**Federal Contract # DTFH61-17D00001 – Task Order #2**

**LONG-TERM BRIDGE PERFORMANCE PROGRAM**

PROGRESS REPORT NO. 3

Report Period: December 1, 2017 – December 31, 2017

Prepared For:

**Federal Highway Administration**

Prepared By:



**A. Account of work performed in this period**

* 1. **Coordination and Meetings Between the Contractor and FHWA LTBP Team**

The Rutgers team held a monthly conference call with Dr. Zobel on the 19th of December and submitted the minutes of the conference call on the 22nd of December.

* 1. **Develop LTBP Program bridge performance strategic research matrix**

Work continued on Task 2.2 in December, adding to the initial efforts from November on Tasks 2.2.1, 2.2.2, and 2.2.3. The concentration of effort in this month centered on three related areas of investigation: 1) The development of automated scripting tools to utilize literature search web service APIs, 2) A trial literature search for testing the data extraction forms and 3) Continued development of data extraction forms and quality rubrics. These efforts are discussed below in relation to their task numbers:

Task 2.2.3.2: Study Selection Strategy and Task 2.2.3.4: Data Extraction Protocol. Data extraction tables were developed for manual data extraction. These protocols and tables are being updated based on the findings from the trial literature search. See these tables in Appendix A.

Task 2.2.3.3: Development of Study Quality Checklists: Rubrics to score study quality were developed. See Appendix B.

Task 2.2.3.2: Study Selection Strategy and Task 2.2.3.4: Data Extraction Protocol. Work was begun on a Python script to search the Thompson-Reuters Web of Science using their Web Services API. This script generates sets of keywords from a master list and retrieves the meta-data records of literature based on these keyword searches.

Project Engineer: 165 hours

Project Support: 13 hours

* 1. **Conduct training for all field personnel on LTBP Protocols**

No work was performed for this task.

* 1. **Development of data collection protocols and RABIT-CE operations manual**

Task 4.2.1. Since Dec 2017, the subcontract agreement between Pennoni and Rutgers has been executed. Multiple discussions have been made to clear out the technical aspects of the instrumentation protocols. Simultaneously, Rutgers reviewed the previous protocols (e.g. data acquisition, sensors, etc.) to assure the consistency of the developing protocols. Appendix C represents samples of the under-development instrumentation protocols.

Task 4.2.2. Multiple conference calls have been made with the NJIT group to discuss multiple aspects of modifying Bridge Documentation (BD) and Legacy Data Mining (LD) protocols for treated bridge decks. Besides specifying the protocols for treated decks, all the existing protocols (published by FHWA) have been reviewed and multiple corrections have been proposed. The corrections have been derived based on the group’s past experience during the data extraction efforts under the old contract. Appendix B illustrates few snapshots of the under-development protocols, in which the added items reflect the properties of treated bridge decks.

Task 4.2.3. As a starting point for the development of RABIT-CE operations manual, the COR has shared a sample operations manual developed under the Long-Term Pavement Performance (LTPP) program. This document was reviewed as a guide in terms of both outline and format. Specific recommendations have been made to the Infratek Solution to reorganize and include additional components to their existing user guide. Multiple conference calls have been made with their team. Appendix E provides a sample of finalized format (which is shared with Infratek Solutions) after the review of operations manual developed by the LTPP program.

Staff Engineer: 15.75 hours

* 1. **Legacy Data Mining data extraction**

The following tasks were accomplished for the month of December:

* Data extraction were performed throughout the month for the bridge plans provided. It should be noted that these data extraction being performed by everyone in the LDM group will take up the majority of the groups effort to complete. We have currently two full time technician working on this.
* Quality control and quality assurance was provided for the data extraction performed this month and last month by reviewing the data collected by the technicians on the data extraction input excel sheet.
* Worked on further updating the Excel input sheet for data extraction to ensure that all of the data being collected and included in the sheet is uniform as well as accurate.

Staff Engineer: 8.25 hours

Technician: 184.00 hours

* 1. **Organize, conduct, and participate in LTBP workshops and meetings**

No work was performed for this task.

* 1. **Publications, website, communications, and technical assistance**

The Rutgers team prepared the electronic version of the monthly progress report and submitted it to FHWA. Moreover, the Rutgers team developed a MS Project file showing the project milestone and submitted it to FHWA.

**B. Work to be accomplished during the next period**

* 1. **Coordination and Meetings Between the Contractor and FHWA LTBP Team**

The Rutgers team will reach out to FHWA to schedule a meeting with Dr. Zobelin January and will submit the meeting minutes shortly after the meeting.

