Wisconsin Highway Research Program

Development and Implementation of the Next Generation Bridge Management System for Wisconsin

Michael Baker Jr., Inc.
March 2013
Work Plan
Project Title: “Development and Implementation of the Next Generation Bridge Management System for Wisconsin”

Proposing Agency: Michael Baker Jr., Inc.

Person Submitting the Proposal: Chad Halverson, P.E., Project Manager
Michael Baker Jr., Inc.
7633 Ganser Way
Suite 206
Madison, WI 53719

Proposal Written By: Jose L. Aldayuz, PE, Senior Project Manager
Proposal Date: January 20, 2012

Principal Investigator: Jose L. Aldayuz, P.E.
Senior Project Manager
Michael Baker Jr., Inc.
3601 Eisenhower Avenue
Alexandria, VA 22304
Phone: 703.317.6522
Email: jaldayuz@mbakercorp.com

Administrative Officer: Kenton Zinn, Vice President
Michael Baker Jr., Inc.
311 West Monroe Suite 1350 Chicago, IL 60606
Phone: 312. 575.3926
Email: Kzinn@mbakercorp.com

Proposed Contract Period: 36 Months (As listed in the RFP) Baker is in a position to finish project sooner at WRHP/WisDOT convenience

Total Contract Amount: $175,000

Indirect Cost Portion at 162.92% (Rate Approved by the WI Transportation Planning and Review Auditor)
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Research Plan

Research Objectives

The objective of this research is to collect and derive Wisconsin specific data for the next generation BMS as well as to test the effectiveness and accuracy of this data on a subset of WisDOT bridges. We propose to use a subset of 10 state-owned bridges from each of the 5 WisDOT Regions for a total of 50 bridges.

The best way to meet this objective is to:

a) catalog the information that Pontis 5.2 will use and information that already exists in the Highway Structures Information System HSI,

b) determine the new information that Pontis 5.2 will need and explore potential sources within WisDOT that can be used to obtain that data,

c) establish and document the protocols for data gathering and its conversion and/or migration, if needed,

d) design and document the protocols for data derivation, and

e) test the data and protocols with a subset of WisDOT bridges.

Steps a) and b) are crucial to the success of this project. The following breakdown is given in order to understand the requirements related to these steps and the data needed to complete them.

Data in the version of Pontis 4.X that will remain in Pontis 5.2

- **Deterioration Models**—Data will be applied differently. Deterioration models will have to be converted from Commonly Recognized Elements (CoRe) to National Bridge Element format.

- **Maintenance Repair and Rehabilitation (MR&R) Costs**—Data remains, but failure cost is no longer used. MR&R costs will need to be converted from CoRe to National Bridge Element (NBE) format.

- **Improvement Costs**—Remains, but data entry effort will be improved by a change in the Graphical User Interface that will facilitate copying data among Districts and functional classifications.

- **Improvement Policy**—Remains, but improved in a similar fashion to the improvement cost data entry (currently one needs to complete 204 entries per District/ADT Class).

- **Network Level Optimization**—Different Use. Network optimization will do two things:
  - Apply budgets, and
  - Evaluate the impact of policy changes on defined projects

New inputs needed in Pontis 5.2

- Utility function value curves
- Risk assessments (optional)
- Replacement templates (optional)
- Bridge level designations (historical, no-widen, etc.) (optional)
- Define corridors (optional)
- Crew work orders (optional)

Important Policy Matrix Updates in Pontis 5.2

- Policy will expand to include posting trucks
- Replacements will be level of service (LOS) driven
- The policy matrix will match the AASHTO Green Book and Highway Capacity Manual standards

A critical element in step c) is the migration of the bridge CoRe element and custom elements used by WisDOT to be consistent with the NBE and Bridge Management Elements (BME) as depicted in the 2011 AASHTO publication, Guide Manual for Bridge Element Inspection. The first version of an open source migration tool has been developed for this purpose by the sub-consultant in the Research Team. Steps d) and e) are self explanatory and are described in the work plan section of this proposal.
Table 1. Items Needed for This Project

