class:	Interstate Highway
Eligibility for the National Register of Historic Places:	Not Eligible
Traffic Direction:	One-way traffic

National Bridge Inventory (NBI) Appraisal Ratings:

Deck Geometry:	Minimum Tolerable
Underclearances:	Equal Minimum Criteria
Approach Alignment:	Equal Desirable Criteria
Structural Evaluation:	Above Min. Tolerable
Channel/Channel Protection:	Bank Slumping
Waterway Adequacy:	Above Desirable Criteria
Bridge Scour Critical Status:	Critical during floods
Riprap Condition:	Good Condition
Debris Present:	Debris Present

HEAVY BANK EROSION UPSTREAM. MINOR SCOUR AND DRIFT. TREE DEBRIS AT PIERS # 4 & 5.
Scour Critical by CHa study, possible pile study?

Date of Underwater Inspection: Nov. 2012

AASHTO CoRe Element Condition State Data:

No.	Description	Env.	Material Notes and Condition Notes
14	Concrete Deck - Protected w/ Membrane and Pavement	Severe	*ASPHALT- CRACKED AND POTHOLED AT APPROACHES. POTHOLED AND PATCHED AT RELIEF JOINTS, PATCH POTHOLED AT RELIEF JOINT # 2. CRACKED OVER RELIEF JOINTS AND LIFTED NEAR CURBS AT EAST. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL GRANITE SECTIONS LOOSENED. MODERATE SPALLS AT WEST FASCIA. CURB STONES LOOSE AND ONE MISSING AT NORTHEAST, LOOSE AND TIPPED AT NORTHWEST.*
107	Painted Steel Beam or Girder (Open Web)	Moderate	*WF-BEAMS WITH WEB STIFFENERS, HAUNCHED AT PIERS* *MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. PEN SIZE HOLE IN GIRDER # 4 AT SPAN 3.*
210	Reinforced Concrete Pier Wall	Moderate	*FEW FINE CRACKS. MINOR SPALLS.*
215	Reinforced Concrete Abutment	Moderate	*LIGHT TO MODERATE CRACKS, DELAMINATIONS AND SPALLS. MODERATE SPALLS IN NORTHWEST WING. LARGE SPALLS IN NORTH OF BACKWALL. MODERATE SPALLS IN SOUTH FOOTER, WITH REBAR EXPOSED.*
234	Reinforced Concrete Cap	Low	*HAMMERHEADS* *LIGHT CRACK IN WEST END OF # 5. MINOR SPALLS IN TOP # 4. MINOR SPALL AT EAST END OF # 3.*

No.	Description	Env.	Material Notes and Condition Notes
304	Open Expansion Joint	Severe	*** Finger Joint *** *15 MISSING OR BROKEN FINGERS ON NORTH JOINT, FEW CRACKED. BROKEN WELDS IN PASSING LANE CAUSING PLATE TO SLAP.*
311	Moveable Bearing (roller, sliding, etc.)	Moderate	*ROCKERS* *SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS # 4 & 5, TO THE NORTH AT PIERS # 1 & 2.*
313	Fixed Bearing	Low	*AT PIER #3* *PAINT PEELING AND LIGHT RUST ON EXTERIORS.*
334	Coated Metal Bridge Railing	Severe	*** Steel Angle Rail** TRANSITION RAILS GALVANIZED* *RUSTED, PAINT FLAKED AND PEELED. MINOR SECTION LOSS. LIGHT TRANSITION RAIL DAMAGE. BOTTOM RAIL ANGLE BRACE BROKEN AT SOUTHEAST.*
359	Soffit of Conc Deck or Slab Condition Warning Flag	Severe	*TRANVERSE CRACKS, LIGHT EFFLORESCENCE THROUGHOUT SOFFIT. SPAN 1 HEAVY SPALLS IN BAY 2. DELAMINATION IN BAY 1,3 AND 4. SPAN 2 BAY 3 HAS 2 LARGE SPALLS. BAY 4 LARGE DELAMINATION. BAY 2 SMALL SPALL. SPAN 3 LARGE DELAMINATION IN BAY 4. SPAN 4 DELAMINATION IN BAYS 1 AND 4. SPALLS IN BAY 3. SPAN 5 DELAMINATION IN BAY 4.*
363	Section Loss Condition Warning Flag	Moderate	*Element record added 2011-12-29.* *LIGHT TO MODERATE SECTION LOSS UNDER RELIEF JOINTS IN SPANS # 3 & 4 TO ANGLE BRACING, STIFFENERS, GUSSET PLATES AND BOTTOMS OF WEB. MINOR SECTION LOSS TO UPPER AND LOWER FLANGES. SPAN # 3, GIRDER # 4, PITTED FULL LENGTH ALONG STIFFENER UNDER RELIEF JOINT. RUST AND SCALE BLEEDING THROUGH PAINT AT INTERIOR BAYS, MODERATE AT EXTERIORS. SMALL HOLE IN WEB, THE SIZE OF A PEN IN GIRDER # 4 UNDER RELIEF JOINT. LOWER LATERAL BRACING RUSTED OFF AT X BRACING ON GIRDER 5 UNDER RELIEF JOINT.*

No.	Description	Env.	Quantity	Units	State 1	State 2	State 3	State 4	State 5
14	Concrete Deck - Protected w/ Membran	Severe	30,107	(SF)	0 %	0 %	100 %	0 %	0 %
107	Painted Steel Beam or Girder (Open We	Moderate	4,209	(LF)	0 %	70 %	20 %	10 %	0 %
210	Reinforced Concrete Pier Wall	Moderate	131	(LF)	95 %	5 %	0 %	0 %	
215	Reinforced Concrete Abutment	Moderate	180	(LF)	8 %	80 %	7 %	5 %	
234	Reinforced Concrete Cap	Low	171	(LF)	89 %	11 %	0 %	0 %	
304	Open Expansion Joint	Severe	69	(LF)	55 %	25 %	20 %		
311	Moveable Bearing (roller, sliding, etc.)	Moderate	30	(EA)	60 %	40 %	0 %		
313	Fixed Bearing	Low	5	(EA)	60 %	40 %	0 %		
334	Coated Metal Bridge Railing	Severe	1,873	(LF)	0 %	0 %	100 %	0 %	0 %
359	Soffit of Conc Deck or Slab Condition W	Severe	1	(EA)	0 %	0 %	0 %	100 %	0 %
363	Section Loss Condition Warning Flag	Moderate	1	(EA)	0 %	100 %	0 %	0 %	

Bridge Notes:

Vietnam Veterans Memorial Bridge (1983, Chapter 362)
LIFT INSPECTION 5/07, 12/11,12/29/2011, 6/13/2013, 6/17,2014. 5/27/2015.
REPAIRS TO RELIEF JOINTS,RUST REMOVED PRIMED AND PAINTED IN JUNE 2012.

Approach and Roadway Notes: *PAVEMENT CRACKED, RUTTED , SETTLED AND POTHOLED AT NORTH APPROACH.*
CURBS STONES SETTLED LOOSE AND MISSING.
W-BEAM APPROACH RAIL.

Inspection History:

Inspection Date: 11/18/2015 **Inspector:** MHC

Deck: 4 Poor
Super: 5 Fair
Substr: 5 Fair
Culvert: N N/A (NBI)

Notes:

MHC - inspection comments -
DECK: ASPHALT- CRACKED IN AREAS. POTHOLED AT RELIEF JOINTS AND APPROACHES. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSE. JOINT- 15 MISSING FINGERS AT NORTH EXPANSION JOINT. CRACKS, DELAMINATION, AND SPALLS IN ALL BAYS AND IN ALL SPANS. MINOR LEAKING IN AREAS, MODERATE AT RELIEF JOINTS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED, RUST AND SCALE STARTING TO BLEED THROUGH. SMALL PEN SIZE HOLE IN GIRDER # 4 NEAR BOTTOM FLANGE UNDER RELIEF JOINT. LOWER LATERAL BRACING RUSTED OFF AT GIRDER # 5 IN SPAN 3.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. SPALLS IN TOP OF BACKWALLS. PIERS - FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #3 AND 4.

PICTURES: B546
22. GRANITE CURB LOOSE AND TIPPED AT NORTH END OF WEST CURB.
23. PATCH POTHOLED OVER RELIEF JOINT # 2.