* 1. **Develop LTBP Program bridge performance strategic research matrix**

Work planned for January includes the continuation of work on the automate search and meta-data extraction scripts. Work also includes continuation of the trial literature search to update data extraction protocols. Work on Task 2.2.3 is anticipated to be completed by end of January.

* 1. **Conduct training for all field personnel on LTBP Protocols**

No work is planned under this task for the next reporting period.

* 1. **Development of data collection protocols and RABIT-CE operations manual**

Task 4.2.1 - Pennoni will submit the initial draft to Rutgers in mid-January for review. Rutgers will then review and modify the initial draft. The revised draft will be submitted to the FHWA for review.

Task 4.2.2 - Rutgers is currently working on drafting the BD and LD protocols. The initial draft will be submitted to the FHWA for review (by the end of Jan 2018).

Task 4.2.3 - Rutgers and Infratek are concurrently working on drafting the RABIT-CE operations manual. The revised draft will be submitted to the FHWA for review (by the end of Jan 2018).

* 1. **Legacy Data Mining data extraction**

The Rutgers team will continue with the data extraction from bridge documentations for the bridges that are assigned by LTBP. In addition, the team will perform QA/QC to make sure that the content being recorded in the main excel file is of high quality. The team will continue to update the main excel sheet with minor improvements in order to increase efficiency.

* 1. **Organize, conduct, and participate in LTBP workshops and meetings**

No work is planned under this task for the next reporting period.

* 1. **Publications, website, communications, and technical assistance**

The Rutgers team will prepare the electronic version of the monthly progress report and will submit it to FHWA. Moreover, the Rutgers team will submit the updated MS Project file to FHWA. No work is planned related to the publications, website, or technical assistance portion of this task.

**C. Problems/Recommended Solutions**

No problems encountered during this period.

**D. How the results of the work performed supports one or more of the FHWA, DOT and LTBP Goals**

The following is a summary of how the work performed on the primary tasks of this task order contribute to meeting the FHWA, DOT, and LTBP program goals.

**Task 2 - Develop LTBP Program bridge performance strategic research matrix**

Fundamentally, the SRMs aim to link the LTBP program to the larger research community. By placing the LTBP efforts in this larger context, the program will be able to identify potential synergies and collaborative opportunities as well as any overlaps that may exist. This will both increase the cost effectiveness of the program as well as the program’s impact on bridge engineering practice through clearly showing how the LTBP program contributes to the overall bridge performance research landscape.

**Task 3 - Conduct training for all field personnel on LTBP Protocols**

At the heart of the LTBP program’s data collection effort is the requirement that data be obtained in a consistent and reliable manner across the breadth of the program. Variations in collection techniques or unreliable practices would pollute the data streams and greatly limit the ability of the program to meets its goal of improving our understanding of long-term bridge performance. Activities under this task aim to ensure that the data collection efforts of the LTBP program are executed by teams with the required expertise to obtain consistent and reliable data.

**Task 4 - Development of data collection protocols and RABIT-CE operations manual**

Similar to the training work being conducted under Task 3, this task is also involved in ensuring consistent and reliable data collection throughout the program. Specifically, this task will develop additional protocols and operations manuals that specify best-practice approaches for data collection.

**Task 5 - Legacy Data Mining data extraction**

In addition to ensuring consistent and reliable data collection efforts, the overarching goal of the program is also dependent upon the completeness of the data collection efforts. This task contributes to this through the collection of available legacy data. This data not only provides a means to ensure field data collection efforts are carried out efficiently (i.e. on bridges best suited to meeting the program’s goals) but also provides context to the data to help explain observed trends and correlations (and thus further our understanding of long-term bridge performance).

**E. Purchases and Rentals**

Nothing was purchased during this period.

**F. Travel Details for Reporting Period**

No travel occurred during this reporting period.

**G. Current and Cumulative Expenditures (cost shown includes benefits and overhead)**

|  |  |  |
| --- | --- | --- |
| **Institution** | **Current Expenditures**  **12/1/2017 – 12/31/2017** | **Cumulative Expenditures**  **10/1/2017 – 12/31/2017** |
| Rutgers, the State University of New Jersey | $ 34,633.50 | $ 81,555.00 |

**Appendix A**

**Data Extraction Forms**

The information gathered from sources will be divided into three levels of differing detail. The first level includes meta-data about the literature source, basic topic information/keywords, as well as funding. The second level includes information that will be used to sort the literature into refined categories and remove some literature sources from the study. The third level will be used to rank sources based on quality and study design hierarchy (if possible).

