Oregon Department of Transportation – Rail Division

Oregon Rail Study Appendix B

Oregon Rail Bridge Assessments, Report of Study Findings

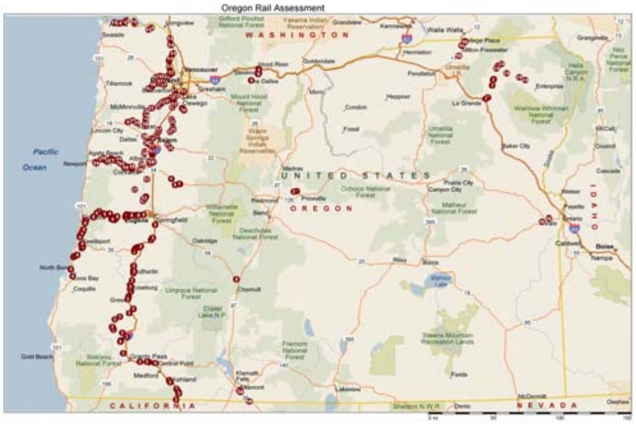
Prepared by:

David Evans and Associates

December 2009

FINAL REPORT OF STUDY FINDINGS

- *Oregon Rail Bridge Assessments*
  ATA No. 25159, WOC No. 11



Prepared for:
Oregon Department of Transportation
Rail Division

December 21, 2009

Prepared by:
David Evans and Associates, Inc.

DAVID EVANS
AND ASSOCIATES INC.

December 21, 2009

Ms. Betsy Imholt
ODOT Rail Study Director
ODOT Rail Division
555 13th St NE Ste 3
Salem, OR 97301-4179

**SUBJECT: FINAL REPORT OF STUDY FINDINGS
OREGON RAIL BRIDGE ASSESSMENTS**

Dear Betsy:

Enclosed is the Final Report of Study Findings for the Oregon Rail Bridge Assessments Project in accordance with Task 5 of our Work Order Contract. Included in the report are formulas using data gathered in Task 4, Railroad Bridge Assessments that can be applied to estimate upgrade or repair and replacement costs for the remaining bridges not reviewed for this study. This report also documents the methodology used in developing these formulas, visual inspections of seventy-two bridges, and periodic inspection reports of two bridges.

If you have any questions, please call me at (503) 361-8635.

Sincerely,

DAVID EVANS AND ASSOCIATES, INC.

Jeff Parker, P.E.
Project Manager

Oregon Rail Bridge Assessments

FINAL REPORT OF STUDY FINDINGS

Personal Services Contract # 25159
Work Order No. 11

Submitted to:

Oregon Department of Transportation
Rail Division

December 21, 2009

REGISTERED PROFESSIONAL ENGINEER
19,472
OREGON
SEPT. 16, 1997
JEFFREY ALLEN PARKER
EXPIRES 12/31/2010

Prepared by:

DAVID EVANS
AND ASSOCIATES INC.

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Executive Summary

This report contains the results of a bridge condition assessment study of 332 bridges located on 15 short line railroads in Oregon. In general, this study included all bridges over 100 feet-in-length, 15 feet off the ground surface, and all steel bridges on these railroads. Railroads included in this study are: Albany & Eastern (AERC), Central Oregon & Pacific (CORP), City of Prineville (COP), Klamath Northern (KNR), Hampton Railway (HR), Idaho Northern & Pacific (INP), Modoc Northern Railroad (MNRR), Mt. Hood Railroad (MHR), Oregon Pacific Railroad (OPR), Palouse River & Coulee City (PCC), Portland & Western (P&W), Willamette & Pacific (W&P), Wallowa Union Railroad (WURR), Willamette Valley Railway (WVR), and Wyoming & Colorado (WYCO/OER).

The purpose of this report is to answer the following questions for each of the study bridges:

- What is the Opinion of State of Maintenance for each bridge?
- Does the bridge have the capacity to carry modern rail cars weighing 286,000 pounds and if so at what speed?
- What is the remaining life span for each bridge?
- What is the cost to upgrade or repair each bridge for an immediate capacity to carry 286,000 pound cars at 10 miles per hour (MPH)?
- What is the cost to upgrade or repair each bridge for an immediate capacity to carry 286,000 pound cars at 25 miles per hour (MPH)?
- What is the cost to replace each bridge?
- What is the cost to modify each bridge to allow for double stack freight?

In addition, this report contains cost estimating instructions and formulas, which allow the user to estimate replacement, upgrade or repair, and modification costs for additional bridges not included in this study.

This study was conducted at the request of the Oregon Department of Transportation (ODOT) Rail Division. This summary is intended for a non-technical audience and to provide an overview of the study results. Additional technical narrative is contained in the body of this report and its attachments.

This study was conducted at a planning level in support of an economic study and is not intended to provide an opinion of each bridge's ability to safely carry commerce now or in the future, but instead is intended to provide a uniform comparison of all study bridges, while answering the questions listed above.

The study and its opinions are founded upon the review of existing bridge inspection records, visual inspections of 72 bridges, periodic inspection of two bridges, and telephone interviews with railroad personnel.

The study team conducted a review of existing bridge inspection records provided by the railroads and passed to the study team by ODOT Rail. Bridge inspection records were not available for several of the railroads. The existing inspection records varied in age, detail of information, and experience qualifications of inspectors.

Bridges visually inspected consisted of those with no bridge inspection records and a representative sampling of several bridges from the remaining rail lines. The purpose of the visual inspections were to provide a minimal understanding of the bridge condition where no bridge records exist or to correlate the existing bridge inspection records with our study team's on-site observations of a representative sample of bridges from each line.

The rail industry does not have a standard to rate the condition of bridges or determine a state of maintenance. However, there is a standard in place for highway bridges. For the purpose of this study, our team developed a bridge condition stratification based upon the Federal Highway Administration's National Bridge Inspection Standards (NBIS) condition rating guide. The NBIS guide uses a numbering system varying from one to ten to rate the condition of each structural element in a bridge. For the purpose of this study, we distilled the ten part

NBIS system into a more general stratification of good, fair, or poor and we applied it to each bridge to form an Opinion of State of Maintenance for each bridge. The condition of bridges varied between lines as well as within each line and is summarized in the following table.

Note: Many longer bridges are actually comprised of a series of different bridges or segments; therefore, this table is broken into segments as each different segment can and often did have a different state of maintenance as well as different structural material (timber, concrete, steel):

Table 1: Summary of Condition of Bridges by Railroad

	Good	Fair	Poor	Total Segments
AERC		5	3	8
COP	6			6
CORP	18	73	91	182
HR		3		3
INP	2	3		5
KNR			1	1
MHR	7	1		8
MNRR	1	2		3
OPR		7	2	9
P&W	44	70	11	125
PCC	2	2	1	5
W&P	23	91	44	158
WURR	7	3		10
WVR	1	4	4	9
WYCO		2		2
Total	111	266	157	534

The evaluation of each bridge's ability to carry modern 286,000 pound cars is based upon an understanding of the load effects of these cars versus the effects of loads used to design railroad bridges (Cooper E Loading). In addition, we investigated the design loads predominately used during the time periods when the study bridges were constructed. Finally, there are structural arrangements of timber bridges, which generally indicate for what Cooper Load it was designed. These three pieces of information taken together allowed our team to form an opinion concerning the ability of each bridge to carry modern rail car loads. Actual load capacity calculations for each bridge were not performed; therefore, our assessments are for the purpose of economic study and system planning only.