Inspection Date: 05/27/2015 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 5 Fair
Culvert: N N/A (NBI)

Notes:

MTC - inspection comments -
DECK: ASPHALT- CRACKED IN AREAS. POTHOLED AT RELIEF JOINTS AND APPROACHES. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSE. JOINT- 9 MISSING FINGERS AT NORTH EXPANSION JOINT. CRACKS, DELAMINATION, AND SPALLS IN ALL BAYS AND IN ALL SPANS. MINOR LEAKING IN AREAS, MODERATE AT RELIEF JOINTS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED, RUST AND SCALE STARTING TO BLEED THROUGH. SMALL PEN SIZE HOLE IN GIRDER 4 NEAR BOTTOM FLANGE UNDER RELIEF JOINT. LOWER LATERAL BRACING RUSTED OFF AT GIRDER 5 IN SPAN 3.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #3 AND 4.

PICTURES: B531. 23-33.

Inspection History:

Inspection Date: 12/12/2014 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC - inspection comments -
DECK: ASPHALT- CRACKED IN AREAS. POTHOLED AT SECOND RELIEF JOINT AT EAST CURB. NORTH APPROACH CRACKED AND POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSE. JOINT- 15 MISSING FINGERS AT NORTH EXPANSION JOINT. CRACKS, DELAMINATION, AND SPALLS IN BAYS 2, 3, AND 4 IN ALL SPANS. MINOR LEAKING IN AREAS, MODERATE AT RELIEF JOINTS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED, RUST AND SCALE STARTING TO BLEED THROUGH.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B518.
1. POTHOLED AT NORTH APPROACH.

Inspection Date: 06/17/2014 **Inspector:** MHC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MHC - inspection comments -
DECK: ASPHALT- CRACKED IN AREAS. RELIEF JOINTS CRACKED AND LIFTED AT EAST CURB. NORTH APPROACH CRACKED AND POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSE. JOINT- 14 MISSING FINGERS AT NORTH EXPANSION JOINT. CRACKS, DELAMINATION, AND SPALLS IN BAYS 2, 3, AND 4 IN ALL SPANS. MINOR LEAKING IN AREAS, MODERATE AT RELIEF JOINTS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED, RUST AND SCALE STARTING TO BLEED THROUGH.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B500
73 - 87 SEE PIC LIST FOR DESCRIPTIONS.

Inspection Date: 11/18/2013 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- CRACKED IN AREAS. RELIEF JOINTS CRACKED AND LIFTED AT EAST CURB. NORTH APPROACH CRACKED AND POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. JOINT- THIRTEEN MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. CRACKS,DELAMINATION,AND SPALLS IN BAYS 2, 3, AND 4 IN ALL SPANS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4.REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED,JUNE 2012.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B486-45. CURBSTONE LOOSE AND MISSING AT NORTHEAST.

Inspection History:

Inspection Date: 07/31/2013 **Inspector:** MHC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MHC inspection comments -
POST FLOOD INSPECTION - TREE DEBRIS AT PIER # 4. ALL ELEMENTS APPEAR STABLE.
DECK: ASPHALT- CRACKED IN AREAS. NORTH APPROACH POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED.
JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT.
CRACKS,DELAMINATION,AND SPALLS IN BAYS 2, 3, AND 4 IN ALL SPANS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4.REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED,JUNE 2012.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALL'S. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

Inspection Date: 06/13/2013 **Inspector:** MHC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MHC - inspection comments -
DECK: ASPHALT- CRACKED IN AREAS. NORTH APPROACH POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED.
JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. CRACKS, DELAMINATION, SPALLS, AREAS OF LEAKING AND RUST STAINING AT SOFFIT.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, AND GIRDER FLANGES IN NORTH SPAN. REPAIRS MADE TO RELIEF JOINT, RUST REMOVED PRIMED AND PAINTED, LIGHT RUST LEACHING THROUGH. BEARINGS AT BOTH ABUTMENTS HEAVILY RUSTED.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, DELAMINATIONS, AND SPALLS IN BACKWALLS. HEAVY DEBRIS ON SEATS. FEW FINE CRACKS, LIGHT SPALLS AND MINOR DELAMINATIONS AT PIERS.

PICTURES: B467 # 15 - 32
SEE PIC LIST FOR DESCRIPTIONS.

Inspection Date: 03/18/2013 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- CRAKED IN AREAS. NORTH APPROACH POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT.
CRACKS,DELAMINATION,AND SPALLS IN BAYS 2, 3, AND 4 IN ALL SPANS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN.HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4.REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED,JUNE 2012.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B454.
94. POTHOLED AT NORTH APPROACH.
95. PATCHED AREA OVER RELIEF JOINT CRACKED.

Inspection History:

Inspection Date: 11/27/2012 **Inspector:** JEL

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
REFER TO STEARNS ENGINEERING UNDERWATER INSPECTION REPORT 11/27/2012

Inspection Date: 11/16/2012 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- CRAKED IN AREAS CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. CRACKS,DELAMINATION,AND SPALLS IN BAYS 3,4 IN ALL SPANS.(SEE 5/21/12 INSPECTION REPORT.)
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN.HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4.REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED,JUNE 2012.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B446.
72. PATCHED AREA OVER RELIEF JOINT.

Inspection Date: 05/21/2012 **Inspector:** NJL

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
DECK: ASPHALT- CRACKED OVER RELIEF JOINTS. FEW CRACKS IN PAVEMENT OVER DELAMINATIONS. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL GRANITE SECTIONS LOOSENED. CURB STONES LOOSE AT NORTH. RAIL- RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE. BOTTOM ANGLE BRACE BROKEN. JOINT- TWELVE BROKEN FINGERS AT NORTH EXPANSION JOINT, WITH ONE CRACKED. SOFFIT- CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS AT BAYS 2,3 AND 4 THROUGH MOST SPANS. SPALLS WITH REBAR EXPOSED IN AREAS. SOME LIGHT LEAKING EVIDENT AT CURBLINE, RELIEF JOINTS AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURE DESCRIPTION IN STRUCTURE NOTES.

Inspection History:

Inspection Date: 12/29/2011 **Inspector:** NJL

Deck: 5 Fair
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
DECK: ASPHALT- NEW. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. RAIL- RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE. BOTTOM ANGLE BRACE BROKEN. JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. SOFFIT- CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B417.
53 THRU 72 OF ANGLE BRACING, LATERAL BRACING CONNECTIONS, STIFFNERS, SCALE ON LOWER WEBS IN SPAN # 3 AND SPAN # 4 UNDER RELIEF JOINTS.

Inspection Date: 12/12/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC: inspection comments -
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.BOTTOM ANGLE BRACE BROKEN.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. ASPHALT-NEW. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.HEAVY DEBRIS BUILD-UP AT PIER #4.

PICTURES: B416.
52.SOUTH ABUTMENT DEBRIS BUILD-UP.
53.SPALL WITH REBAR EXPOSED AT SPAN 1 BAY 2.
54.CROSS BRACING RUSTED AT SPAN #1 BAY #1
55.DELAMINATION AND SPALL AT SPAN 2 BAY 3
56.CROSS BRACING RUSTED AT SPAN #3 BAY #4
57.DELAMINATION AND SPALL AT SPAN #5 BAY #4.

Inspection History:

Inspection Date: 08/29/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

*MTC: inspection comments - * HIGH WATER INSPECTION:8/29/11 DEBRIS AT #4 PIER.**
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. ASPHALT- WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. ONE QUICK SET PATCH BREAKING UP OVER SPAN 3. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B408.
1.DEBRIS AT PIER #4.
2.NORTH VIEW OF HIGH WATER.

Inspection Date: 06/13/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC: inspection comments -
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. ASPHALT- WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. ONE QUICK SET PATCH BREAKING UP OVER SPAN 3. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B399-3.
3.MODERATE DELAMINATIONS AT NORTH NEAR FINGER JOINT TPYICAL OF SEVERAL AREAS.