***Level 1***

Using data from meta-data and title

|  |  |
| --- | --- |
| Date of Review |  |
| Reviewer |  |
| Title |  |
| Author(s) |  |
| Search Engine+ |  |
| Keywords Used in Search |  |
| Publication Date |  |
| Publication Title |  |
| Publication Category\* |  |
| Publication Keyword(s)++ |  |

\* See list of categories below

+ Or targeted journal/source search, or citation reference (Google Scholar, Web of Knowledge, or Scopus versus ASCE Journal of Bridge Engineering versus High-impact citation in another accepted study)

++ If available, usually provided with publication metadata

***Level 2***

Using information from meta-data, title, and abstract only

|  |  |
| --- | --- |
| Funding Agency |  |
| Funding Amount |  |
| Funding Date (Start/End) |  |
| Funding Source Category |  |
| SRM Topic\* |  |
| SRM Element Type\* |  |
| Keyword(s)+ |  |
| Number of Citations |  |
| Study Objective (from Abstract) |  |
| Study Conclusion(s) (from Abstract) |  |
| Complete Abstract |  |
| Reason for Exclusion++ |  |

\* See table below

+ If different from Publication Keywords, based on reviewer opinion

++ If applicable

***Level 3***

Using information from full-text source

|  |  |
| --- | --- |
| Study Quality Score\* |  |
| SRM Subtopic(s)\*\* |  |
| Notable Citations\* |  |
| Notes\* |  |
| Reason for Exclusion+ |  |

\* See explanation below

\*\* See table below

+ If applicable

**Data Extraction Guidelines**

***Publication Categories***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tier 1 | Tier 2 | Tier 3 |  |  |
| NCHRP Synthesis | Journal Articles | State Research Reports |  |  |
| Meta-Analysis Journal Articles | NCHRP Reports |  |  |  |
|  | FHWA Research |  |  |  |
|  | European Research Reports |  |  |  |
|  | UTC Reports |  |  |  |

**Appendix B**

**Relevance Criteria**

The importance, significance, and usefulness of the research problem, objectives, processes, and findings to the problem context

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Definition** | **Rubric Scale** |
| Clearly defined context that falls under the scope of the SRM topics and relevant to the problem of long-term bridge performance | The context is well defined and described and analyzed sufficiently to identify research entry points. Research problem is relevant to the problem context. | The context is well-defined, described, and analyzed sufficiently to identify the need for research. The research problem is defined and framed in a way that clearly shows its relevance to the context and that demonstrates that consideration has been given to the practical application of research activities and outputs. |
| Explicit theory of change | The research explicitly identifies its main intended outcomes and how they are intended/expected to be realized and to contribute to longer-term outcomes and/or impacts. | The research explicitly identifies its main intended outcomes and how they are intended/expected to be realized and to contribute to longer-term outcomes and/or impacts. |
| Relevant research objectives and design | The research objectives and design are relevant, timely, and appropriate to the problem context, including attention to stakeholder needs and values. | The documentation clearly demonstrates, through sufficient analysis of key factors, needs, and complexity within the context, that the research objectives and design are relevant and appropriate. |

**Credibility**

The research findings are robust and the sources of knowledge are dependable. This includes clear demonstration of the adequacy of the data and the methods used to procure the data including clearly presented and logical interpretation of findings.

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Definition** | **Rubric Scale** |
| Broad preparation, clear research problem and objective definition | The research is based on a strong integrated theoretical and empirical foundation that is relevant to the context. The research is clearly defined and presented in the larger context of the existing literature. | The documentation demonstrates critical understanding of an appropriate breadth and depth of literature and theory relevant to the context. The authors clearly articulate how their research is integrated into the current body of knowledge. |
| Objectives met | Objectives states in research study are clearly met. | Problem and objectives are both clearly stated and shown to have been met with any necessary adaptation noted and explained. |
| Appropriate purpose, methods, and implementation | Methods are fit to purpose and well-suited to answering the research questions and achieving the objectives. Research execution is suitable to the problem context and relevant research objectives. | The documentation explicitly states the rationale for the inclusion of methods with reference to the context. Methods are clearly described, and documentation demonstrates that the methods are fit to purpose, systematic yet adaptable, and transparent. Novel (unproven) methods or adaptations are justified and explained, including why they were used and how they maintain scientific rigor. |
| Clearly presented argument | The movement from analysis through interpretation to conclusions is transparently and logically described. Sufficient evidence is provided to clearly demonstrate the relationship between evidence and conclusions. | Results are clearly presented. Analyses and interpretations are adequately explained, with clearly described terminology and full exposition of the logic leading to conclusions, including exploration of possible alternate explanations. |

**Legitimacy**

The research process is perceived as fair and ethical. This encompasses the ethical and fair representation of possible sources of bias, assumptions, financing, etc.