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<thead>
<tr>
<th>Artifact</th>
<th>Owner</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSI Schema</td>
<td>Wisconsin DOT</td>
<td>Schema, data dictionary, and entity relationship diagram in electronic format is preferred</td>
</tr>
<tr>
<td>Pontis 5.1.3 Software</td>
<td>AASHTO</td>
<td>Needed to test migration protocols</td>
</tr>
<tr>
<td>Pontis 5.2 Schema and Database Upgrade Scripts</td>
<td>AASHTO</td>
<td>Needed to confirm consistency with Pontis 5.1.3 database and to execute steps a), b), c), and d) listed above</td>
</tr>
<tr>
<td>Bridge Element Cost Information Sources</td>
<td>Wisconsin DOT</td>
<td>A list of sources (data and experts) for WisDOT specific NBE MR&amp;R action cost is needed. (i.e., deck spall patch, steel girder painting, etc)</td>
</tr>
<tr>
<td>Visual Element Migrator Tool Version 1.1.0.19</td>
<td>AASHTO</td>
<td>The software and documentation are needed</td>
</tr>
<tr>
<td>Improvement Projects Legal and Design Standards and Cost Data Sources</td>
<td>Wisconsin DOT</td>
<td>List of sources for WisDOT Improvement Projects information is needed</td>
</tr>
</tbody>
</table>
Work Plan

Phase I: Bridge Management System Development

Task 1: Literature Review

Under this task, Baker will collect, review, and interpret relevant practice, performance data, research findings, and other information related to this research project. An executive summary report will be prepared depicting the documents Title, Author(s), Date, Source/URL, Description, and Contents will be prepared and added as an Appendix to the interim report to be completed in Task 3. The literature review related to the Development of Element Repair Costs and Estimated Life Expectancy for Bridge Maintenance prepared by CTC & Associates LLC will also be included.

A component of the literature review that needs particular attention is the database structure of Pontis 5.1.3 when compared and contrasted with the latest copy of the Pontis 5.2 Design Document (as it pertains to the database structure). It is crucial to verify that the database structure that will assimilate the NBE data collection guidelines is the same in these two versions.

A project kickoff meeting with WisDOT key personnel will be scheduled. The Principal Investigator and the Technical Manager or the sub-consultant will represent the research team at this event.

Task 2: Database Development

Under this task, Baker will study the existing and future HSI database schemas to develop the protocols for element data migration. WisDOT has provided the current database and will provide the future HSI database once approved by the Information Technology Services Bureau (BITS). The development of the migration protocols will be first tested on Pontis 5.1.3 and later in the future HSI database as it exists before the end of Phase I.

Study of bridge element inspection database tables and data changes

It is essential to first determine the modifications needed to HSI to meet the new guidelines specified in the 2011 AASHTO Guide Manual for Element Inspection. For instance, some elements have one less condition state (going from five conditions to four conditions) while others have one more condition state (going from three conditions to four conditions).

The open-source “Visual Element Migrator” Version 1.1.0.19 furnished by AASHTO will be utilized to perform the condition state migration, while the AASHTO Guide Manual for Bridge Element Inspection publication will be used to identify the proper feasible actions associated with each condition state.

Baker will then document the migration protocols for all the CoRe and custom elements contained in HSI, and also provide recommendations for future changes in the HSI. It is anticipated that changes will be needed in the WisDOT inspection and pocket manuals to reflect the correct NBE condition state and feasible actions language. The documentation prepared under this task will be done in a way to facilitate future updates to these two documents by WisDOT.

The initial testing of the migration protocols, on a subset of bridges in HSI, will be done using Pontis 5.1.3 database structure. This testing will be conducted to ensure that the protocols are consistent with the AASHTO Guide Manual for Bridge Element Inspection 2011 Edition.

Changes to the HSI data structure will be recommended after the review of the Pontis 5.1.3 migration scripts is completed and the database schema for the bridge inspection information between the Pontis 5.1.3 and the future available version of the HSI are contrasted and compared. It is anticipated that the recommendations for changes will take place during the first quarter of Phase I.