Inspection History:

Inspection Date: 03/19/2009 **Inspector:** FNM

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

FNM inspection comments -
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. ASPHALT- WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. ONE QUICK SET PATCH BREAKING UP OVER SPAN 3. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. SIX BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPER: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUB: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS. PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B360-
12. QUICK SET PATCH BREAKING UP OVER SPAN 3.
13. FINGER CRACKED AT NORTH EXPANSION JOINT. (SIX MISSING)

Inspection Date: 05/08/2007 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

BEP inspection comments -
RAIL: RUSTED, PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. SIX BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPER: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUB: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS. PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURE A220-
20: HEAVY DEBRIS AT INTERIOR BEARINGS ON SOUTH ABUTMENT.
21: TYPICAL OF DECK DELAMINATIONS.
22: SPALL AND FORMWORK UNDER PATCHED AREA IN DECK.
23: TYPICAL OF HEAVY RUSTING UNDER RELIEF JOINT IN SPAN #3. BRACING GUSSET RUSTED THRU AT UPSTREAM GIRDER.
24: HEAVY DEBRIS ON INTERIOR BEARINGS AT NORTH ABUTMENT WITH ROCKERS LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS.

Bridge Inspection Report

Inspection History:

Inspection Date: 09/17/2003 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 07/29/2004 09:41:20
BEP inspection comments -
RAIL: RUSTED, PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SO

Inspection Date: 06/12/2001 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 10/15/2002 14:31:19

BEP inspection comments -
RAIL: MODERATE RUSTING. PAINT POOR. NORTH TRANSITIONS DAMAGED.
DECK: CRACKS, LIGHT EFFLORESCENCE, STAINS AND SPALLS WITH AREAS OF LIGHT TO MODERATE L

Inspection Date: 08/09/1999 **Inspector:** WBL

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

LIFT INSPECTION
STEEL ANGLE RAIL: MODERATE RUSTING. PAINT POOR. NORTH TRANSITIONS DAMAGED.
DECK: CRACKS, MEDIUM SPALLS AND DELAMINATIONS. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. MODERATE LEAKING IN AREAS WITH RUST STAINING EVIDENT. FINGER JOIN

Inspection Date: 05/01/1997 **Inspector:** Not Available

Deck: 5 Fair
Super: 7 Good
Substr: 7 Good
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 12-23-98 08:05:16

Inspection Date: 04/01/1995 **Inspector:** Not Available

Deck: 6 Satisfactory
Super: 8 Very Good
Substr: 7 Good
Culvert: N N/A (NBI)

Notes:

Inspection Date: 07/01/1993 **Inspector:** Not Available

Deck: 6 Satisfactory
Super: 8 Very Good
Substr: 7 Good
Culvert: N N/A (NBI)

Notes:

Copy Distribution:

- [ ] (2) Bureau of Municipal Hghways
- [ ] (3) Bureau of Municipal Hghways
- [ ] Bureau of Turnpikes
- [x] Border State
- [ ] Bureau of Rail and Transit
- [ ] Army Corps Of Engineers
- [ ] Railroad
- [ ] Dept. of Res. and Econ. Dev.
- [ ] Dept. of Environmental Services
- [ ] USDA Forest Service
- [ ] Bureau of Traffic

Bridge Inspection Report

Lebanon 044/104

Date of Inspection: 03/18/2013
Date Report Sent: 4/11/2013
☑ Picture taken during inspection
Owner: NHDOT
Bridge also in: Hartford , Vermont

I-89 NB
Over
CONNECTICUT RIVER,NECRR
Vietnam Veteran Memorial
Interstate Bridge Number: 071

Recommended Postings:

Weight: No Posting Required — ☑ Weight Sign OK

Width: Not Required — ☑ Width Sign OK

Primary Height Sign Recommendation: *None*
Optional Centerline Height Sign Rec: *None*

Clearances: (Feet) Over: Under: 38.98 Route:

☑ Height Signs OK

Condition: State Redlist
Deck: 4 Poor
Superstructure: 5 Fair
Substructure: 6 Satisfactory
Culvert: N N/A (NBI)

Structure Type and Materials:
Number of Spans Main Unit: 6
Number of Approach Spans: 0

Main Span Material and Design Type
Steel Continuous Multiple Beam

Sufficiency Rating: 61.7%
NBI Status: Structurally Deficient

Bridge Rail: Substandard
Rail Transition: Substandard
Bridge Approach Rail: Substandard
Approach Rail Ends: Substandard

NH Bridge Type: I Beams w/ Concrete Deck
Deck Type: Concrete, Cast in Place
Wearing Surface: Bituminous
Membrane: Other
Deck Protection: None
Pavement thickness: Not Applicable
Curb Reveal: 8.5 in
Plan Location: 17-4-1

Bridge Dimensions:
Length Maximum Span: 150.0 ft
Left Curb/Sidewalk Width: 0.7 ft
Width Curb to Curb: 30.0 ft
Approach Roadway Width (W/ Shoulders): 40.0 ft

Total Bridge Length: 847.0 ft
Right Curb/Sidewalk Width: 0.7 ft
Total Bridge Width: 35.8 ft
Median: No median
Bridge Skew: 10.00 °

Bridge Service:
Type of Service on Bridge: Highway
Type of Service under: Railroad-waterway
Lanes on bridge: 2
Lanes Under: NA

Year Built: 1966
Year Rebuilt: Not Rebuilt
Detour Length: 1.0 mi

AADT: 19500 Percent Trucks: 6 % Year of AADT: 2012
Future AADT: 28860 Year of Future AADT: 2032

Federal or State Definition Bridge:	Fed. Definition Bridge
Roadway Functional Class:	Urban Interstate
New Hampshire Highway System and Class:	Interstate Highway
Eligibility for the National Register of Historic Places:	Not Eligible
Traffic Direction:	One-way traffic

National Bridge Inventory (NBI) Appraisal Ratings:

Deck Geometry:	Minimum Tolerable
Underclearances:	Equal Minimum Criteria
Approach Alignment:	Equal Desirable Criteria
Structural Evaluation:	Above Min. Tolerable
Channel/Channel Protection:	Bank Slumping
Waterway Adequacy:	Above Desirable Criteria
Bridge Scour Critical Status:	Critical during floods
Riprap Condition:	Good Condition
Debris Present:	Debris Present

HEAVY BANK EROSION UPSTREAM. MINOR SCOUR AND DRIFT.
Scour Critical by CHa study, possible pile study?

Date of Underwater Inspection: Nov. 2012

AASHTO CoRe Element Condition State Data:

No.	Description	Env.	Material Notes and Condition Notes
14	Concrete Deck - Protected w/ Membrane and Pavement	Severe	*ASPHALT- CRACKED OVER RELIEF JOINT #1. FEW CRACKS IN PAVEMENT OVER DELAMINATIONS. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL GRANITE SECTIONS LOOSENED. CURB STONES LOOSE AND ONE MISSING AT NORTH.*
107	Painted Steel Beam or Girder (Open Web)	Moderate	*WF-BEAMS WITH WEB STIFFENERS, HAUNCHED AT PIERS* *MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING.*
210	Reinforced Concrete Pier Wall	Moderate	*FEW FINE CRACKS.*
215	Reinforced Concrete Abutment	Moderate	*LIGHT TO MODERATE CRACKS ANDDELAMINATIONS. MODERATE SPALLS IN NORTHWEST WINS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER.*
234	Reinforced Concrete Cap	Low	*HAMMERHEADS* *LIGHT CRACK IN WEST END OF #5. MINOR SPALLS IN TOP #4.*
304	Open Expansion Joint	Severe	** *Finger Joint* ** *12 MISSING OR BROKEN FINGERS ON NORTH JOINT, ONE CRACKED.*

No.	Description	Env.	Material Notes and Condition Notes
311	Moveable Bearing (roller, sliding, etc.)	Moderate	*ROCKERS* *DEBRIS BUILD-UP AT ABUTMENTS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.*
313	Fixed Bearing	Low	*AT PIER #3* *PAINT PEELING AND LIGHT RUST ON EXTERIORS.*
334	Coated Metal Bridge Railing	Severe	*** Steel Angle Rail** TRANSITION RAILS GALVANIZED* *RUSTED, PAINT FLAKED AND PEELED. MINOR SECTION LOSS. LIGHT TRANSITION RAIL DAMAGE.BOTTOM RAIL ANGLE BRACE BROKEN AT SOUTHEAST.*
359	Soffit of Conc Deck or Slab Condition Warning Flag	Severe	*CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS AT BAYS 2, 3 AND 4 THROUGH MOST SPANS. SPALLS WITH REBAR EXPOSED IN AREAS. SOME LIGHT LEAKING EVIDENT AT CURBLINE, RELIEF JOINTS AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.*
363	Section Loss Condition Warning Flag	Moderate	*Element record added 2011-12-29.* *LIGHT TO MODERATE SECTION LOSS IN SPAN # 3 AND SPAN # 4 UNDER RELIEF JOINTS TO ANGLE BRACING, STIFFNERS, GUSSET PLATES AND BOTTOMS OF WEB. MINOR SECTION LOSS TO UPPER AND LOWER FLANGES. SPAN # 3, GIRDER # 4, PITTED FULL LENGTH ALONG STIFFNER, UNDER RELIEF JOINT.*