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Definition** | **Rubric Scale** |
| Disclosure of perspective | Actual, perceived, and potential bias is clearly stated and accounted for. This includes aspects of: researchers’ position, sources of support, financing, collaborations, partnerships, research mandate, assumptions, goals, and bounds placed on commissioned research. | The documentation identifies potential or actual bias, including aspects of researchers’ positions, sources of support, financing, collaborations, partnerships, research mandate, assumptions, goals, and bounds placed on commissioned research. |

**Effectiveness**

The research generates knowledge and and can stimulate actions that address the problem and contribute to solutions and innovations

|  |  |  |
| --- | --- | --- |
| **Criteria** | **Definition** | **Rubric Scale** |
| Contribution to knowledge | Research contributes to knowledge and understanding in academic and social realms in a timely, relevant, and significant way. | There is evidence that knowledge created through the project is being/has been used by intended audiences and end-users. |
| Practical application | Research has a practical application. The findings, process, and/or products of research can used. | There is evidence that innovations developed through the research and/or the research process have been (or will be applied) in the real world. |
| Significant outcome | Research contributes to the solution of the targeted problem or provides unexpected solutions to other problems. | There is evidence that the research has contributed to positive change in the problem context. |
| Transferable/generalizable research findings | Appropriate and rigorous methods ensure the study’s findings are externally valid (generalizable). In some cases, findings may be too context specific to be generalizable in which case research would be judged on its ability to act as a model for future research. | Document clearly explains how the research findings are transferable to other contexts OR, in cases that are too context-specific to be generalizable, discusses aspects of the research process or findings that may be transferable to other contexts and/or used as learning cases. |

**Criteria from Belcher et al 2015 with minor adaptation.**

**Appendix C. Instrumentation protocols samples (ongoing)**

Sample Protocol for Instrumentation Configuration

|  |  |
| --- | --- |
| Type of bridge size category | e.g. short span, midsize span, or long-span |
| Number of sensor per span per lane | e.g. 1, 2, 3 |
| Location of sensor # 1 | e.g. X, Y, span # 1 |
| Type of sensor | e.g. electrical, fiber optic (discrete or distributed), piezo, vibrating wire gauge |
| Type of measured response | e.g. strain, tilt, acceleration, temperature, deflection |
| Sensor manufacturer | e.g. Micron Optics |
| Frequency of measurement | e.g. 100 Hz |
| Sensor lifetime | e.g. 10 years |
| Sensor accuracy | e.g. 3 microns |
| Type of data acquisition system | e.g. EG2000 |
| … | … |

Sample Protocol for Acceleration Measurement (& sensing unit)