There is no standard in the bridge industry to estimate the remaining life of a rail or highway bridge. Therefore, our team developed a methodology for this estimate. A detailed presentation of this method is contained in our report. Our remaining life estimate assumes that only routine maintenance will be conducted until the bridge becomes unserviceable. All bridges, if continuously rehabilitated or repaired, have an indefinite service life. In other words, if a bridge Owner would continuously repair or rehabilitate a bridge, then it should last forever. Our method assumes the Owner will not repair or rehabilitate the bridge and estimates the remaining life span for each bridge before service would likely be unsafe or discontinued. Viewed differently, our estimate of remaining life is a planning or budgeting tool, which tells a bridge Owner how long they have until significant reinvestment in a bridge is required to continue service.

We have developed costs to upgrade or repair, replace, and modify each bridge of this study. The following tables contain the cost for each option by rail line. Costs by bridge are contained in the report. The reader is reminded this cost is reflective of the costs to upgrade or repair, replace, and modify the 332 bridges:

Table 2: Summary by Railroad of Costs to Upgrade or Repair to Achieve 286,000 Pound Capacity at 10 MPH

Railroad	Line	Total by Line	Total by Company	Overall Total
AERC	3S	$491,129	$491,129	$124,284,593
CORP	C	$6,618,997	$52,290,416	
CORP	CO	$45,571,935		
CORP	CR	$99,484		
COP	16A	$89,536	$89,536	
KNR	36A	$16,459	$16,459	
HR	35A	$274,166	$274,166	
INP	2G	$381,843	$381,843	
MNRR	CFA	$261,146	$261,146	
MHR	24A	$154,915	$154,915	
OPR	CJ	$935,991	$935,991	
PCC	2H	$327,749	$327,749	
P&W	5A	$3,273,821	$34,443,902	
P&W	8U	$788,191		
P&W	3F	$367,286		
P&W	F	$2,105,403		
P&W	FD	$3,826,156		
P&W	3E	$24,083,045		
W&P	FCA	$1,079,510	$31,668,250	
W&P	CK	$14,976,598		
W&P	F	$8,510,234		
W&P	P	$6,979,016		
W&P	FE	$122,892		
WURR	2G	$81,123	$81,123	
WVR	CC	$2,726,547	$2,726,547	
WYCO/OER	45A	$141,422	$141,422	

Table 3: Summary by Railroad of Costs to Upgrade or Repair to Achieve 286,000 Pound Capacity at 25 MPH

Railroad	Line	Total by Line	Total by Company	Overall Total
AERC	3S	$491,129	$491,129	$142,586,356
CORP	C	$14,561,278	$62,178,136	
CORP	CO	$47,517,374		
CORP	CR	$99,484		
COP	16A	$194,872	$194,872	
KNR	36A	$16,459	$16,459	
HR	35A	$274,166	$274,166	
INP	2G	$381,843	$381,843	
MNRR	CFA	$261,146	$261,146	
MHR	24A	$154,915	$154,915	
OPR	CJ	$1,002,557	$1,002,557	
PCC	2H	$327,749	$327,749	
P&W	5A	$4,800,391	$41,728,287	
P&W	8U	$788,191		
P&W	3F	$367,286		
P&W	F	$2,227,125		
P&W	FD	$5,350,874		
P&W	3E	$28,194,419		
W&P	FCA	$1,079,510	$32,276,057	
W&P	CK	$14,939,365		
W&P	F	$8,832,533		
W&P	P	$7,301,756		
W&P	FE	$122,892		
WURR	2G	$81,123	$81,123	
WVR	CC	$3,076,497	$3,076,497	
WYCO/OER	45A	$141,422	$141,422	

Table 4: Summary by Railroad of Costs for Replacement

Railroad	Line	Total by Line	Total by Company	Overall Total
AERC	3S	$7,487,206	$7,487,206	$1,435,978,807
CORP	C	$179,515,187	$646,409,845	
CORP	CO	$462,229,426		
CORP	CR	$4,665,233		
COP	16A	$3,616,125	$3,616,125	
KNR	36A	$291,320	$291,320	
HR	35A	$2,511,934	$2,511,934	
INP	2G	$5,832,597	$5,832,597	
MNRR	CFA	$2,846,120	$2,846,120	
MHR	24A	$12,225,179	$12,225,179	
OPR	CJ	$7,001,464	$7,001,464	
PCC	2H	$8,680,520	$8,680,520	
P&W	5A	$73,786,837	$438,308,878	
P&W	8U	$4,831,609		
P&W	3F	$3,249,297		
P&W	F	$10,477,849		
P&W	FD	$45,643,801		
P&W	3E	$300,319,485		
W&P	FCA	$11,072,301	$260,650,602	
W&P	CK	$152,809,409		
W&P	F	$48,452,146		
W&P	P	$47,649,674		
W&P	FE	$667,073		
WURR	2G	$11,420,906	$11,420,906	
WVR	CC	$20,225,460	$20,225,460	
WYCO/OER	45A	$8,470,648	$8,470,648	

We have developed costs for structural modifications to increase vertical clearance and allow for double stack commerce. It was found that all bridges in this study have adequate vertical clearance; therefore, the following table contains zero cost for the required modification to allow double stack freight on each rail line.

Table 5: Summary by Railroad of Costs to Modify for Double Stack Clearance

Railroad	Line	Total by Line	Total by Company	Overall Total
AERC	3S	$0	$0	$0
CORP	C	$0	$0	
CORP	CO	$0		
CORP	CR	$0		
COP	16A	$0	$0	
KNR	36A	$0	$0	
HR	35A	$0	$0	
INP	2G	$0	$0	
MNRR	CFA	$0	$0	
MHR	24A	$0	$0	
OPR	CJ	$0	$0	
PCC	2H	$0	$0	
P&W	5A	$0	$0	
P&W	8U	$0		
P&W	3F	$0		
P&W	F	$0		
P&W	FD	$0		
P&W	3E	$0		
W&P	FCA	$0	$0	
W&P	CK	$0		
W&P	F	$0		
W&P	P	$0		
W&P	FE	$0		
WURR	2G	$0	$0	
WVR	CC	$0	$0	
WYCO/OER	45A	$0	$0	

Project Background

The 2007 Oregon Legislature directed ODOT to conduct a statewide multimodal study of the transportation system. The legislation, House Bill 2278, states “The study shall include an assessment of the infrastructure, capacity demand and constraints, development of criteria for strategic investments and return on investment and identification of potential funding sources and strategies.”

The work on this project is a part of the Oregon Statewide Freight/Multimodal Planning Initiative, which will be the first integrated, statewide freight topic plan under the new Oregon Transportation Plan (OTP).

ODOT Rail Division has retained David Evans and Associates, Inc. (DEA) to complete an assessment of selected rail bridges as a part of an infrastructure assessment. This study does not include an on-site inspection for most bridges. However, some structures, where little or no data exists or a representative sample was desired, received an on-site inspection. The study encompasses 332 bridges and included 74 structure on-site observations.

Railroads with bridges included in this study are: Albany & Eastern, Central Oregon & Pacific, City of Prineville, Klamath Northern, Hampton Railway, Idaho Northern & Pacific, Modoc Northern Railroad, Mt. Hood Railroad, Oregon Pacific Railroad, Palouse River & Coulee City, Portland & Western, Willamette & Pacific, Wallowa Union Railroad, Willamette Valley Railway, and Wyoming & Colorado.

Purpose and Need for Report

The objective of this report is to document a planning level study assessing the condition of 332 railroad bridges in Oregon selected by ODOT. Of these 332 bridges, 314 have been previously inspected.

For each of these bridges, the study has developed three planning level cost estimates. They are: upgrade or repair needed to achieve 286,000 pound car capacity at 10 MPH and at 25 MPH , total replacement, and modification to meet domestic double stack clearance. Site specific considerations to account for detailed site constraints or bridge conditions are not included in these planning level cost estimates.