No.	Description	Env.	Quantity	Units	State 1	State 2	State 3	State 4	State 5
14	Concrete Deck - Protected w/ Membran	Severe	30,107	(SF)	0 %	0 %	100 %	0 %	0 %
107	Painted Steel Beam or Girder (Open We	Moderate	4,209	(LF)	0 %	77 %	20 %	3 %	0 %
210	Reinforced Concrete Pier Wall	Moderate	131	(LF)	95 %	5 %	0 %	0 %	
215	Reinforced Concrete Abutment	Moderate	180	(LF)	13 %	80 %	7 %	0 %	
234	Reinforced Concrete Cap	Low	171	(LF)	94 %	6 %	0 %	0 %	
304	Open Expansion Joint	Severe	69	(LF)	68 %	20 %	12 %		
311	Moveable Bearing (roller, sliding, etc.)	Moderate	30	(EA)	67 %	33 %	0 %		
313	Fixed Bearing	Low	5	(EA)	60 %	40 %	0 %		
334	Coated Metal Bridge Railing	Severe	1,873	(LF)	0 %	0 %	100 %	0 %	0 %
359	Soffit of Conc Deck or Slab Condition W	Severe	1	(EA)	0 %	0 %	100 %	0 %	0 %
363	Section Loss Condition Warning Flag	Moderate	1	(EA)	0 %	100 %	0 %	0 %	

Bridge Notes:

Vietnam Veterans Memorial Bridge (1983, Chapter 362)
LIFT INSPECTION 5/07
LIFT INSPECTION 12/11
LIFT INSPECTION 12/29/2011.
REPAIRS TO RELIEF JOINTS,RUST REMOVED PRIMED AND PAINTED IN JUNE 2012.

Approach and Roadway Notes: *PAVEMENT CRACKED, RUTTED , SETTLED AND POTHOLED AT NORTH APPROACH.*
CURBS STONES SETTLED LOOSE AND MISSING.
W-BEAM APPROACH RAIL.

Inspection History:

Inspection Date: 03/18/2013 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- CRAKED IN AREAS. NORTH APPROACH POTHOLED. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. CRACKS,DELAMINATION,AND SPALLS IN BAYS 2, 3, AND 4 IN ALL SPANS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN.HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4.REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED,JUNE 2012.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B454.
94. POTHOLED AT NORTH APPROACH.
95. PATCHED AREA OVER RELIEF JOINT CRACKED.

Inspection Date: 11/27/2012 **Inspector:** JEL

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
REFER TO STEARNS ENGINEERING UNDERWATER INSPECTION REPORT 11/27/2012

Inspection Date: 11/16/2012 **Inspector:** MTC

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- CRAKED IN AREAS CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. CRACKS,DELAMINATION,AND SPALLS IN BAYS 3,4 IN ALL SPANS.(SEE 5/21/12 INSPECTION REPORT.)
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN.HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4.REPAIRS MADE TO RELIEF JOINT,RUST REMOVED PRIMED AND PAINTED,JUNE 2012.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B446.
72. PATCHED AREA OVER RELIEF JOINT.

Inspection History:

Inspection Date: 05/21/2012 **Inspector:** NJL

Deck: 4 Poor
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
DECK: ASPHALT- CRACKED OVER RELIEF JOINTS. FEW CRACKS IN PAVEMENT OVER DELAMINATIONS. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL GRANITE SECTIONS LOOSENED. CURB STONES LOOSE AT NORTH. RAIL- RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE. BOTTOM ANGLE BRACE BROKEN. JOINT- TWELVE BROKEN FINGERS AT NORTH EXPANSION JOINT, WITH ONE CRACKED. SOFFIT- CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS AT BAYS 2,3 AND 4 THROUGH MOST SPANS. SPALLS WITH REBAR EXPOSED IN AREAS. SOME LIGHT LEAKING EVIDENT AT CURBLINE, RELIEF JOINTS AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURE DESCRIPTION IN STRUCTURE NOTES.

Inspection Date: 12/29/2011 **Inspector:** NJL

Deck: 5 Fair
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
DECK: ASPHALT- NEW. CURBS- CRACKS AND LIGHT TO MODERATE SPALLS WITH SEVERAL STONES LOOSENED. RAIL- RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE. BOTTOM ANGLE BRACE BROKEN. JOINT- TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. SOFFIT- CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND LATERAL BRACING CONNECTION PLATES TO GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B417.
53 THRU 72 OF ANGLE BRACING, LATERAL BRACING CONNECTIONS, STIFFNERS, SCALE ON LOWER WEBS IN SPAN # 3 AND SPAN # 4 UNDER RELIEF JOINTS.

Bridge Inspection Report

Inspection History:

Inspection Date: 12/12/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC: inspection comments -
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.BOTTOM ANGLE BRACE BROKEN.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. ASPHALT-NEW. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3 AND SPAN #4. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #1 #2 #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.HEAVY DEBRIS BUILD-UP AT PIER #4.

PICTURES: B416.
52.SOUTH ABUTMENT DEBRIS BUILD-UP.
53.SPALL WITH REBAR EXPOSED AT SPAN 1 BAY 2.
54.CROSS BRACING RUSTED AT SPAN #1 BAY #1
55.DELAMINATION AND SPALL AT SPAN 2 BAY 3
56.CROSS BRACING RUSTED AT SPAN #3 BAY #4
57.DELAMINATION AND SPALL AT SPAN #5 BAY #4.

Inspection History:

Inspection Date: 08/29/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

*MTC: inspection comments - * HIGH WATER INSPECTION:8/29/11 DEBRIS AT #4 PIER.**
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.
ASPHALT- WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. ONE QUICK SET PATCH BREAKING UP OVER SPAN 3.
CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B408.
1.DEBRIS AT PIER #4.
2.NORTH VIEW OF HIGH WATER.

Inspection Date: 06/13/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC: inspection comments -
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS.
ASPHALT- WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. ONE QUICK SET PATCH BREAKING UP OVER SPAN 3.
CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. TWELVE MISSING OR BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPERSTRUCTURE: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUBSTRUCTURE: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS.
PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B399-3.
3.MODERATE DELAMINATIONS AT NORTH NEAR FINGER JOINT TPYICAL OF SEVERAL AREAS.

Inspection History:

Inspection Date: 03/19/2009 **Inspector:** FNM

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

FNM inspection comments -
RAIL: RUSTED, MINOR SECTION LOSS. PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. ASPHALT- WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. ONE QUICK SET PATCH BREAKING UP OVER SPAN 3. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. SIX BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPER: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUB: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS. PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURES: B360-
12. QUICK SET PATCH BREAKING UP OVER SPAN 3.
13. FINGER CRACKED AT NORTH EXPANSION JOINT. (SIX MISSING)

Inspection Date: 05/08/2007 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

BEP inspection comments -
RAIL: RUSTED, PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SOME LIGHT LEAKING EVIDENT AT CURBLINE AND RELIEF JOINTS, AND IN FEW AREAS IN NORTH SPAN. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. WHEEL RUTS AND SHORT, LIGHT CRACKS IN PAVEMENT WITH SEVERAL SMALL AREAS DELAMINATING. CRACKS AND LIGHT TO MODERATE SPALLS IN CURBS WITH SEVERAL STONES LOOSENED. SIX BROKEN FINGERS AT NORTH EXPANSION JOINT. FEW DRAINS PLUGGED.
SUPER: MINOR TO LIGHT RUST. SOME HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND ON EXTERIOR GIRDERS IN NORTH SPAN. PAINT CRACKED AND PEELING. SEVERAL LOOSE BRACING FRAME BOLTS. HEAVY SECTION LOSS IN ANGLE BRACING AND GUSSET AT EXTERIOR GIRDERS UNDER RELIEF JOINT IN SPAN #3. DEBRIS BUILD-UP AT ABUTMENT BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS. INTERIOR ROCKERS AT NORTH LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS. ROCKERS TIPPED BACK TO NEAR FULL EXPANSION AT NORTH AND TIPPED SLIGHTLY TO SOUTH AT PIERS #4 AND #5.
SUB: FINE AND LIGHT CRACKS. LIGHT DELAMINATIONS. LIGHT SPALLS IN TOP OF BACKWALLS. MODERATE SPALLS IN SOUTH FOOTER. HEAVY DEBRIS ON SEATS. PIERS: FEW FINE CRACKS. LIGHT CRACK IN DOWNSTREAM END OF CAP #5. MINOR SPALLS IN TOP OF #4.

