TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Oregon Department of Transportation

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period:**
TPF 5(259)	☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) X Quarter 4 (October 1 – December 31)

Project Title: **Imaging Tools for Evaluation of Gusset Plate Connections in Steel Truss Bridges**		
Name of Project Manager(s): **Steven Soltesz**	**Phone Number:** **503-986-2851**	**E-Mail** steven.m.soltesz@odot.state.or.us
Lead Agency Project ID: **TPF5259**	**Other Project ID (i.e., contract #):** **Agreement 17384** **Work Order 12-05**	**Project Start Date:** April 2012
Original Project End Date: **9/30/2014**	**Current Project End Date:** **9/30/2014**	**Number of Extensions:** 0

Project schedule status:

X On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Percentage of Work Completed to Date
$440,000	$83,000	17%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	$41,000	31%

Project Description:

The collapse of the I-35W Bridge in Minnesota has resulted in considerable interest in steel truss and gusset plate connection performance. The load paths in many truss bridges are non-redundant and thus failure of a truss member or connection may cause collapse of the structure. Periodic inspections and structural evaluations are crucial for these types of bridges.

The most common method of evaluation that has been used to assess the safety of highway bridges is load rating, an approach used to estimate the available strength and allowable load on a bridge. Although sophisticated bridge load rating computer programs are available, these programs do not explicitly consider the gusset plates connecting the truss members. Hence, after the initial design calculations are completed and checked, it is unlikely that recalculations for load rating purposes have been made for gusset plates. As an outcome of the investigation into the collapse of the I-35W Bridge, steel truss bridge connections are required to undergo review. This additional scrutiny requires development of new tools to efficiently and effectively evaluate the large numbers of steel truss bridge connections in the inventory.

Digital imaging techniques have been developed to enable rapid collection of field geometric data from in-service gusset plates. These tools are implemented in software that allows extraction of gusset plate dimensional information to facilitate ratings. The present tools provide a basic set of functionality such as image rectification and scaling and allow geometric data extraction such as length, perimeter, and angles. However, these basic functions need enhancement to take full advantage of the advancements available to bridge inspection and management with digital imaging. Enhancements such as automation of rectification tasks and identification of features within the images are proposed that will enable transportation agencies to efficiently and effectively collect geometric and condition data and use this data to evaluate and rate gusset plate connections.

There are four main objectives of this research:

1. Develop methods to collect dimensional gusset plate connection information including surface geometry and out-of-plane deformations on in-service gusset plates. The information to be collected includes the geometry of the connectors, members, and overall plate dimensions. It also includes out-of-plane distortions of the gusset plate.

2. Develop methods to automate identification and optimization of reference target points, and to automate identification and extraction of the gusset plate edges, fastener locations and their corresponding member affiliations, as well as member orientations. These dimensional data feed directly into the connection rating tasks.

3. Develop finite element modeling and analysis techniques to directly rate gusset plates using extracted digital image data as the input source.

4. Develop software tools to manage and organize images and image data to enhance bridge management and allow identification of condition changes over time.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Task 1: Literature Review
Schedule status: *On schedule*
Percent complete: 75%

Task status: *Literature being collected and synthesized as research progresses.*

Task 2: Software Development and Data Collection
Schedule status: *On schedule*
Percent complete: 35%

Task status: *Computer Science Graduate student continuing to develop software. Algorithm for automated target recognition complete and is robust. Fastener detection algorithms have been improved with better results for detecting bolts. The improved approach consists of two computational steps, as illustrated in Figure 1. The first step, Step 1, is aimed at detecting likely locations of bolts, called candidates. There could be a number of false positives among the candidates. The second step, Step 2, is aimed at reducing the false positive rate by reasoning about the spatial layout of the candidates.*

Figure 1. (Left) Step 1: Bolts are detected by scanning the bolt detector (the window marked white) across the image in raster scan. The detector identifies the locations and sizes of candidates that are likely to be bolts in the image. (Right) Step 2: The detected candidates can be grouped into clusters based on their collinearity. The figure shows one such cluster forming a straight line, which could help: (i) Estimate that one bolt detection is missing; (ii) Correct locations and sizes of the detected bolts.

Task 3: Gusset Plate Analysis
Schedule status: *On schedule*
Percent complete: 0%

Task status: *Not yet underway*

Task 4: Implementation Example
Schedule status: *On schedule*
Percent complete: 0%

Task status: *Not yet underway*

Task 5: Imaging Data Informatics for Bridge Management
Schedule status: *On schedule*
Percent complete: 0%

Task status: *Not yet underway*

Task 6: Analysis Software
Schedule status: *On schedule*
Percent complete: 40%

Task status: *Triangular meshing algorithm implemented in OpenSees and gusset plate geometries were meshed accurately. Shell element formulation in use for elastic and inelastic behaviors. Eigenvalues and eigenvectors of gusset plate model are computed and mesh is distorted out of plane according to the eigenvector corresponding to the fundamental mode of plate deformation. All possible loading combinations of bolt groups are included in the analysis sequence and the von Mises yield criterion is used as the terminating condition for each analysis. The above algorithms were used to develop an OpenSees model of an in situ gusset plate. The analysis results will be compared with the ABAQUS solution. Refinements have been made in the analysis software to improve loading sequences and calling a streamlined FORTRAN J2 plasticity model. The original C++ version was coded poorly and inefficient, so this change will make the batched analyses run much faster when loaded past first yield.*

Anticipated work next quarter:

Task 1: Literature Review- *Continue review and synthesis*

Task 2: Software Development and Data Collection – *Continue to improve fastener identification algorithm and edge detection algorithm. Begin export algorithms to transfer information to analysis software inputs.*

Task 3: Gusset Plate Analysis – *None*

Task 4: Implementation Example - *None*

Task 5: Imaging Data Informatics for Bridge Management - *None*

Task 6: Analysis Software – *Compare OpenSees results for elastic and inelastic plate buckling with classical solutions and commercial finite element software for the gusset plate model already developed.*

Significant Results:

Preliminary results at present

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None

Potential Implementation:

Future