A second testing will be conducted to ensure that the export file from the element migrator is properly imported into the HSI schema capable of accepting NBE’s and BME’s.

Data migration process

WisDOT maintains its element data in several related tables that in combination can be presented in a set of views that correspond to the BrM/Pontis tables ELEMDEFS and ELEMINSP, which are the sources of data for migration. A review of the data dictionary spreadsheet and the entity-relationship diagram presented as part of the original RFP materials indicates that while named,
organized, and related somewhat differently from the standard BrM/Pontis tables, the HSI information is nevertheless largely consistent in semantic meaning and cardinality.

The Migrator software itself only understands and processes XML text data presented in concordance with its input and output XML schemas, which are largely defined based on the Pontis element-related tables. This requires all the HSI data to be downloaded as XML files for processing by the Migrator.

Also, it should be noted that the Migrator software does not provide functionality to migrate general structure information or general inspection information - only element specifications and inspection results.

In order to migrate the WisDOT element data, the following steps at a minimum will be required:

**Survey HSI element data**

- Enumerate all element types used in Wisconsin, and verify element ID and element TYPE codes are consistent with the Migrator INPUT XML schema, and identify variances.
- Document the relationship of WisDOT elements to the new AASHTO elements.
- Identify any elements that are to be deprecated and/or combined into new AASHTO elements during this process.
- Identify element characteristics affecting migration such as number of condition states for each element.
- Identify any needed transformation rules for WisDOT specific elements, including rules for the WisDOT elements not found in standard rule set as well as those that are at variance with the assumptions or specifications of the standard Migrator rules.
- Confirm that element data state quantities sum up to element total quantities (these will be identified for correction - data cleaning is not assumed to be part of the migration work).

**Extract and reorganize the existing HSI data for migration**

- Determine approach to present element definitional information in XML format consistent with Migrator requirements, using SQL views
- Determine approach to present element inspection information in XML format consistent with Migrator requirements, using SQL views
- Copy and transform input data from source tables to temporary tables—original data is not modified.
- Iteratively, using SQL and any necessary follow-on editing:
  - generate Migrator-ready element specifications XML file
  - generate Migrator-ready element inspection data XML file
  - review input data and compare with source for correctness
  - as appropriate, discuss process and input data with WisDOT staff

**Document process and tools used**

The documentation to be written in this step will be part of the Task 3 deliverables.

**Transform for migration to BrM/Pontis**

- Using the Migrator, import existing WisDOT element specifications XML file, verify, and report
- Create and validate all rules for migration, using element specifications from 3.1, verify, compile, and report
- Using the Migrator, import existing WisDOT element data from XML files
- Iteratively:
  - apply transformation rules to generate output XML files
  - review results and correct or modify rules, as necessary
  - import XML inspections to test BrM/Pontis 5.1.3 database prepared by others on team (from HSI bridge records and inspection records), review, and report
  - review data in BrM/Pontis 5.1.3 and compare with HSI source for correctness
  - as appropriate, discuss process and migrated inspection results with WisDOT staff
Transform BrM/Pontis data back to HSI format

Within this framework, the Migration effort is concluded with the creation of the temporary tables, at which point all the data has been migrated and is ready to be imported to a new HSI that has its database table structure modified as necessary to accommodate BrM/Pontis 5.1.3 conventions. These modification, in short, will be to accommodate new data at the BRIDGE, INSPECTION, ROADWAY, and ELEMENT level, such as LRFR ratings, GPS latitude and longitude, network analysis groups, and other new entities and data items pertaining to BrM/Pontis 5.1.3 that are different from or entirely new to HSI. Since one of the main intentions behind this project is to facilitate/implement a two-way exchange of information between BrM/Pontis 5.1.3/5.2 and HSI, the HSI data structure will necessarily need to be updated as part of the feasibility study effort. Additional HSI modifications will likely be required to support BrM/Pontis 5.2 when it is more well-defined.

The summary of these steps is shown in Table 3.