PICTURE A220-
20: HEAVY DEBRIS AT INTERIOR BEARINGS ON SOUTH ABUTMENT.
21: TYPICAL OF DECK DELAMINATIONS.
22: SPALL AND FORMWORK UNDER PATCHED AREA IN DECK.
23: TYPICAL OF HEAVY RUSTING UNDER RELIEF JOINT IN SPAN #3. BRACING GUSSET RUSTED THRU AT UPSTREAM GIRDER.
24: HEAVY DEBRIS ON INTERIOR BEARINGS AT NORTH ABUTMENT WITH ROCKERS LIFTED SLIGHTLY DUE TO PACK RUST AND DEBRIS.

Inspection History:

Inspection Date: 09/17/2003 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 07/29/2004 09:41:20
BEP inspection comments -
RAIL: RUSTED, PAINT FLAKED AND PEELED. LIGHT TRANSITION RAIL DAMAGE.
DECK: CRACKS, LIGHT EFFLORESCENCE AND STAINS. MODERATE TO HEAVY DELAMINATIONS. SO

Inspection Date: 06/12/2001 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 10/15/2002 14:31:19

BEP inspection comments -
RAIL: MODERATE RUSTING. PAINT POOR. NORTH TRANSITIONS DAMAGED.
DECK: CRACKS, LIGHT EFFLORESCENCE, STAINS AND SPALLS WITH AREAS OF LIGHT TO MODERATE L

Inspection Date: 08/09/1999 **Inspector:** WBL

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

LIFT INSPECTION
STEEL ANGLE RAIL: MODERATE RUSTING. PAINT POOR. NORTH TRANSITIONS DAMAGED.
DECK: CRACKS, MEDIUM SPALLS AND DELAMINATIONS. SEVERAL FORMS IN PLACE FROM DECK REPAIRS. MODERATE LEAKING IN AREAS WITH RUST STAINING EVIDENT. FINGER JOIN

Inspection Date: 05/01/1997 **Inspector:** Not Available

Deck: 5 Fair
Super: 7 Good
Substr: 7 Good
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 12-23-98 08:05:16

Inspection Date: 04/01/1995 **Inspector:** Not Available

Deck: 6 Satisfactory
Super: 8 Very Good
Substr: 7 Good
Culvert: N N/A (NBI)

Notes:

Inspection Date: 07/01/1993 **Inspector:** Not Available

Deck: 6 Satisfactory
Super: 8 Very Good
Substr: 7 Good
Culvert: N N/A (NBI)

Notes:

Copy Distribution:

- [ ] (2) Bureau of Municipal Hghways
- [ ] (3) Bureau of Municipal Hghways
- [ ] Bureau of Turnpikes
- [x] Border State
- [ ] Bureau of Rail and Transit
- [ ] Army Corps Of Engineers
- [ ] Railroad
- [ ] Dept. of Res. and Econ. Dev.
- [ ] Dept. of Environmental Services
- [ ] USDA Forest Service
- [ ] Bureau of Traffic

Bridge Inspection Report

Lebanon 044/103

Date of Inspection: 03/18/2013
Date Report Sent: 4/17/2013
☑ Picture taken during inspection
Owner: NHDOT
Bridge also in: Hartford , Vermont

I-89 SB
Over
CONNECTICUT RIVER,NECRR
Vietnam Veteran Memorial
Interstate Bridge Number: 071

Recommended Postings:

Weight: No Posting Required — ☑ Weight Sign OK

Width: Not Required — ☑ Width Sign OK

Primary Height Sign Recommendation: *None*
Optional Centerline Height Sign Rec: *None*

Clearances: (Feet) Over: Under: 37.99 Route:

☑ Height Signs OK

Condition: State Redlist
Deck: 5 Fair
Superstructure: 4 Poor
Substructure: 6 Satisfactory
Culvert: N N/A (NBI)

Structure Type and Materials:
Number of Spans Main Unit: 6
Number of Approach Spans: 0

Main Span Material and Design Type
Steel Continuous Multiple Beam

Sufficiency Rating: 49.9%
NBI Status: Structurally Deficient

Bridge Rail: Substandard
Rail Transition: Substandard
Bridge Approach Rail: Meets Standards
Approach Rail Ends: Substandard

NH Bridge Type: I Beams w/ Concrete Deck
Deck Type: Concrete, Cast in Place
Wearing Surface: Bituminous
Membrane: Other
Deck Protection: None
Pavement thickness: Not Applicable
Curb Reveal: 8.5 in
Plan Location: 17-4-1

Bridge Dimensions:
Length Maximum Span: 150.0 ft
Left Curb/Sidewalk Width: 0.7 ft
Width Curb to Curb: 30.0 ft
Approach Roadway Width (W/ Shoulders): 40.0 ft

Total Bridge Length: 846.0 ft
Right Curb/Sidewalk Width: 0.7 ft
Total Bridge Width: 35.8 ft
Median: No median
Bridge Skew: 10.00 °

Bridge Service:
Type of Service on Bridge: Highway
Type of Service under: Railroad-waterway
Lanes on bridge: 2
Lanes Under: NA

Year Built: 1966
Year Rebuilt: Not Rebuilt
Detour Length: 1.0 mi

AADT: 19500 Percent Trucks: 9% Year of AADT: 2012
Future AADT: 28860 Year of Future AADT: 2032

Bridge Inspection Report

Federal or State Definition Bridge:	Fed. Definition Bridge
Roadway Functional Class:	Urban Interstate
New Hampshire Highway System and Class:	Interstate Highway
Eligibility for the National Register of Historic Places:	Not Eligible
Traffic Direction:	One-way traffic

National Bridge Inventory (NBI) Appraisal Ratings:

Deck Geometry:	Minimum Tolerable
Underclearances:	Equal Minimum Criteria
Approach Alignment:	Equal Desirable Criteria
Structural Evaluation:	Minimum Tolerable
Channel/Channel Protection:	Bank Slumping
Waterway Adequacy:	Above Desirable Criteria
Bridge Scour Critical Status:	Critical during floods
Riprap Condition:	Good Condition
Debris Present:	No Debris Present

LIGHT BANK EROSION. SCOUR: REFER TO MOST RECENT DIVE REPORT.
Scour Critical by CHA study. Pile study? TREE DEBRIS AT PIER # 4.

Date of Underwater Inspection: Nov. 2012

AASHTO CoRe Element Condition State Data:

No.	Description	Env.	Material Notes and Condition Notes
14	Concrete Deck - Protected w/ Membrane and Pavement	Severe	*ASPHALT- SEAM AT CENTERLINE. DEICING SYSTEM REMOVED, CRACK SEALED. LOOSENED CURBSTONES. MORTAR CRACKED AND MISSING AT MOST JOINTS. CURBSTONES CRACKED, TIPPED AND MOVED AT NORTHWEST. CONCRETE CORE SAMPLES DRILLED AT SOUTHEAST.*
107	Painted Steel Beam or Girder (Open Web)	Moderate	*PAINT CRACKED WITH LIGHT FLAKING AND PEELING. LIGHT RUST; HEAVY RUST UNDER EXPANSION AND RELIEF JOINTS AND IN AREAS ON EXTERIOR FLANGES.HEAVY RUST AND PITTING AT BEAMS #4 & #5 AT BOTTOM OF WEBS IN SPAN #3 AND BEAMS #1, #4, & #5 AT SPAN #4 UNDER EXPANSION JOINT. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3. REPAIRED WITH A PLATES AND BOLTED AT WEB AND BOTTOM FLANGE BY B.O.B.M.*
210	Reinforced Concrete Pier Wall	Moderate	*FEW FINE CRACKS AND MINOR POP OUT SPALLS.*
215	Reinforced Concrete Abutment	Moderate	*FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED. LIGHT TO MODERATE SPALLS IN BACKWALLS.*
234	Reinforced Concrete Cap	Low	*HAMMERHEADS* *FEW FINE CRACKS; MINOR DELAM IN NORTHWEST CORNER #2.*