This study includes an opinion of state of maintenance, an estimate of the remaining life span for each bridge, and an assessment of the capability of each bridge to carry cars weighing 286,000 pounds at 25 MPH. The load capacity assessment is for planning level decisions in support of the OTP and not intended to be an actual representation of capacity. Actual capacity calculations based upon condition analysis and detailed inspection of each individual member of each bridge is not included in this study.

Study Organization and Methodology

ODOT Rail Division staff began the process of gathering information and data for the study team. This information was supplemented with additional information obtained by the study team through their contacts with the rail lines. This existing information is organized by line and bridge mile post number and is included in Attachment A.

Bridge location maps for each of the study bridges are included in Attachment B and were developed from an ODOT Rail Division data base and Microsoft Streets and Maps© software.

The cost estimating program and instructions, along with representative examples, are included in Attachments E through I.

A listing of all study bridges is titled Exhibit A and located in Attachment D.

The study team has visually inspected 17 of the bridges with no existing bridge inspection reports and an additional 55 bridges comprising a representative sample of all other bridges and lines. Information from these observations is included in Attachment C.

Two bridges with existing bridge inspection records have been inspected to confirm the accuracy of these inspection records. These periodic inspections are included in Attachment J and K.

The methodology for developing cost estimates included development of unit costs and multipliers. Unit costs and multipliers for bridge replacement, upgrade or repair, and modification were based on examination of typical standard railroad details, comparison to bid results for previous railroad bridges, comparison to bid results for previous highway bridges, discussion with senior engineers familiar with railroads, and engineering judgment.

For the total replacement costs (spans less than 50 feet, spans greater than 50 feet but less than 100 feet, spans greater than 100 feet, and moveable bridges), the unit cost was compared with costs generated from similar bridges using bid item unit costs current with 2008 bidding history. The similar bridges examined included the Burlington Northern Santa Fe (BNSF) standard details for steel trestles, as well as bridges recently designed and bid.

The replacement multipliers serve to increase the gradation of the possible costs for bridge replacement. Multipliers were based on rules of thumb and engineering judgment.

The upgrade and repair unit costs were based on the observed quantity of defects, and severity of defects. Upgrade and repair cost estimates were generated assuming a certain level of member strengthening or replacement. For example, timber trestle upgrade costs were assumed to require replacement or the addition of one pile per bent and two (2) stringers per span. Upgrade and repair unit costs were generated based on an assumed quantity of required new materials and recent bidding history unit costs.

For the modification unit costs, typical thru truss bridges with potential vertical clearance infringement were examined and estimates made of the quantity of steel work required to remove the obstructing members and the addition of steel members required for bracing outside the clearance envelope. Modify unit costs were generated based on the assumed quantity of steel to be removed and replaced and recent bidding history unit costs.

Bridge Assessments

ODOT Rail Division collected the existing inspection reports from the majority of studied rail lines and provided these records to the study team. The study team reviewed this information for both content and completeness and key information from those records was collected and input into a spreadsheet creating the framework for the project's database.

The study team conducted telephone interviews of railroad staff using a standardized format to obtain supplemental operational information in support of this study. All railroads were contacted and interviews were completed with 11 of the 15 rail lines. Information received from these interviews was added into the database.

After the initial data input was complete, a determination of missing information and recommendations for additional information was provided to ODOT Rail in our *Summary Memorandum*, dated September 19, 2008. After concurrence by ODOT Rail on the number and type of further inspections, the study team collected supplemental information through the visual inspections of 55 additional bridges. (Note: These inspections are in addition to 17 visual inspections necessary for bridges with no inspection records.)

Visual inspections were the primary method used by the study team to collect relevant information. Seventeen (17) bridges in the study had no inspection reports at all so visual inspections were necessary to collect basic information. In addition, 55 other rail bridges were selected by the study team as a representative sample that would provide a more comprehensive understanding of the information provided from the railroads.

The representative bridges selected were chosen after an initial review of the existing records and summary of the types and sizes of the bridges on each rail line. Also factored into this decision was the assessment of level of detail within the reports and the experience of the previous inspection staff. Performing a visual inspection of a bridge where some records existed allowed the study team to correlate the information with that witnessed in the field, providing a higher level of confidence and understanding of the rest of the information available on each of these rail lines.

As requested by ODOT Rail, the study team performed periodic bridge inspections on CORP Bridge 716.4 and P&W Bridge 743.27. Both bridges had existing bridge inspection records. The intent of the inspections was a peer level review to better understand the records provided. On Bridge 716.4, the study team found reliable agreement with the existing reports on both the timber and steel components. However, for Bridge 743.27 the last available report was from 1977. There were also current W&P timber reports. The timber reports were not as detailed as the 1977 report. The 1977 reports were not considered reliable for comparison due to the 31 year time gap. The study teams' findings were in general agreement with the current W&P timber reports for the detail available; however, a full comparison was not possible. The study team identified a few piles approaching a condition of failure that were not mentioned in the W&P reports. The study team notified W&P and encouraged them to take immediate action. There were no current steel reports provided for P&W Bridge 743.27; however, the bridge appears in better shape than CORP Bridge 716.4. The full inspection reports prepared by the study team are included in Attachments J and K.

From all the information collected, the study team developed a database from which to complete the study. The database also provided the framework to develop specific spreadsheets to illustrate the information requested by ODOT Rail. The database and the assessment tools embedded within it were the basis of summary assessments for the planning level elements identified for each bridge. These are:

- State of Maintenance Opinion
- Expected Bridge Life Span
- Load Assessment to carry a 286,000 pound rail car at 10 MPH and at 25 MPH
- Planning level cost estimates for:
  - Replacement
  - Upgrade or Repair to achieve the immediate capacity to carry 286,000 pound rail cars at 10 MPH and at 25 MPH
  - Modify to double stack clearance

Opinion of State of Maintenance

The rail industry, through the American Railway Engineering and Maintenance-of-Way Association (AREMA), has developed guidelines over the years for bridge inspection. Although general guidelines exist, there is no rail industry standard to rate the condition of bridges. The review of the existing inspection records and interviews conducted for this study supported this finding. The frequency of inspections and information collected varied greatly from railroad to railroad as a result of such factors as frequency and type of freight use, age of the bridges, and level of experience of the previous inspection staff.

Therefore, for this study we developed a way to rank the condition of these bridges that could be used both with the existing inspection records provided by ODOT Rail as well as with the data collected by the study team through the visual inspection.

The rail bridges were one of three types of material—concrete, steel or timber. These are the same materials used on highway bridges and whether a rail or highway bridge, they deteriorate in the same manner. For this reason, the study team used as its model FHWA’s National Bridge Inspection Standards condition rating guide.

The FHWA bridge inspection program regulations were developed as a result of the Federal-Aid Highway Act of 1968 (Sec. 26, Public Law 90-495, 82 Stat. 815, at 829) that required the Secretary of Transportation to establish national bridge inspection standards (NBIS). The primary purpose of the NBIS is to locate and evaluate existing bridge deficiencies to ensure the safety of the traveling public.

The NBIS sets the national standards for the proper safety inspection and evaluation of all highway bridges. The NBIS regulations apply to all publicly owned highway bridges longer than twenty feet located on public roads. Railroad and pedestrian structures that do not carry highways are not covered by the NBIS regulations.

The NBIS condition ratings do not replace detailed notes describing specific conditions or deficiencies. The condition rating guide, when used properly, is to provide an overall characterization of the general condition of the entire component being rated. To establish an Opinion of State of Maintenance for the bridges in this study, the overall characterization was needed.