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **#** |  | **FIELD NAME** | **DATA TYPE** | **ACCURACY** | | | | | **UNIT** |  | **FIELD DESCRIPTION** | **ROW COLOR** |
| **1** | State |  | Text |  | | | | |  | State Code, e.g., Virginia = VA | | Green |
| **2** | NBI structure number | | Text |  | | | | |  | Item 8, structure number, from NBI Coding Guide | | Green |
| **3** | Structure name | | Text |  | | | | |  | Descriptive name for the bridge, e.g., Route 15 SB over I–66 | | Green |
| **4** | Protocol name | | Text |  | | | | |  | Title of the protocol | | Green |
| **5** | Protocol version | | Text | Month and year | | | | |  | Month and year the protocol version was published; e.g., May 2015 | | Green |
| **6** | Personnel inputting sensor information | | Text |  | | | | |  | First name(s) Last name(s) | | Green |
| **7** | Date completed | | Text | Exact date | | | | |  | mm/dd/yyyy | | Green |
| **Sensor Information** | | | | | | | | | | | | Pink |
| **8** | Unique Sensor Designation | | Text | |  | | | | | Unique designation for this type of sensor for this bridge. Provide data in rows 9–42 for each different type of accelerometer in the instrumentation plan. | | Blue |
| **9** | Type of Accelerometer | | List | |  | | | | | Select 3 letter code from list:  -Piezoelectric = PEA; --Surface micro-machined capacitive (MEMs) = MEM; -Electromechanical servo (force balance) = SER;  -Other (explain in comment item 42) = AMO | | Yellow |
| **10** | Manufacturer of accelerometer | | Text | |  |  | | | | Provide name of manufacturer | | Yellow |
| **11** | Model number of accelerometer | | Text | |  |  | | | | Provide sensor model name | | Yellow |
| **12** | Length of actual sensor | | Number | | 0.1 | in | | | | Physical length of accelerometer | | Yellow |
| **13** | Width of actual sensor | | Number | | 0.1 | in | | | | Physical width of accelerometer | | Yellow |
| **14** | Height of actual sensor | | Number | | 0.1 | in | | | | Physical height of accelerometer | | Yellow |
| **15** | Resolution of the accelerometer | | Number | | 1 | µg | | | | What is the smallest measurement that this sensor can make? | | Yellow |
| **16** | Accuracy of the accelerometer (as per manufacturer) | | Number | |  | ± % | | | | Example: 0.5 means accuracy is ±5% | | Yellow |
| **17** | Lower range of the accelerometer | | Number | | 1 | µg | | | | Smallest measurement that the accelerometer can make | | Yellow |
| **18** | Upper range of the accelerometer | | Number | | 1 | µg | | | | Largest measurement that the accelerometer can make. | | Yellow |
| **19** | Lowest temperature that the accelerometer can operate in (as per manufacturer) | | Number | | 1 | oF | | | | Lowest temperature that the accelerometer can operate in. Example: -20oF | | Yellow |
| **20** | Highest temperature that the accelerometer can operate in (as per manufacturer) | | Number | | 1 | oF | | | | Highest temperature that the accelerometer can operate in. Example: 100oF | | Yellow |
| **21** | Is this a temperature-compensating accelerometer? | | List | |  | | | | | Yes  No | | Yellow |
| **22** | Does the accelerometer also contain a temperature sensor? | | List | |  | | |  | | Yes  No | | Yellow |
| **23** | Does the accelerometer include filtering? | | List | |  | |  | | | Yes  No | | Yellow |
| **24** | If the accelerometer does contain filtering, what is the lower bandwidth? | | Number | | 1 | | Hz | | | Hertz (Hz) | | Yellow |
| **25** | If the accelerometer does contain filtering, what is the upper bandwidth? | | Number | | 1 | | Hz | | | Hertz (Hz) | | Yellow |
| **26** | Expected fatigue life (cyclic performance) of accelerometer | | Number | | 1 | | Number of cycles | | | Examples:  1  1000000 | | Yellow |
| **27** | The recommended lower input voltage of the accelerometer | | Number | | 1 | | V | | | Volts | | Yellow |

**Appendix D. Samples of the protocols developed for treated decks (ongoing)**

Sample Protocol for Bridge Documentation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| # | Field Name | Data Type | Accuracy | Unit | Field Description | Row Color |
| Deck Details | | | | | | Pink |
| 1 | Type of overlay | Predefined List |  |  | Concrete, Latax Concrete, Low Slump Concrete, Epoxy Overlay, Bituminous, Wood, gravel, chip seal, none, other (Specify in comments) | Yellow |
| 2 | Type of Membrane | Predefined List |  |  | Built-up, Performed Fabric, Epoxy, Unknown, other, none | Yellow |
| 3 | Original deck material | Predefined List |  |  | Concrete, Timber, Steel grid | Yellow |
| 4 | Overlay wearing surface, date of application | Predefined List | Month and year |  | mm,yyyy, if applicable | Yellow |
| 5 | Overlay wearing surface thickness | Predefined List | 0.25 | in. | If applicable | Yellow |
| 6 | AASHTO Overlay Specification | Text |  |  |  | Yellow |
| 7 | State overlay specifications | Text |  |  | Document name | Yellow |
| 8 | Overlay bonding | Predefined List |  |  | Unbonded, Bonded, Partially Bonded, Unknown | Yellow |
| 9 | Adhesive type between overlay and original deck | Text |  |  | Binder name | Yellow |
| 10 | Concrete overlay-cement type | Predefined List |  |  | I, II, III, IV, or V | Yellow |
| 11 | Modified concrete type | Predefined List |  |  | Latex Modified Cement, Microsilica Modified Concrete, Cement Epoxy | Yellow |
| 12 | Microsilica (silica fume) quantity | Number | 1 | lb/yd3 | Amount from mix design | Yellow |
| 13 | Epoxy quantity | Number | 1 | lb/yd3 | Amount from mix design | Yellow |
| 14 | Latex quantity | Number | 1 | lb/yd3 | Amount from mix design | Yellow |
| 15 | Specified concrete overlay water-cement (w/c) ratio | Number | 0.01 |  |  | Yellow |
| 16 | Overlay thickness | Number | 0.25 | in. |  | Yellow |
| 17 | Unit weight of overlay | Number | 1 | pcf |  | Yellow |
| 18 | Concrete overly reinforcement | Predefined List |  |  | yes, no, none, unknown | Yellow |
| 19 | Removal of existing/previous overlay | Predefined List |  |  | yes, no, none, unknown | Yellow |
| 20 | Thinckness of original deck removed for treatment | Number | 0.25 | in. |  | Yellow |
| 21 | Clear cover from top of overlay to original deck reinforcement | Number | 0.25 | in. | Clear cover to top reinforcement from original deck/overlay interface | Yellow |
| 22 | Clear cover from top of overlay to overlay reinforcement | Number | 0.25 | in. |  | Yellow |
| 23 | Overlay and original deck thickness | Number | 0.25 | in. | thickness of combined original deck and overlay | Yellow |