Table 3. Task 2 Subtasks

<table>
<thead>
<tr>
<th>Subtask</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Review HSI CoRe and custom elements data structure and condition state language.</td>
</tr>
<tr>
<td>2.2</td>
<td>Develop migration rules for CoRe elements where the HSI condition state language differs from the AASHTO CoRe Guide and also for the HSI custom elements.</td>
</tr>
<tr>
<td>2.3</td>
<td>Test migration rules in Pontis 5.1.3 with a subset of bridges with the last inspection in record. The purpose of this testing is to ensure that the protocols are consistent with the AASHTO Guide Manual for Bridge Element Inspection 2011 Edition.</td>
</tr>
<tr>
<td>2.4</td>
<td>Migrate the last inspection information for all state bridges into Pontis 5.1.3 by creating an XML output file from the AASHTO Migrator.</td>
</tr>
<tr>
<td>2.5</td>
<td>Review proposed HSI schema for bridge inspection and recommend changes (if needed) to successfully import the XML file created in subtask 2.4.</td>
</tr>
<tr>
<td>2.6</td>
<td>Develop import XML process.</td>
</tr>
<tr>
<td>2.7</td>
<td>Test the XML import to the new HSI using the same sample used in subtask 2.3.</td>
</tr>
<tr>
<td>2.8</td>
<td>Import the file created in subtask 2.4 into the new HSI database.</td>
</tr>
</tbody>
</table>

Task 3: Work Plan Development and Interim Report

Under this task, Baker will prepare a work plan and an interim report. The Phase II work plan will include an updated project schedule. Both documents will be prepared based on the results of Tasks 1 and 2. Baker understands that approval of the interim report and work plan by Project Oversight Committee (POC) must be obtained prior to continuation of study. The report will be reviewed by a senior technical writing specialist prior to submission.

Phase II: Bridge Management Customization and Implementation

Task 4: State-Specific Customization

Study of Pontis 5.2 Modeling and Programming Database and Data Changes

Once the database changes to HSI, as a result of the assimilation of NBE elements are determined, Baker will continue with the following activities:
Identify data gathering and transfer protocols for the development of:

- **WisDOT Preservation Policy**
  - Deterioration models information based on the NBE condition state language
  - Cost models information based on NBE feasible action language

- **WisDOT Improvement Policy**
  - Design and legal standards
  - Cost Information for widening, strengthening, raising, and replacing structures

Identify data derivation and transfer protocols for the development of:

- **WisDOT utility function value curves**

  Pontis 5.2 will include the incorporation of multi-objective analysis using utility functions. The *Pontis 5.2 Design Document* specifies utility functions as a means of combining multiple objectives at the bridge, project, and program levels. Utility function weights can be generated using expert elicitation, or by experimenting with actual programs to evaluate and adjust their effect on program performance. It is envisioned that a master set of default utility function weights will be produced at the system-wide level.

- **WisDOT risk assessment**

  Risk assessment fits into the utility framework above-mentioned as other types of performance. This will keep the analysis easy to understand and use, and will maximize the potential for further use of the information in asset management. The *Pontis 5.2 Design Document* uses the following figure to illustrate how these two concepts fit together.

![Figure 2. Utility Function and Risk Assessment](image-url)
Identifying data gathering and data derivation protocols will be the cornerstone to develop a work plan for Phase II of this project. The data transfer protocols for each activity will also be determined at this point. Data transfer protocols considered will be XML or SQL. Microsoft Excel spreadsheets will be used to store collected or derived information.

Baker will analyze and develop agency specific factors for the BMS. It is anticipated that the budget established for Phase II of this project will allow for the customization of the following items:

- **WisDOT Preservation Policy**
  - Customize deterioration models information based on the NBE condition state language
  - Customize cost models information based on NBE feasible action language

- **WisDOT Improvement Policy**
  - Customize data for Pontis 5.2 tables containing design and legal standards information
  - Customize data for Pontis 5.2 tables containing cost Information for widening, strengthening, raising, and replacement of structures projects

- **WisDOT utility function value curves and risk assessment**
  
  A master set of default utility function weights will be produced at the system-wide level. The risk assessment will then be fit into the utility framework as other types of performance for the following performance measures:
  