It should be noted that there is a fundamental difference between the NBIS condition rating guide and the intended use for this study's Rail Bridge Condition Rating system. The Rail Bridge Condition Rating Guide was for planning level purposes only. Public safety was not a criterion for this planning level study. For this reason, the study team simplified the NBIS system while maintaining its overall descriptions of the spectrum of bridge conditions. The NBIS condition ratings guide and how it was simplified is shown in Attachment D.

The resulting ODOT Rail Division Planning Level Bridge Condition Rating Guide established for this study is shown in Tables 6, 7 and 8 below.

Planning Level Rail Bridge Condition Rating Guide

Table 6: Concrete Bridge Condition Guide

CONCRETE PRIMARY MEMBERS: GIRDERS, CAPS AND PILES	
Rating for Planning Study Purposes	**Definition of Rating**
Good Condition	Some minor problems, non-structural cracking.
Fair Condition	Structural members are sound but may have substantial deterioration or disintegration. Non-hairline structural cracking or spalling present with minor section loss.
Poor Condition	Extensive disintegration. Structural cracks or large spall areas. Reinforcing steel exposed with corrosion section loss. Load capacity of bridge may be affected.

Table 7: Timber Bridge Condition Guide

TIMBER PRIMARY MEMBERS: STRINGERS, CAPS AND PILES	
Rating for Planning Study Purposes	**Definition of Rating**
Good Condition	Insignificant decay, cracking or splitting of timber members.
Fair Condition	Minor to moderate decay, cracking, splitting or minor crushing of timber members. A few secondary members may need replacement. Fire damage with minor section loss.
Poor Condition	Extensive decay, cracking, splitting or crushing of timber members. Fire damage with significant section loss. Load capacity of bridge may be affected.

Table 8: Steel Bridge Condition Guide

STEEL PRIMARY MEMBERS: TRUSS TOP AND BOTTOM CHORDS, TRUSS DIAGONALS, TRUSS HANGERS AND POSTS, GIRDERS, FLOOR BEAMS, CAPS AND PILES	
Rating for Planning Study Purposes	**Definition of Rating**
Good Condition	Paint system may be showing early signs of distress. There is little or no active corrosion. There is no exposed metal.
Fair Condition	Paint system is failing. There is exposed metal with moderate to heavy surface rust. There may be minor section loss.
Poor Condition	Paint system has failed. Extensive corrosion section loss in steel members. Fatigue or out-of-plane bending cracks may be present in critical areas. Load capacity of bridge may be affected.

As in shown in this guide, for the purpose of this study, the study team reduced the number of NBIS condition ratings to three—Good Condition, Fair Condition and Poor Condition. A brief summary of these descriptions are:

- **Good Condition:** Available information indicates that the overall condition of the bridge segment appears to have no apparent deficiencies.
- **Fair Condition:** Available information indicates that the overall condition of the bridge segment appears to have minor deficiencies.
- **Poor Condition:** Available information indicates that the overall condition of the bridge segment appears to have significant deficiencies where the load capacity may be affected.

The Planning Level Rail Bridge Condition Rating Guide was applied to the primary members for each structure. The conditions of the primary members in a bridge were determined from the available inspection reports and site observations. When neither was available; the study team extrapolated and assigned a condition from the records of similar bridge types on the same railroad. This was necessary for only 2% of the bridges. When possible, the quantity and severity of deficiencies in the primary members was used in assessing the affect these could have on the carrying capacity of the bridge.

The condition of the primary members controlled the overall assignment and characterization of the entire bridge (or a segment of a bridge that had different span types) leading to the general overall condition rating for the State of Maintenance Opinion contained in Attachment D.

Lastly, the database created by the study team and provided to ODOT Rail Division has been developed to allow ODOT Rail to expand the database to include additional rail bridges. The database can also be used by ODOT Rail to supplement the existing information available to ODOT in Microsoft Streets and Maps software. The Bridge location maps included in Attachment B are an example of the exhibit options, which could be enhanced by ODOT Rail, if desired.

The following is a brief overview of the information available to the study team:

Albany & Eastern (AERC) Railroad

Line 3S:

- There was uncertainty concerning the completeness of the inspections and the qualifications of the inspectors.
- Two of the four bridges had no inspection reports and there was a lack maintenance history.
- The study team conducted visual inspections on all 4 bridges.

City of Prineville (COP) Railroad

Line 16A:

- Overall the inspection reports provided had good details of the member properties and conditions and the inspections were performed by a qualified inspection consultant.
- Some maintenance history was available.
- The study team conducted visual inspections on both bridges.

Central Oregon & Pacific (CORP) Railroad

- Overall the inspection reports provide had good details of the member properties and conditions and the inspections were performed by a qualified inspection consultant.
- Some maintenance history was available.
- The study team conducted visual inspections of several bridges on the CORP C and all bridges on the CR and CO lines. (Note: The majority of the CO line inspections were conducted as part of a separate study for the International Port of Coos Bay.)

Hampton Railway (HR) Railroad

- Even though a standard inspection report is provided, the level of effort or performance level of these inspections is not defined. There is uncertainty concerning the completeness of the inspections.
- The condition of the timber piles and stringers are given by an undefined code.
- No conditions provided for steel members.
- Member number and sizes are provided, except for steel pile and cap sizes.
- No photographs are provided.
- No maintenance history was provided.
- The study team conducted visual inspections of the bridges on this line.

Idaho Northern & Pacific (INP) Railroad

- Even though a standard inspection report is provided, the level of effort or performance level of these inspections is not defined. There is uncertainty concerning the completeness of the inspections.
- Stringer sizes are not provided.
- Condition of the timber piles and stringers are given by an undefined code.
- Some maintenance history provided.
- No comments provided on condition of steel members.
- No photographs were provided.
- The study team conducted visual inspections of the bridges on this line.

Klamath Northern (KNR) Railroad

- The inspection report provides sufficient details of the member types and conditions.
- Photographs were provided by OBEC.
- Inspection performed by a qualified inspection consultant.
- No maintenance history was provided
- The study team conducted visual inspections of the bridges on this line.

Mt. Hood Railroad (MHR) Railroad

- Inspection report documents are not provided; however, a summary review of on-site observations by CH2M Hill is available.
- Conditions were provided in a narrative.
- Sizes of stringers were not provided.
- The level of effort or performance level of these inspections is not defined nor documented. There is uncertainty concerning the completeness of the inspections.

- No photographs provided.
- Some maintenance history provided.
- The study team conducted visual inspections of the bridges on this line.

Modoc Northern Railroad (MNRR) Railroad

- No inspection report or other descriptions of bridges including photographs on file.
- The study team conducted visual inspections of the bridges on this line.

Oregon Pacific Railroad (OPR) Railroad

- No inspection report or other descriptions of bridges including photographs on file.
- The study team conducted visual inspections of the bridges on this line.

Portland & Western (P&W) Railroad

- Even though a standard inspection report is provided, the level of effort or performance level of these inspections is not defined. There is uncertainty concerning the completeness of the inspections.
- Not all stringer sizes are provided.
- No conditions of steel members are provided.
- Lacks maintenance history.
- No photographs were provided.
- Vertical clearance for thru trusses not given (typical for all lines).
- The study team conducted several visual inspections of the bridges on this line.

Palouse River & Coulee City (PCC) Railroad

- No inspection report or other descriptions of bridges including photographs on file.
- The study team conducted visual inspections of the bridges on this line.

Willamette & Pacific (W&P) Railroad

- Even though a standard inspection report is provided, the level of effort or performance level of these inspections is not defined. There is uncertainty concerning the completeness of the inspections.
- Conditions of timber members are given by an undefined code.
- Not all stringer sizes are provided.
- No conditions of steel members are provided.
- Minimal maintenance history available.
- No photographs were provided.
- Vertical clearance for thru trusses not given.
- The study team conducted several visual inspections of the bridges on this line.