No.	Description	Env.	Material Notes and Condition Notes
304	Open Expansion Joint	Severe	*SEVERAL WELDED REPAIRS MADE TO FINGERS ON SOUTH, SEVENTEEN MISSING. SOUTH DECKEND SETTLED. HOLED AREA AT SOUTHEAST APPROACH. JOINT WELDS BROKEN, SLAPPING AND HOLLOW SOUNDING. ONE FINGER MISSING ON NORTH. RUSTED.*
311	Moveable Bearing (roller, sliding, etc.)	Moderate	*ROCKERS* *HEAVY RUST; SECTION LOSS ON ANCHOR BOLTS AT SOUTH END AND #4 AT NORTH. BEARING #3 LIFTED 1/4 INCH FROM DIRT BUILD UP AT SOUTH. SEVERAL ANCHOR BOLTS APPEAR LIFTED AT PIERS.*
313	Fixed Bearing	Low	*AT CENTER PIER* *LITTLE DETERIORATION.*
334	Coated Metal Bridge Railing	Severe	*** Steel Angle Rail ** PAINTED ANGLE / POSTS WITH GALVN. TRANSITIONS* *MODERATE RUST. LIGHT DAMAGE.*
359	Soffit of Conc Deck or Slab Condition Warning Flag	Severe	*LIGHT TO MODERATE DELAMINATIONS AND LEAKING IN ALL SPANS BAYS 1,2, AND 3. MEDIUM SPALL, REBAR EXPOSED IN SPAN #2, BAY #2. FEW TRANSVERSE CRACKS, MINOR DELAMINATIONS, MINOR SPALLS AT EXTERIORS.*
363	Section Loss Condition Warning Flag	Severe	*INTERIOR BOTTOM FLANGES RUSTED ALONG EDGES UNDER LEAKING DECK RELIEF JOINTS WITH MEASURMENTS AS FOLLOWS - 7/8 INCH GRIDER #1, SPAN #3 AND AND 15/16 INCH GIRDER #5, SPAN #4. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3, UNDER RELIEF JOINT.REPAIRED BY B.O.B.M. WITH PLATES AT WEB AND BOTTOM FLANGE.*

No.	Description	Env.	Quantity	Units	State 1	State 2	State 3	State 4	State 5
14	Concrete Deck - Protected w/ Membran	Severe	30,290	(SF)	0 %	0 %	100 %	0 %	0 %
107	Painted Steel Beam or Girder (Open We	Moderate	4,209	(LF)	0 %	70 %	10 %	20 %	0 %
210	Reinforced Concrete Pier Wall	Moderate	131	(LF)	100 %	0 %	0 %	0 %	
215	Reinforced Concrete Abutment	Moderate	180	(LF)	20 %	70 %	10 %	0 %	
234	Reinforced Concrete Cap	Low	171	(LF)	100 %	0 %	0 %	0 %	
304	Open Expansion Joint	Severe	69	(LF)	42 %	33 %	25 %		
311	Moveable Bearing (roller, sliding, etc.)	Moderate	30	(EA)	67 %	33 %	0 %		
313	Fixed Bearing	Low	5	(EA)	100 %	0 %	0 %		
334	Coated Metal Bridge Railing	Severe	1,873	(LF)	0 %	0 %	80 %	20 %	0 %
359	Soffit of Conc Deck or Slab Condition W	Severe	1	(EA)	0 %	0 %	100 %	0 %	0 %
363	Section Loss Condition Warning Flag	Severe	1	(EA)	0 %	100 %	0 %	0 %	

Bridge Notes:

Vietnam Veterans Memorial Bridge (1983, Chapter 362) DEICING SYSTEM INSTALLED IN WEARING SURFACE AT CENTERLINE.
LIFT INSPECTION 9/03.
LIFT INSPECTION 5/07.
LIFT INSPECTION 12/27/11 ADDED TO STATE REDLIST.
B.O.B.M MADE REPAIRS TO RELIEF JOINTS AND REMOVED RUST AND PRIMED AND PAINTED RUSTED BEAMS UNDER RELIEF JOINTS.JUNE OF 2012.

Approach and Roadway Notes: *ASPHALT- NEW 2012. W-BEAM RAIL- LIGHT DAMAGE.*

Inspection History:

Inspection Date: 03/18/2013 **Inspector:** MHC

Deck: 5 Fair
Super: 4 Poor
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MHC - inspection comments -
BRIDGE RAIL: MODERATE RUST.
DECK: ASPHALT SEALED AT CENTERLINE. GRANITE FACING CRACKED AND TIPPED AT NORTHWEST. MORTAR CRACKED, AND MISSING AT MOST JOINTS. CRACKS, DELAMINATIONS, MINOR SPALLS, AND LIGHT LEAKING AT SOFFIT.
SUPERSTRUCTURE: PAINT CRACKED AND FLAKING. HEAVY RUST UNDER EXPANSION JOINTS, RELIEF JOINTS, AND EXTERIOR FLANGES. HEAVY RUST AT MOVABLE BEARINGS, ANCHOR BOLTS LIFTED AT SEVERAL PIER BEARINGS.
SUBSTRUCTURE: MINOR TO LIGHT CRACKS, DELAMINATIONS, AND SPALLS AT ABUTMENTS AND BACKWALLS. LIGHT CRACKS, MINOR SPALLS AT PIERS.

PICTURES: B454
92. SPALLS BEHIND GRANITE CURBSTONES.
93. GRANITE CURBSTONES CRACKED AND TIPPED AT NORTHWEST.

Inspection Date: 11/27/2012 **Inspector:** JEL

Deck: 5 Fair
Super: 4 Poor
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

JEL inspection comments -
REFER TO STEARNS ENGINEERING UNDERWATER INSPECTIONS 11/27/12

Inspection Date: 11/16/2012 **Inspector:** MTC

Deck: 5 Fair
Super: 4 Poor
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- NEW 2012 CURBS- LIGHT TO MODERATE SPALLS, REBAR EXPOSED. SOFFIT- FINE CRACKS, LIGHT LEAKING, MEDIUM SPALLS AND DELAMINATIONS. RELIEF JOINTS REPAIRED AND SEALED AT CURBS. FINGERS JOINT HAS SEVENTEEN MISSING ON SOUTH EXPANSION JOINT, ONE MISSING FINGER ON NORTH.
SUPERSTRUCTURE:PAINT CRACKED WITH LIGHT FLAKING AND PEELING. LIGHT RUST; HEAVY RUST UNDER EXPANSION AND RELIEF JOINTS AND IN AREAS ON EXTERIOR FLANGES REPAIRED AND PRIMED AND PAINT.HEAVY RUST AND PITTING AT BEAMS #4 & #5 AT BOTTOM OF WEBS IN SPAN #3 AND BEAMS #1, #4, & #5 AT SPAN #4 UNDER EXPANSION JOINT. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3. REPAIRED WITH A PLATES AND BOLTED AT WEB AND BOTTOM FLANGE BY B.O.B.M.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS. LIGHT AND MEDIUM SPALLS IN BACKWALLS. VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS. FEW FINE CRACKS AND MINOR SCOURING AT WATERLINE AND SMALL POP OUTS AT CONSTRUCTION JOINTS ON PIERS.

Inspection History:

Inspection Date: 05/24/2012 **Inspector:** MTC

Deck: 5 Fair
Super: 4 Poor
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK:SEAM AT CENTERLINE FOR DEICING SYSTEM INSTALLED AT CENTERLINE SEALED.CURBS LIGHT TO MODERATE SPALLS, REBAR EXPOSED.SEVERAL DECK DRAINS PLUGGED WITH DEBRIS. RAIL MODERATE RUST, PAINT POOR, LIGHT DAMAGE. SOFFIT- FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. MODERATE LEAKING AT RELIEF JOINTS. FINGER JOINT SEVERAL WELDED REPAIRS MADE TO FINGERS ON SOUTH, FIFTEEN MISSING AND ONE AT NORTH. PATCHED AREA AT SOUTHEAST APPROACH JOINT LOUD AND HOLLOW SOUNDING.
SUPERSTRUCTURE: LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3 (REPAIRED BY BOBM, BOLTED WEB AND FLANGE PLATES). NEARLY HOLED THROUGH AT SPAN #3 BEAM #5 AT BOTTOM OF WEB NEAR FLANGE. INTERIOR EDGE OF BOTTOM FLANGE RUSTED TO 7/8 INCH IN SAME AREA. BEARINGS-HEAVY RUST ON SOUTH WITH SECTION LOSS ON ANCHOR BOLTS. MODERATE RUST AT NORTH. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DEBRIS BUILD UP.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS. LIGHT AND MEDIUM SPALLS IN.VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS

PICTURE: B431.
18.DELAMINATION IN BAY 3 SPAN 5.
19.CURB SPALLED AT WEST.
20.DELAMINATION IN SPAN 2 BAY 1.
21SPALL WITH REBAR EXPOSED SPAN 2 BAY 2.
22.BEARINGS # 3,4 DEBRIS COVERED ON SOUTH.
23.JOINT AT SOUTH BROKEN AND SLAPPING.
24.ASPHALT POTHOLED AT SOUTH IN SPAN 3.