Sample Protocol for Legacy Data Mining

**3.3 If possible determine any correlation between the NBI rating of the deck and the following:**

**3.3.1** Overlay type.

**3.3.2** Overlay thickness.

**3.3.3** Membrane type.

**3.3.4** Membrane thickness.

**3.3.5** Combined overlay and deck thickness.

**3.3.6** Air content in cement based overlays.

**3.3.7** Compressive strength of overlay.

**3.3.8** Time before traffic was allowed on overlay or membrane.

**3.3.8** Time cement based overlays were cured for.

**3.3.9** 28 day Compressive strength of cement based overlays.

**3.3.15** Moisture (rain) present on day of overlay.

**3.3.16** Ambient temperature when treatment was applied.

**3.3.17** Wind speed when treatment was applied.

**3.3.18** Actual Bituminous compaction.

**3.3.19** Clear cover:

**Appendix E. Overview of the proposed RABIT-CE manual’s structure**

* **Forward (or Executive Summary)**
* **Disclaimer (and/or Acknowledgment)**
* **Chapter 1 – Introduction**
  + Overview of the LTBP program
  + Significance of NDT data collection for the program
  + Multiple techniques for NDT testing
  + Importance of automated NDT collection
  + Overview of RABIT-CE
  + Overview of the manual
* **Chapter 2 – Data Collection using RABIT-CE**
  + Introduction
  + Overview of the components
* Camera
* GPS
* Impact Echo
  + Transmitter sensor
  + Receiver sensor
  + Sensor arrangement
  + Sample raw data
  + Sensor picture
* Electrical Resistivity
* ….
  + Features of the device
    - Type of saved data
    - Exporting data
    - Pre- and post-run data
    - …..
  + Computer and software setting (& installation)
  + Equipment specific operational guidelines
    - Sensor QA/QC
    - Sensor positioning
    - Sensor cleaning
    - Tire pressure
    - GPS positioning
  + Field Operation Guidelines
    - Site preparation
    - Deck gridline
    - Reference point
    - Power up procedure
    - Event initiation
    - Operating speed
    - End of run
    - File naming
    - Power down procedure
  + Data Collection (during the test)
    - Impact echo
    - Electrical resistivity
    - GPR
    - Camera
  + Calibration/Calibration check (we should discuss in details)
  + Equipment maintenance, repair, and replacement
    - Routine maintenance
    - Scheduled major preventive maintenance
    - Unscheduled maintenance
    - ….
  + Record back-up
* **Chapter 3 – Safety**
* Keep as it is
* Read section 2.6 from the LTPP manual and customize it for RABIT-CE
* **Chapter 4 – Post-processing (office)**
  + Introduction
  + Data conversion
  + Data validation
  + Naming and record keeping
  + Data storage
  + Reporting
  + Uploading into the LTBP Bridge Portal
* **References**
* **Appendix**
  + RABIT-CE problem report form
  + Standard form for data collection operation
  + Standard form for maintenance request
  + Standard form for validation/calibration
  + Standard form for data conversion
  + Troubleshooting guide