Wallowa Union Railroad (WURR) Railroad

- For inspection reports provided, the level of effort or performance level of these inspections are not defined. There is uncertainty concerning the completeness of the inspections.
- Stringer sizes are not given.
- Steel members lack condition description.
- Timber member conditions given by an undefined code.

- Lacks maintenance history.
- No photographs were provided.
- The study team conducted visual inspections of the bridges on this line.

Willamette Valley Railway (WVR) Railroad

- No inspection report or other descriptions of bridges including photographs on file.
- The study team conducted visual inspections of the bridges on this line.

Wyoming & Colorado (WYCOOER) Railroad

- No vertical clearance for the thru truss bridge provided.
- One elevation view photo provided with each bridge.
- Timber stringer number and size are not provided for the one timber bridge.
- Some maintenance history given.
- Overall the inspection reports provide adequate details of the condition except for the stringers in the timber bridge.
- Inspection performed by a qualified inspection consultant.
- The study team conducted visual inspections of the bridges on this line.

Assessment of Load Capacity

Introduction

Modern railroads are currently being designed to carry standard cars with a capacity of 115 tons that have a total weight on the rails of 286,000 pounds. One key objective desired by the ODOT Rail Division in completing this study is to determine the potential upgrade or repair cost required to enable the structures to safely carry this standard load.

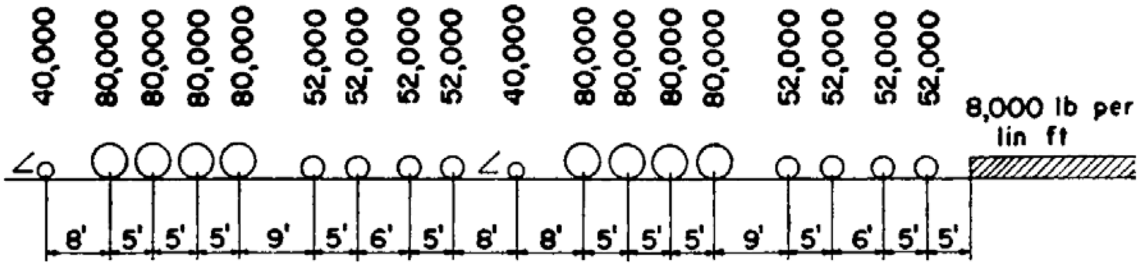
Another aspect of the safe load carrying capacity of the structures is the speed at which the standard load can be moved across. Freight railroads, especially short line railroads, routinely slow down when crossing potentially substandard bridges. This is because the amount of dynamic impact load is reduced at slower speeds, thereby allowing a greater safety factor when crossing potentially unsafe bridges. ODOT Rail Division has set a minimum design speed of 10 MPH for determination of the upgrade or repair necessary to render the current capacity greater than or equal to the 286,000 pound load effects. ODOT Rail Division also requested a second design speed of 25 MPH for determination of the upgrade and repair necessary to render the current capacity greater than or equal to the 286,000 pound load effects.

To make this determination, the loads the bridge was initially designed for, including dynamic impact, must be understood and the design capacity of the bridge must be established. Most of the bridges in this study, especially the timber trestle structures, have no design plans available. Throughout the first half of the 20th century, rail bridges were routinely constructed by railroad crews without having detailed construction plans. Standard length timber stringers determined maximum trestle span length and timber piles were driven “to refusal”. The typical construction practices used at the time the bridges were constructed can be used to approximate the live load carrying capacity the original bridge was built to carry. This assessment will be based on a planning level study of the assumed design load capacity and should not be considered as a load rating for the current load capacity of the structures.

Live Loads

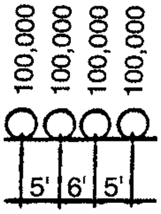
Capacity rating of railroad bridges is expressed as a Cooper E loading. The Cooper E loading was introduced by Theodore E. Cooper in 1894 for the design of railway bridges. It was calculated using the axle loading and spacing based on the configuration and weight of a steam locomotive of that era followed by a tender. The original configuration is still used to design modern bridges; however, the axle loading has been increased over the years to reflect actual equipment weight in use at that time. Currently, Cooper E80 loading is used to design new bridges. This loading represents axle loads of 80,000 pounds maximum, spaced in the same configuration as Cooper's steam locomotive. The axle loads and spacing for a Cooper E80 load are shown in the following diagram.

Cooper E80 Axle Load Diagram

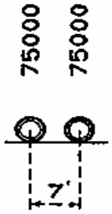


Along with the Cooper E loading shown above, AREMA presents an alternative live load (cart) which is comprised of fewer axles having a greater axle load. From around 1895 to 1967, this alternative live load cart consisted of two axles having a concentrated load that was 25 percent greater than the corresponding Cooper design axle load of the time. There was a period from 1967 until 1995 where the alternative live load cart was not included in the AREMA manual; thereafter the alternative live load cart was modified and included into the AREMA manual in its current form. Currently the alternate live load cart consists of four (4) axles having a 25 percent greater axle load. The purpose for the alternative live load cart is to address problems associated with fatigue in short span bridges. The previous and current spacing for the alternative live load cart are shown in the diagrams below.

Current Alternative Live Load Cart for Cooper E 80



Previous Alternative Live Load Cart for Cooper E 60



The 286,000 pound rail car consists of four (4) axles, each carrying an equally distributed load of 71.5 kips. Two car lengths, 50 feet and 75 feet were used to determine live load capacity of the subject bridges in this study.

Impact Loading

Dynamic impact loading is considered as a percentage of the live load applied. According to the 2006 AREMA manual, impact loading varies depending on the material the bridge is constructed from—timber, concrete, or steel, as well as the type of locomotive engine the rail line will primarily carry, steam or diesel-electric powered. If the rail line is to be designed to carry diesel-electric powered engines, then a lesser impact factor is allowed.

This is due to a lack of "hammer blow" effects that are present in the older steam powered engines. Additionally, when considering the determination of the design loading for an existing bridge, the impact loading in use during the period of construction must be considered. When rating an existing bridge to determine the speed at which a 286,000 pound rail car can safely travel, the impact loading may be reduced according to the speed of the train.

Impact loading for steel and concrete structures is separated into two categories for the purpose of this assessment—design loading and rated loading. The design loading category consists of the design impact loads that AREMA/AREA had standardized during the time period that a bridge was constructed. The rated loading category consists of current impact loads that have been reduced based on the speed of the engine crossing the bridge. Design impact loads will be applied to the assumed Cooper E design loading of the bridge in order to determine its design capacity, while the rated impact loads will be applied to the 286,000 pound rail car for various speeds.

Steel Bridges

For bridges built prior to 1945, vertical design impact loading can be calculated using span length in the following equation (1921 AREA):

$$I = [300/(300+L^2/100)]$$

This equation assumes that the train will be powered by a steam engine. For diesel-electric engines, the resulting value would be multiplied by a factor of 0.5.