Inspection Date: 03/15/2012 **Inspector:** MTC

Deck: 5 Fair
Super: 4 Poor
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK: ASPHALT- SEVERAL CRACKS, LIGHT DEPRESSIONS AND HOLLOW SOUNDING IN AREAS. CRACKED AND DEPRESSED AREA IN SPAN FOUR NEAR CENTERLINE. CURBS-LIGHT TO MODERATE SPALLS, REBAR EXPOSED. HEAVY DIRT AND DEBRIS BUILD UP AT CURBS WITH LOOSENED CURBSTONES. SEVERAL DECK DRAINS PLUGGED WITH DEBRIS. DEICING SYSTEM INSTALLED AT CENTERLINE.SOFFIT- FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. MODERATE LEAKING AT RELIEF JOINTS AT CURBLINES. FINGERS JOINT HAS SEVENTEEN MISSING ON SOUTH EXPANSION JOINT, ONE MISSING FINGER ON NORTH.
SUPERSTRUCTURE:(SEE 12/27/12 REPORT) LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS. ONE INCH HOLE IN WEB OF GIRDER #1, SPAN #3 AND NEARLY HOLED THROUGH IN SPAN 5 AND INTERIOR EDGES OF BOTTOM FLANGES RUSTED TO 7/8 INCH IN SAME AREA. BEARINGS- HEAVY RUST ON SOUTH WITH SECTION LOSS ON ANCHOR BOLTS. MODERATE RUST AT NORTH. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DIRT BUILD UP.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS. LIGHT AND MEDIUM SPALLS IN BACKWALLS. VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS. FEW FINE CRACKS AND MINOR SCOURING AT WATERLINE AND SMALL POP OUTS AT CONSTRUCTION JOINTS ON PIERS.

PICTURE: B423.
38. TRAVEL LANE IN SOUTHBOUND LANE SETTLED.

Inspection History:

Inspection Date: 12/27/2011 **Inspector:** MTC

Deck: 5 Fair
Super: 4 Poor
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

MTC inspection comments -
DECK:SEAM AT CENTERLINE FOR DEICING SYSTEM INSTALLED AT CENTERLINE SEALED.CURBS LIGHT TO MODERATE SPALLS, REBAR EXPOSED.SEVERAL DECK DRAINS PLUGGED WITH DEBRIS. RAIL MODERATE RUST, PAINT POOR, LIGHT DAMAGE. SOFFIT- FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. MODERATE LEAKING AT RELIEF JOINTS. FINGER JOINT SEVERAL WELDED REPAIRS MADE TO FINGERS ON SOUTH, FIFTEEN MISSING AND ONE AT NORTH. PATCHED AREA AT SOUTHEAST APPROACH JOINT LOUD AND HOLLOW SOUNDING.
SUPERSTRUCTURE: LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3 (REPAIRED BY BOBM, BOLTED WEB AND FLANGE PLATES). NEARLY HOLED THROUGH AT SPAN #3 BEAM #5 AT BOTTOM OF WEB NEAR FLANGE. INTERIOR EDGE OF BOTTOM FLANGE RUSTED TO 7/8 INCH IN SAME AREA. BEARINGS-HEAVY RUST ON SOUTH WITH SECTION LOSS ON ANCHOR BOLTS. MODERATE RUST AT NORTH. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DEBRIS BUILD UP.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS. LIGHT AND MEDIUM SPALLS IN.VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS

PICTURE: B417.
36.BEAM #4 SPAN 3 RUST AND PITTING.
37.BEAM 5 SPAN 3 EXTERIOR SIDE.
38.BEAM 5 SPAN 3 INTERIOR RUSTED AND PITTING.
39.REPAIRS AT BEAM 1 SPAN 3 EXTERIOR WEB.
40.REPAIRS AT BEAM 1 SPAN 3 INTERIOR WEB.
41.REPAIRS AT BEAM 1 SPAN 3 INTERIOR WEB.
42.BEAM 1 SPAN 4 EXTERIOR WEB RUSTED AND PITTING.
43.BEAM 1 SPAN 3 INTERIOR WEB SCALING
44.BEAM 4 SPAN 4 SCALING.
45.BEAM 5 SPAN 4 RUSTED AND PITTING.
46.BEAM 5 SPAN 4 RUSTED AND PITTING.

Inspection History:

Inspection Date: 12/14/2011 **Inspector:** NJL

Deck: 5 Fair
Super: 5 Fair
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
DECK: ASPHALT- RESURFACED, SEAM AT CENTERLINE. DEICING SYSTEM INSTALLED AT CENTERLINE, CRACK SEALED. CURBS- LIGHT TO MODERATE SPALLS, REBAR EXPOSED. LOOSENED CURBSTONES FULL LENGTH AT EAST AND WEST. CONCRETE CORE SAMPLES DRILLED AT SOUTHEAST. SEVERAL DECK DRAINS PLUGGED WITH DEBRIS. STEEL ANGLE RAIL- MODERATE RUST, PAINT POOR, LIGHT DAMAGE. SOFFIT- FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. MODERATE LEAKING AT RELIEF JOINTS AT CURBLINES. JOINTS- SEVERAL WELDED REPAIRS MADE TO FINGERS ON SOUTH, FIFTEEN MISSING. PATCHED AREA AT SOUTHEAST APPROACH; JOINT LOUD AND HOLLOW SOUNDING. ONE FINGER MISSING ON NORTH. RUSTED.
SUPERSTRUCTURE: LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3, UNDER RELIEF JOINT AND NEARLY HOLED THROUGH IN SPAN #5, INTERIOR EDGES OF BOTTOM FLANGES RUSTED TO 7/8 INCH IN SAME AREA. BEARINGS- HEAVY RUST ON SOUTH WITH SECTION LOSS ON ANCHOR BOLTS. MODERATE RUST AT NORTH. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DIRT BUILD UP.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS. LIGHT AND MEDIUM SPALLS IN BACKWALLS. VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS. FEW FINE CRACKS AND MINOR SCOURING AT WATERLINE AND SMALL POP OUTS AT CONSTRUCTION JOINTS ON PIERS.

PICTURE: B416.
64. BEARING #4 AT NORTH ABUTMENT, NUT RUSTED AND BOLT LIFTED.
65. CROSS BRACING RUSTED AND HOLED AT #5 GIRDER, SPAN #4 UNDER RELIEF JOINT.
66. 16" VERTICAL CRACK ADJACENT TO 1 1/2 BY 2 1/2 HOLE IN WEB OF GIRDER #1 IN SPAN #3.
67. INSIDE VIEW OF CRACK AND HOLE IN GIRDER #1, SPAN #3, UNDER RELIEF JOINT.