  - Scour
  - Fatigue
  - Deterioration
  - Traffic
  - Crash

**Task 5: User Manual**

Under this task, Baker will prepare a WisDOT BMS Next Generation Modeling Data User Manual. The manual, limited to no more than 100 pages, will include documentation to illustrate the development protocols completed in Task 4. The manual will be reviewed and edited by a senior technical writing specialist prior to submission. An accompanying CD containing the XML and spreadsheets created in Task 2 necessary for long-term updates to the user specific data collected in Task 4 will be prepared.

**Task 6: Bridge Management System Pilot**

If the Pontis 5.2 software is available, Baker will pilot and demonstrate the BMS utilizing the subset of bridges from Task 2 and the data collected in Task 4. This will include uploading the elements developed in Task 2 as well as uploading relevant information from an upgraded HSI database to perform modeling and optimization. The upgrade of the HSI database is assumed to be completed by the WisDOT Bureau of Automation Services (BAS).

If the Pontis 5.2 software is not available, the testing pilot will be conducted by walk thorough of the XML transfer protocol and the utilization of the data as contained in the spreadsheets files contained in the CD developed under Task 5.

**Task 7: Implementation Plan**

Based on the results obtained in Task 6, Baker will prepare an implementation plan for WisDOT to migrate to the next generation BMS, including element migration, user-specific data updates, etc. Implementation options to migrate specific regions in detailed order will be prepared.

**Task 8: Project Deliverables**

Under this task, Baker will submit a draft final report three (3) months prior to end of contract for Technical Oversight Committee (TOC) review. The report will document the research results, as well as proposed revisions to the WisDOT Bridge Inspection and
Pocket Manual. These revisions will be included in the Report Appendix. As noted on Task 2, Baker will prepare the documentation so the updates to these documents can be completed with ease.

Baker also plans to present the findings of the research in a Project Closeout Presentation. The presentation will emphasize critical aspects of the BMS Next Generation Implementation Plan prepared under Task 7.

Once feedback related to the draft final report and Project Closeout Presentation are received, Baker will revise the draft final report and submit a final report to WHRP. It is understood that an electronic copy and 15 hard copies of the report are required.

Contributions from WisDOT Staff

It is anticipated that WisDOT will provide staff to monitor project progress, review the interim report, and review/approve the draft final report. Cost data for bridge preservation, improvement and replacement projects is anticipated as well as bridge legal and design standards information. It is anticipated that WisDOT experts will participate in the development of cost data.

Baker will be responsible for scheduling periodic meetings/conference calls with the POC to support timely completion of project tasks. A communication plan will be prepared to keep all parties informed that are involved with this research project. The plan will include three face-to-face meetings in Phase I, and three face-to-face meetings in Phase II.

Donation of Equipment and Materials from Industry

No equipment will be donated to the project. Baker further understands that no WisDOT equipment will be available.

Anticipated Research Results and Implementation Plan

Baker anticipates that the results of this research project will be fully usable in the implementation plan for the migration of CoRe elements to NBE elements, as well as to have protocols to gather or derive data needed for modeling in Pontis 5.2. The results will identify changes needed to the *WisDOT Bridge Inspection Manual*, the *Bridge Inspection Pocket Manual*, the *HSI Inspection Module*, queries and reports related to bridge elements, bridge projects and bridge programs in HSI. The corrections needed to the Inspection Module will be highlighted to place WisDOT in an advantageous position to plan and fund these changes.

Utility functions associated with a risk assessment will be derived for a framework intended to combine dissimilar performance measures, such as condition, life-cycle cost, and risk into criteria suitable for use in priority setting. The WisDOT data gathered or derived in this project will feed into a framework that will address the standardization and scaling of measures, and weighing the measures according to the relative importance of policy objectives and the relative importance of specific bridges.