For bridges built after 1945, design impact loading for steel structures is separated into impact from vertical effects and rocking effects. According to AREMA 1.3.5.c, impact due to vertical effects is determined according to span length as follows:

Diesel-Electric

For $L < 80$ feet $\quad I = [40-3L^2/1600]\%$

For $L \geq 80$ feet $\quad I = [16+600/(L-30)]\%$

Steam

For $L < 100$ feet $\quad I = [60-L^2/500]\%$

For $L \geq 100$ feet $\quad I = [10+1800/(L-40)]\%$

AREMA 1.3.5.d specifies that impact due to the rocking effect can be calculated as a vertical force couple with 20 percent of the wheel load acting down on one rail and up on the other. Essentially, when looking at the maximum vertical effect on a single stringer beneath a rail, a downward force of 20 percent of a wheel load is equivalent to an additional 10 percent of the axle load as illustrated below.

$$0.2 \text{ wheel loads} \times \frac{1 \text{ axle load}}{2 \text{ wheel loads}} = \frac{0.2 \text{ axle loads}}{2} = 0.1 \text{ axle load}$$

When rating an existing bridge, AREMA 7.3.3.3.a allows a reduction of impact according to speed by the following factor:

$$1 - \frac{0.8}{2500} \times (60 - S)^2 \geq 0.2 \text{ where S} = \text{Speed in mph}$$

Combining the impact factor for span length (less than or greater than 80 feet) with the reduction factor for speed, the following table summarizes the dynamic impact factor for existing steel structures in a fraction of live load.

Table 9: Impact Percentage for Steel Bridges at Various Speeds

Span length	Unfactored % Impact	Plus 10% Rocking	Impact % (Including Speed Reduction)					
			10 mph	20 mph	30 mph	40 mph	50 mph	60 mph
15	39.6	49.6	9.9	24.2	35.3	43.2	48.0	49.6
30	38.3	48.3	9.7	23.6	34.4	42.1	46.8	48.3
50	35.3	45.3	9.1	22.1	32.3	39.5	43.9	45.3
80	28.0	38.0	7.6	18.5	27.1	33.1	36.8	38.0
100	24.6	34.6	6.9	16.9	24.6	30.1	33.5	34.6
150	21.0	31.0	6.2	15.1	22.1	27.0	30.0	31.0

These reduced impact factors will be applied to the 286,000 pound car when comparing the load effects versus the design capacity of the bridge to determine the speed at which the bridge can safely carry the 286,000 pound car.

Concrete Bridges

According to AREMA 2.2.3.d, the percentage of live load for impact loading is determined by span length as follows:

For $L \leq 14$ feet $I = 60\%$
For 14 feet $< L \leq 127$ feet $I = [225/(\sqrt{L})]\%$
For $L > 127$ feet $I = 20\%$

These equations assume a diesel-electric power or similar locomotive. For steam locomotives with hammer blow, the impact calculated shall be increased by 20%.

When rating an existing bridge, AREMA 19.3.4.b allows a reduction of impact loading for speeds less than 40 MPH "in a straight line variation from full effect at 40 MPH to 0.5 of the full effect at 10 MPH". This methodology was applied to the 286,000 pound car and compared to the bridge's design capacity.

Table 10: Impact Percentage for Concrete Bridges at Various Speeds

Span Length (feet)	Speed (MPH)			
	10	20	30	40
15	29	39	48	58
30	21	27	34	41
50	16	21	27	32
100	11	15	19	23
150	10	13	17	20

Timber Bridges

According to AREMA 2.5.5.6, dynamic impact loading is not considered for timber structures. It has been determined that the total increased impact load effect is less than the increased strength of timber for short cumulative duration of loading, which railroad bridges are subjected to. Additionally, impact loading was taken into account in the derivation of the allowable working stresses for timber design.

Existing Bridge Design Capacities

Without explicitly knowing the original design capacity of existing railroad structures, by examining the structure and looking at the date built an approximation can be made. The date built can be particularly telling since AREMA/AREA has been standardizing rail bridge design live loads in their Railway Engineering Manual since the early 1900s; therefore, a timeline of standard design loads can be used to estimate the design live load capacities. From the age of the structure, we can also make an assumption for the impact loads which were used in the design. In the early 20th century steam engines were the predominant engine in use, but diesel-electric engines were becoming more and more conventional. By 1960, steam engines were replaced as the primary rail engine. With this information a timeline was developed, as shown in the table below, to provide a standard estimate of structural design capacity.

Table 10: Timeline for Standard Design Loads

Present	1995-1967	1967-1960	1960-1935	1935-1920	1920-1914	<1913
E80 w/ 100kip cart	E80 w/ out Alternative Live Load	E72 w/ 90kip cart	E72 w/ 90kip cart	E60 w/ 75kip cart	E50 w/ 62.5kip cart	E40 w/ 50kip cart
Diesel-Electric Engines			Steam Engines			

If the structure has not been retrofitted, a bridge built between 1895 and 1913 was typically designed for a Cooper E40 load. If the structure was built between 1913 and 1920, it was typically designed for a Cooper E50 load; if the structure was built between 1920 and 1935, it was likely designed for a Cooper E60 load; if the structure was built between 1935 and 1967, it was likely designed for a Cooper E72 load; and, if the structure was built after 1967, then it was designed using the current E80 load. This methodology was used to determine the design capacity for all steel and concrete bridges.

Additionally, in a timber bridge, the number of piles in a bent can be a telling sign of the structures design capacity. A bent with three interior vertical piles typically has an E60 design capacity, while a bent with four interior vertical piles typically has an E80 design capacity. The number of stringers below each rail in a timber bridge can also help identify the design load. If there are four stringers below each rail, the design load is likely E80. If there are only three stringers, an E50 or E60 design load is the most likely. This rationale, rather than the original year of construction, was used to assess timber bridge design capacity.

Analysis

In order to determine the ability of existing bridges to carry 286,000 pound car loads, several simple span analyses were run to compare 286,000 pound cars at various speeds against the various Cooper E loads with impact loads that correspond with the design timeline shown in the above section. Shear and moment envelopes were developed for these loads and is summarized in the table below. Based on the shear and moment envelopes for simple spans, the tables below show the ability of the span to carry a 286,000 pound car load, according to the Cooper E load (design load) the structure was constructed. Tables are given for steel, concrete, and timber.

Table 11: Speed at Which Steel Bridges Can Carry 286,000 Pound Cars Given the Design Load and Span Length

Span Length	E80 w/ cart	E80 w/out cart	E72 DE	E72 Steam	E60	E50	E40
10	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph
15	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph
20	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph
25	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph
30	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph
50	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	30 mph
100	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	30 mph
150	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	30 mph
200	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	10 mph

Table 12: Speed at Which Concrete Bridges Can Carry 286,000 Pound Cars Given the Design Load and Span Length

Span Length	E80 w/ cart	E80 w/out cart	E72 DE	E72 Steam	E60	E50	E40
10	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph	<10 mph
15	60 mph	60 mph	60 mph	60 mph	60 mph	30 mph	<10 mph
20	60 mph	60 mph	60 mph	60 mph	60 mph	30 mph	<10 mph
25	60 mph	60 mph	60 mph	60 mph	60 mph	25 mph	<10 mph
30	60 mph	60 mph	60 mph	60 mph	60 mph	20 mph	<10 mph
50	60 mph	60 mph	60 mph	60 mph	60 mph	30 mph	<10 mph
100	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	10 mph
150	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	10 mph
200	60 mph	60 mph	60 mph	60 mph	60 mph	60 mph	10 mph

Table 13: Ability of Timber Bridges to Carry 286,000 Pound Cars Given the Design Load and Span Length

Span Length	E80	E72	E60	E50	E40
10	YES	YES	NO	NO	NO
15	YES	YES	NO	NO	NO
20	YES	YES	NO	NO	NO
25	YES	YES	NO	NO	NO
30	YES	YES	NO	NO	NO

Flowcharts detailing this decision making process, along with associated costs, can be found in the Appendix H of this report.

Common Short-Line Locomotives

An important consideration that should also be considered is the weight of the various locomotives routinely used by short line railroads. A list of common short-line locomotives, their weights and number of axles is shown below.