Inspection History:

Inspection Date: 06/13/2011 **Inspector:** NJL

Deck: 5 Fair
Super: 6 Satisfactory
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

NJL inspection comments -
DECK: ASPHALT- SEVERAL CRACKS, LIGHT DEPRESSIONS AND HOLLOW SOUNDING IN AREAS. CRACKED AND DEPRESSED AREA IN SPAN FOUR NEAR CENTERLINE. CURBS- LIGHT TO MODERATE SPALLS, REBAR EXPOSED. HEAVY DIRT AND DEBRIS BUILD UP AT CURBS WITH LOOSENED CURBSTONES. SEVERAL DECK DRAINS PLUGGED WITH DEBRIS. DEICING SYSTEM INSTALLED AT CENTERLINE. STEEL ANGLE RAIL- MODERATE RUST, PAINT POOR, LIGHT DAMAGE. SOFFIT- FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. MODERATE LEAKING AT RELIEF JOINTS AT CURBLINES. JOINTS- WELDED REPAIRS TO FINGERS WITH THIRTEEN MISSING ON SOUTH EXPANSION JOINT, ONE MISSING FINGER ON NORTH.
SUPERSTRUCTURE: LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS. ONE INCH HOLE IN WEB OF GIRDER #1, SPAN #3 AND NEARLY HOLED THROUGH IN SPAN 5 AND INTERIOR EDGES OF BOTTOM FLANGES RUSTED TO 7/8 INCH IN SAME AREA. BEARINGS- HEAVY RUST ON SOUTH WITH SECTION LOSS ON ANCHOR BOLTS. MODERATE RUST AT NORTH. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DIRT BUILD UP.
SUBSTRUCTURE: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS. LIGHT AND MEDIUM SPALLS IN BACKWALLS. VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS. FEW FINE CRACKS AND MINOR SCOURING AT WATERLINE AND SMALL POP OUTS AT CONSTRUCTION JOINTS ON PIERS.

PICTURE: B399-
02. NORTHWEST APPROACH IN SOUTHBOUND LANE, CRACKED SETTLED AND PATCHED.

Inspection Date: 03/19/2009 **Inspector:** JEL

Deck: 5 Fair
Super: 6 Satisfactory
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

JEL inspection comments -
STEEL ANGLE RAIL: MODERATE RUST; PAINT POOR; LIGHT DAMAGE.
DECK: FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. CURBS CRACKED WITH MODERATE SPALLS AND LOOSE CURBSTONES. DIRT AND DEBRIS BUILD UP AT CURBS. MODERATE LEAKING AT RELIEF JOINTS AT CURBLINES. WELDED REPAIRS TO FINGERS WITH NINE MISSING ON SOUTH EXPANSION JOINT, ONE MISSING FINGER ON NORTH. FEW CRACKS IN PAVEMENT; SOME SEALED. SEVERAL LOOSENED CURB STONES. MANY SCUPPERS PLUGGED. CRACKED AND DEPRESSED AREA NEAR CENTERLINE SPAN FIVE.
SUPER: LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS; ONE INCH HOLE IN WEB OF GIRDER #1, SPAN #3 AND NEARLY HOLED THROUGH IN SPAN 5 AND INTERIOR EDGES OF BOTTOM FLANGES RUSTED TO 7/8 INCH IN SAME AREA. HEAVY RUST ON SOUTH BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS; MODERATE RUST ON NORTH BEARINGS. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DIRT BUILD UP.
SUB: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS; LIGHT AND MEDIUM SPALLS IN BACKWALLS. VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS. FEW FINE CRACKS AND MINOR SCOURING AT WATERLINE AND SMALL POP OUTS AT CONSTRUCTION JOINTS ON PIERS.

PICTURES B360-
10: CRACKED AND DEPRESSED AREA NEAR CENTERLINE SPAN FIVE. DRIVING LANE
11: NINE FINGER JOINTS MISSING AT SOUTH DECK END.
12: DIRT AND DEBRIS BUILD UP AT CURBS, TYPICAL.

Inspection History:

Inspection Date: 05/07/2007 **Inspector:** WBL

Deck: 5 Fair
Super: 6 Satisfactory
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

WBL inspection comments -
STEEL ANGLE RAIL: MODERATE RUST; PAINT POOR; LIGHT DAMAGE.
DECK: FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. CURBS CRACKED WITH MODERATE SPALLS AND LOOSE CURBSTONES. MODERATE LEAKING AT RELIEF JOINTS AT CURBLINES. WELDED REPAIRS TO FINGERS WITH FOUR MISSING ON SOUTH EXPANSION JOINT, CRACKED FINGER ON NORTH. FEW CRACKS IN PAVEMENT; SOME SEALED. SEVERAL LOOSENED CURB STONES. MANY SCUPPERS PLUGGED.
SUPER: LIGHT RUST; HEAVY UNDER RELIEF AND EXPANSION JOINTS. FEW AREAS MINOR SECTION LOSS ON EXTEROIR GIRDER FLANGES WITH HEAVY LOSS ON BRACING GUSSETS AND MEMBERS UNDER RELIEF JOINTS. SMALL AREAS OF HEAVY SECTION LOSS IN WEBS AT WELDED GUSSET PLATE BRACING ATTACHMENTS UNDER RELIEF JOINTS; ONE INCH HOLE IN WEB OF GIRDER #1, SPAN #3 AND NEARLY HOLED THROUGH IN SPAN 5 AND INTERIOR EDGES OF BOTTOM FLANGES RUSTED TO 7/8 INCH IN SAME AREA. HEAVY RUST ON SOUTH BEARINGS WITH SECTION LOSS ON ANCHOR BOLTS; MODERATE RUST ON NORTH BEARINGS. SOUTH ROCKER #3 LIFTED UP TO 1/4 INCH DUE TO DIRT BUILD UP.
SUB: FINE AND LIGHT CRACKS, MINOR AND LIGHT DELAMINATIONS, PATCHES CRACKED IN ABUTMENTS, SEATS, BACKWALLS AND WINGS; LIGHT AND MEDIUM SPALLS IN BACKWALLS. VERY HEAVY DIRT AND DEBRIS BUILD-UP ON SEATS. FEW FINE CRACKS AND MINOR SCOURING AT WATERLINE AND SMALL POP OUTS AT CONSTRUCTION JOINTS ON PIERS.

PICTURES A220-
10: TYPICAL HEAVY DIRT BUILD UP AT NORTH ABUTMENT BEARINGS.
11: HEAVY SECTION LOSS TO BRACING FRAME AND GUSSET PLATE, GIRDER #5, SPAN #4 UNDER RELIEF JOINT.
12: GIRDER #1 WEB HOLED AT BRACING FRAME GUSSET PLATE ATTACHMENT, SPAN #3 AT RELIEF JOINT.
13: TYPICAL MODERATE DELAMINATIONS IN UNDERSIDE OF DECK.
14: VERY HEAVY DIRT BUILD UP WITH BEARING #3 LIFTED 1/4 +/- INCH. TYPICAL MODERATE SPALLS IN BACKWALLS.

Inspection Date: 09/17/2003 **Inspector:** WBL

Deck: 5 Fair
Super: 6 Satisfactory
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 07/29/2004 09:41:19
WBL inspection comments -
STEEL ANGLE RAIL: MODERATE RUST; PAINT POOR; LIGHT DAMAGE.
DECK: FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. CURBS CRACKED WITH MODERATE SPALLS AND L

Inspection Date: 06/12/2001 **Inspector:** WBL

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 10/15/2002 14:31:19

WBL inspection comments - WALK AROUND INSPECTION
STEEL ANGLE RAIL: MODERATE RUST; PAINT POOR; LIGHT DAMAGE.
DECK: FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. CURBS CRACK

Inspection Date: 08/10/1999 **Inspector:** BEP

Deck: 5 Fair
Super: 7 Good
Substr: 6 Satisfactory
Culvert: N N/A (NBI)

Notes:

Sufficiency Rating Calculation Accepted by DEP at 03-24-2000 15:57:18
STEEL ANGLE RAIL: MODERATE RUST; PAINT POOR; LIGHT DAMAGE.
DECK: FINE CRACKS, LIGHT LEAKING, MEDIUM DELAMINATIONS. CURBS CRACKED WITH LIGHT SPALLS AND LOOSE CURBSTONES. MODERATE

Inspection History:

Inspection Date: 05/01/1997 **Inspector:** Not Available

Notes:
Sufficiency Rating Calculation Accepted by DEP at 12-23-98 08:05:16

Deck: 5 Fair
Super: 7 Good
Substr: 7 Good
Culvert: N N/A (NBI)

Inspection Date: 04/01/1995 **Inspector:** Not Available

Notes:

Deck: 6 Satisfactory
Super: 8 Very Good
Substr: 7 Good
Culvert: N N/A (NBI)

Inspection Date: 07/01/1993 **Inspector:** Not Available

Notes:

Deck: 6 Satisfactory
Super: 8 Very Good
Substr: 7 Good
Culvert: N N/A (NBI)

Bridge Lighting and Utilities: *DEICING SYSTEM INSTALLED IN PAVEMENT AT CENTERLINE.*

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