The documentation prepared in this research will constitute a “blue print” that WisDOT can use in the future, if additional risk assessment or utility functions are needed. Baker plans to explicitly show how the data needs to be derived or gathered, and where this data needs to reside in the Pontis 5.2 database tables. The primary stakeholder groups of this project depicted on the following table will either participate in this project, assist the implementation of the BMS Next Generation Implementation, or benefit from its outputs.
### Table 3. Project Stakeholders

<table>
<thead>
<tr>
<th>Name</th>
<th>Stakeholder Group</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scot Becker</td>
<td>Bureau of Structures</td>
<td>Bureau Director</td>
</tr>
<tr>
<td>William Oliva</td>
<td>Bureau of Structures</td>
<td>Development Section Chief</td>
</tr>
<tr>
<td>Shiv Gupta</td>
<td>Bureau of Structures</td>
<td>Bridge Management Engineer</td>
</tr>
<tr>
<td>Travis McDaniel</td>
<td>Bureau of Structures</td>
<td>Bridge Management Engineer</td>
</tr>
<tr>
<td>Joshua Dietsche</td>
<td>Bureau of Structures</td>
<td>Bridge Management Engineer</td>
</tr>
<tr>
<td>Dave Babler</td>
<td>Bureau of Highway Maintenance</td>
<td>Bridge Maintenance Engineer</td>
</tr>
<tr>
<td>David Genson</td>
<td>Bureau of Highway Maintenance</td>
<td>Bridge Maintenance Supervisor</td>
</tr>
<tr>
<td>Joe Balice</td>
<td>FHWA</td>
<td>Regional Bridge Engineer</td>
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<tr>
<td>Oracle Database Manager</td>
<td>Bureau of Information Technology Services</td>
<td>Oracle Database Manager</td>
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<tr>
<td>Cost Expert</td>
<td>Bureau of Highway Maintenance</td>
<td>Civil Engineer</td>
</tr>
<tr>
<td>Highway Standards Expert</td>
<td>Bureau of Technical Services</td>
<td>Civil Engineer</td>
</tr>
</tbody>
</table>

### Time Requirement

#### Table 4. Summary of Hours Phase I

<table>
<thead>
<tr>
<th>INDIVIDUALS</th>
<th>TASKS</th>
<th>TOTAL HOURS</th>
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<tr>
<td>Principal Investigator</td>
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<td>Sub-Consultant</td>
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<td>Technical Manager</td>
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<td>BMS Specialist</td>
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<td>Bridge Inspection Data Advisor</td>
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<td><strong>TOTALS</strong></td>
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#### Table 5. Summary of Hours Phase II

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<th>INDIVIDUALS</th>
<th>TASKS</th>
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<td><strong>TOTALS</strong></td>
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Budget Worksheet

Redacted by WisDOT.
Schedule

Phase I

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<th>Task</th>
<th>Task Name</th>
<th>Start</th>
<th>Finish</th>
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<tbody>
<tr>
<td>Task 1</td>
<td>Literature Review</td>
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<td>Task 2</td>
<td>Database Development</td>
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<td>April 2014</td>
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<td>Task 3</td>
<td>Work Plan Development and Approval Report</td>
<td>June 2014</td>
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Phase II

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<th>Finish</th>
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<td>Phase I</td>
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<tr>
<td>State Specific Customization</td>
<td>8 wks</td>
<td>Mon 1/20</td>
<td>Fri 1/24</td>
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<tr>
<td>User Manual</td>
<td>6 wks</td>
<td>Mon 1/13</td>
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<td>Bridge Management System Pilot</td>
<td>4 wks</td>
<td>Mon 1/6</td>
<td>Fri 1/10</td>
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<tr>
<td>Implementation Plan</td>
<td>6 wks</td>
<td>Mon 1/6</td>
<td>Fri 1/10</td>
</tr>
<tr>
<td>ProjectDeliverables</td>
<td>6 wks</td>
<td>Mon 1/20</td>
<td>Fri 1/24</td>
</tr>
<tr>
<td>Project Ends</td>
<td>0 days</td>
<td>Fri 1/3</td>
<td>Fri 1/3</td>
</tr>
</tbody>
</table>

Gantt Chart for Phase II