Locomotive	Weight (lb)	Number of Axles
GP 7	251,000	4
GP 9	257,000	4
GP 35	278,000	4
GP 38	275,000	4
GP 39	261,000	4
GP 40	278,000	4
SD 7	330,000	6
SD 9	360,000	6
SD 40-2	411,000	6
SD 45	414,000	6

As seen above, the GP series 4-axles diesel locomotives weigh less than 286,000 pounds. Since they are of similar length to the 286,000 pound car, we can say that the 286,000 pound car is the controlling load. The SD series , 6-axle locomotive weighs are greater than 286,000 pounds. Additional analysis should be considered to determine the controlling load if this locomotive is used. These locomotive weights are average weights and should not be used for design purposes.

Opinion of Expected Bridge Lifespan

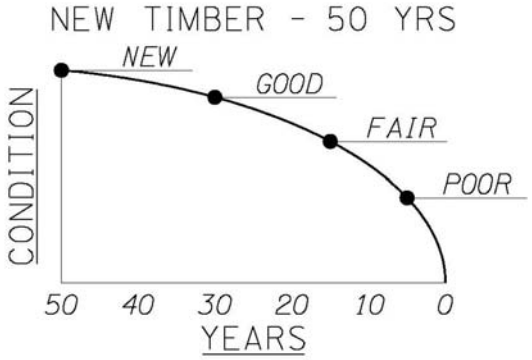
The estimated remaining life of a bridge is defined as the period of time from the date of this study, until the bridge's service condition declines to an unusable level. The estimated remaining life of each bridge in this assessment was determined using the following criteria:

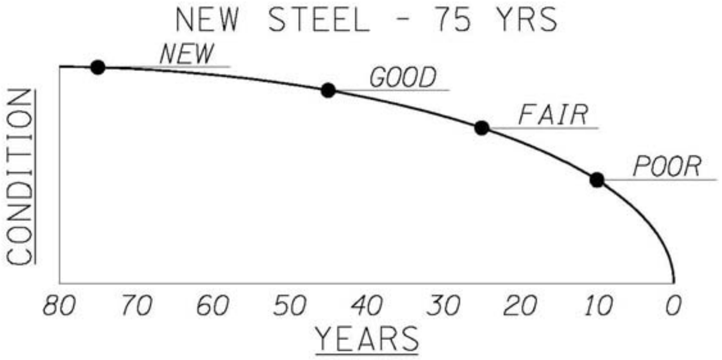
- **The present condition of each bridge.** This was determined from data in inspection reports conducted by railroad staff or by inspectors hired by the railroad, DEA site observations, and/or extrapolation from other similar bridge type inspections on the railroad line and/or geographical area.
- **Future maintenance of the bridge.** In establishing the estimated remaining life, it is assumed that only routine maintenance is performed on the bridge from now to the end of its useful life. Routine maintenance is actions routinely performed to inspect and care for the bridge. This includes such activities as cleaning to retard deterioration of members subject to rusting or decay, spot painting, maintaining approaches, applying preservatives, tightening bolts, and removal of drift and unwanted vegetation to reduce risk of scour at supports in waterways and fires spreading to the bridge.
- **Age of the bridge.** The year built is used to estimate the likelihood of existing but undetected deterioration that could further reduce the life. Several bridges have undergone replacement of various original members. The remaining original members are likely still the controlling consideration for determining the bridge's remaining life span.
- **The material types in the bridge.** Historically, it has been found that the different materials used to construct bridges deteriorate at different rates under similar environments and uses. The railroad bridges in this study are comprised mainly of timber, steel and concrete materials. Timber is estimated as having the shortest useful life and concrete having the longest useful life of the three materials.

The primary factor associated with the life of timber is the deterioration by decay, both from rot and insect infestation, with breakage being a lesser factor. Deterioration of the steel in bridges was found to be mainly due to the paint system failure and the subsequent corrosion and section loss in members. Concrete deterioration is generally associated with cracking and spalling with exposure of reinforcing steel that corrodes and fosters progressive cracking and spalling.

As the deterioration of material progresses with time, the rate of condition change is estimated to increase. That is, the period of time to change condition from fair to poor is less than that to change from good to fair. As protective systems or mechanisms reach their life expectancy, the exposure of the bridge member to deteriorating elements is increased. For example, as the creosote protective system on a timber member weathers and breaks down, or cracks and splits break through to the untreated core of the member, its exposure to decay causing fungi is increased and the rate of deterioration is accelerated.

The three graphs below illustrate the varying degree and rate of deterioration based on material and remaining lifespan.





Cost Estimating

Costs for bridge upgrade or repair work to achieve capacity for 286,000 pound cars at 10 and 25 MPH, for total bridge replacement, and for modifying to accommodate double stack freight clearances have been developed for each bridge in the study. See the flowcharts in Attachment H for visual guide to determination of costs.

Cost estimates were developed with the following assumptions.

General Assumptions

- Work to replace, upgrade or repair, or modify the bridges is completed through contractors, and not by the railroad's maintenance staff. Prevailing wage assumed to dictate labor rates.
- The default costs reported for replacement, upgrade or repair, and modify are based on estimated construction costs for 2009. If a different year is preferred, an alternative year can be selected as well as an associated annual inflation rate.
- There are no aesthetic considerations given to the replacement, upgrade or repair, or modification costs.
- A contingency to allow for uncertainties discovered during project development and construction has been included in the cost estimations in this study. The assumed default contingency cost associated with replacement, upgrade or repair, and modification costs is 20% of the construction subtotal for all bridges except steel thru truss bridges for which the default contingency is 40%. It is assumed that due to the simplicity of non steel thru truss bridges, there are limited unknowns and a lower contingency is warranted. Steel thru truss brides are larger bridges with more unknowns and warrant a higher contingency. Contingency can be changed from the default input to any percentage desired.
- The assumed default for construction engineering cost associated with replacement, upgrade and repair, and modification costs is 8% of the construction subtotal. Construction engineering cost percentage can be changed from the default input to any percentage desired.
- The assumed default for professional engineering costs associated with replacement and upgrade and repair is 5% of the total project cost for all bridges, except steel thru truss bridges which has a default of 15%. It is assumed that all bridge replacements and upgrades and repairs, except thru truss bridges, can be designed with minimal professional engineering due to main line railroad design programs and standard drawings. Professional engineering cost percentage for any bridge can be changed from the default input to any percentage desired.
- The assumed default for professional engineering costs associated with modification of steel thru truss bridges for vertical clearance is 15% of the total project cost. Professional engineering cost percentage for modification of steel thru truss bridges can be changed from the default input to any percentage desired.
- The assumed default for mobilization cost associated with replacement, upgrade or repair, and modification costs is 10% of the construction subtotal. Mobilization cost percentage can be changed from the default input to any percentage desired.

Replacement Assumptions

- Replacement bridge span lengths are assumed to be similar to the existing bridge span lengths.
- Replacement bridge structure type is consistent with current practices, which may not necessarily be similar to the existing bridge structure type.
- Replacements of all timber trestle bridges will be with steel pile trestles and concrete superstructures.
- Replacement bridges are assumed to be ballasted deck bridges. Replacement costs do not include the cost of the ballast, rails or ties. The track cost of the ballast, rails and ties are accounted for by others.
- Replacement bridges are assumed to be designed to the AREMA Cooper E80 loading.

- Replacement bridges are assumed to include seismic design and detailing. New bridges are assumed to have substructure ductility and strength to prevent seismic failure, and prevention of seismic superstructure pull-off and seismic bearing failure.
- Unit costs for replacement of thru truss bridges include consideration for construction access. For other bridge types, the existing bridge can serve as access. However, with truss bridges typically a construction access platform, barge, or other special considerations are required.

Replacement Commentary

A replacement cost is provided for all bridges included in the scope of this study.

There are six base unit costs for replacement. The six costs are associated with existing moveable bridges, moveable thru truss bridges, spans less than 50 feet, spans greater than 50 feet and less than 100 feet, spans greater than 100 feet, and thru truss spans greater than 100 feet. This base unit cost is modified by two multipliers that take into account items that typically have an impact on the cost of bridge replacement. The multipliers applied to the base unit case consist of the following:

- The crossing multiplier differentiates what the railroad bridge crosses over. The base replacement unit cost is based on replacement over land and thus the multiplier for an over land crossing is 1.0. If the railroad bridge is over a roadway or over water, the multiplier increases to 1.05 and 1.10 respectively.
- The seismic zone multiplier accounts for more costly details for seismic detailing and ductility requirements. The base replacement unit cost is based on a single span bridge in seismic zone 1 or 2 and thus the multiplier for these bridges is 1.0. Multiple span bridges in seismic zone 1 or 2, as well as bridges in seismic zone 3 or 4, require more seismic detailing and ductility requirements; these bridges have a multiplier of 1.05.

The base unit cost of replacement is also increased by one additional. The additional cost added to the base unit cost consists of the following:

- The additional cost is a function of the type of bridge removal required for the existing bridge. Simple bridges, such as timber bridges that are not over live traffic or are tall, have a lower bridge removal unit cost than bridges over live traffic, tall bridges, or steel bridges with lead paint. Truss bridge removal has the highest unit cost. Of the available bridge removal selections available, if more than one type of bridge removal is applicable, the one with the highest unit cost is applied.

See *Flowchart #1: Bridge Replacement Costs* in Attachment H for a summary of the replacement cost estimating process.

Upgrade and Repair Assumptions

- Determination of whether a bridge requires Upgrade, Repair, or neither is a function of the bridge's as-constructed capacity and condition of maintenance. See the Assessment of Load Capacity section and the Opinion of the State of Maintenance section of this report for details. For cost estimates for work required to achieve 286,000 pound car capacity at 10 MPH, Upgrade 1 or Repair costs were considered, not both. Similarly, for cost estimates at 25 MPH, Upgrade 2 or Repair costs were applied, not both.
- The definition of Upgrade is increasing a bridge's as-constructed load capacity by the addition of members or by strengthening members to attain the immediate capacity adequate to carry 286,000 pound cars. Upgrade 1 does this for 286,000 pound cars traveling at 10 MPH, and Upgrade 2 does this for 25 MPH. For this project, Upgrade 1 was only considered for bridges with an as-constructed capacity of 286,000 pound cars at 10 MPH or less. Upgrade 2 was only considered for bridges with an as-constructed capacity of 286,000 pound cars at 25 MPH or less. Typical railroad industry maintenance measures done over the service life of the bridge are not included as part of Upgrade.

- The definition of Repair is replacement or strengthening defective or deteriorated members that threaten the as-constructed capacity of the bridge. For this project, repair was only considered for brides with an as-constructed capacity of 286,000 pound cars or greater but have deteriorated to a fair or poor condition of maintenance. Typical railroad industry maintenance measures done over the service life of the bridge are not included as part of Repair.
- Upgrade or Repair of existing bridges will not change the type of bridge.
- Steel bridges identified as exposed to salt water spray are defaulted to include painting for Upgrade and Repair work. Steel bridges not exposed to salt water spray have a default of no paint for Upgrade and Repair work. The user may change these defaults for steel bridges as desired. For non-steel bridges, the program applies no additional painting costs as painting is not applicable for these bridges. Seismic retrofit of bridges is not included in Upgrade or Repair work.
- Upgrade and Repair costs for open deck timber bridges do not include the cost of the rails, but do include the cost for the ties due to longer ties supporting walkways. Upgrade and Repair costs for ballast deck bridges do not include the cost of the ballast, rails or ties. The track cost of the ballast, rails, and ties as appropriate are accounted for by others.

Upgrade and Repair Commentary

The variables assessed for determining the total cost to Upgrade or Repair bridges are the existing bridge type, the as-constructed capacity of the bridge, the shortest longitudinal element span length, the state of maintenance of the existing bridge, and whether or not existing steel bridges are exposed to salt water spray. See *Flowcharts #2 thru #6* located in Attachment H for a summary of the cost estimating process for Upgrade and Repair.

Regarding the paint option for steel bridges, the use of weathering steel in new steel structures precludes replacement bridges from requiring paint. However, older steel bridges were not constructed from weathering steel as weathering steel was not available. Bridges not constructed with weathering steel and not protected with paint will experience section loss, even bridges not exposed to salt water spray. This section loss will lead to reduction in the service life of the bridge. It is believed that older steel railroad bridges were over-sized and can incur significant section loss prior to reduction in capacity below as-constructed load demand. Because of this over capacity design, the railroad industry perceives the practice of not painting steel bridges as a prudent means of maintenance.

Modify Assumptions

- Modification of a bridge modifies the vertical clearance of a thru-type bridge, such as a thru truss, to meet the domestic double stack clearance envelope requirements. See the *Domestic Double Stack Clearance Figure* located in Attachment I.
- Modify costs of existing structures to double stack clearance is only applied to structures with sub-standard vertical clearance. Structures with sub-standard vertical clearance are typically steel through trusses which require modification to the portal bracing, sway bracing, or top lateral struts between trusses. Structures with substandard horizontal clearance typically include steel through trusses and through girders. Modifications to increase horizontal clearance are not feasible; therefore, are excluded from estimated upgrade costs. A double stack car may potentially “fit” on structures with sub-standard horizontal clearance at slow speeds, but the structure will not meet the specified clearance and will require an ODOT variance.
- Substandard vertical clearance is divided into two classifications in the cost estimating spreadsheet as follows:
  - Minimal substandard vertical clearance is defined as a structure with vertical clearance infringement due to portal bracing and or sway bracing between the vertical truss members. Modification would simply require removal of the conflicting portal bracing and/or sway bracing, and new bracing added to the exterior of the clearance envelope.

  - Major substandard vertical clearance is defined as a structure with clearance infringement due to top lateral struts. Modification would require removal of the top lateral struts, extension of all vertical elements of the truss, and construction of new top lateral struts above the vertical clearance envelope.

Upgrade Commentary

A total of 44 bridges in the scope of this study included a thru truss span for at least a portion of the total structure length. Of these 44 thru truss bridges, the vertical clearance on 12 of these structures was measured. A survey rod with a maximum height of 25 feet was used. The vertical clearance immediately above the track rail was measured, as well as observations made of the portal bracing, sway bracing and top lateral strut configuration. It was found that in all 12 bridges, the measurement immediately above the track rail exceeded the 20’-3’ required clearance. Therefore, in all 12 thru trusses measured, all had adequate vertical clearance and no modification work is required.

Of the 32 thru trusses that were not measured, records were reviewed for any previous measurements and none were found. Photos of these 32 thru trusses were reviewed, an assessment of the truss type (pinned or riveted) was made, span length and year built were determined and all elements were compared to the 12 bridges measured by the study team. Each of the 32 bridges with no measurements was found to be very similar to at least one of the bridges that were measured, and therefore, it was extrapolated that all 32 of these bridges also have adequate vertical clearance and require no modification work.

- See the *Thru Truss Double Stack Vertical Clearance Table* in Attachment I for a summary of all 44 thru truss bridges.
- See the *Truss Bridge Modify Costs Flowchart* in Attachment H for a summary of the cost estimating process.