Massachusetts Department of Transportation Guide for Submitting a Research Report

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Table of Contents

List of Tables

List of Figures

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Massachusetts Department of Transportation
Guide for Submitting a Research Report

Introduction

The Massachusetts Department of Transportation (MassDOT) Research Program provides for research to be funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds.

The instructions in this Guide are addressed to Principal Investigators (PIs) whose responsibility is to finalize and submit draft final research reports under the MassDOT Research Program. Please remember that draft final reports must be submitted three months (90 days) prior to the end of the contract**.** Please plan accordingly.

Because these instructions are updated intermittently, you should review all information in this Guide before submitting reports or other deliverables to MassDOT. This guide covers the required organization and formatting of final reports for publication, the requirements for compliance with Section 508 accessibility standards, and instructions for submittal. The Guide refers to the **Sample Research Report** (see Appendix) for further clarity.

Reports that do not follow this Guide will not be accepted as final deliverables. In the event that you believe a change in format or organization would offer a more effective presentation for the research material, please contact the Manager of Research and the Project Champion as soon as possible in writing, requesting permission for a change. Any change must be authorized in writing by the Director of Research.

Please address questions regarding the application of this Guide to Melissa Paciulli, Manager of Research and Development. Other resources, such as an MS Word report template, can be provided to help you if needed.

Please refer to the checklist on the following page prior to submitting a draft final report to MassDOT.

Checklist for Final Report

1.0 Content and Organization:
- ☐ Report is written clearly and concisely.
- ☐ All front matter is included.
- ☐ All required report chapters are included.
- ☐ Deviations from the above have been approved in writing by MassDOT.

2.0 Required Format:
- ☐ Language used is in third person throughout.
- ☐ Microsft Word 2007 or higher has been used.
- ☐ Normal style has been followed for body text.
- ☐ Styles have also been defined (as explained in this section) for three levels of heading, bulleted and numbered lists, and table and figure captions.
- ☐ Margins are correct.
- ☐ Pagination is correct (Roman numeral vs. Arabic, continuous numbering except cover).
- ☐ Tables of contents for the report, and for tables and figures, are automated and updated.
- ☐ Chicago style has been followed.
- ☐ All acronyms have been defined.
- ☐ References and citations are consistent with TRB style, and citations have been double-checked against Reference List.
- ☐ Bulleted and numbered lists are consistent in style.
- ☐ Deviations from above have been approved in writing by MassDOT.
- ☐ A final spellcheck and grammar check have been done.

3.0 Section 508 Compliance:
- ☐ Document layout and formatting has been checked against standards (see Section 3.21).
- ☐ Tables, figures, and other objects and images have been checked against standards (see Sections 3.22 and 3.23).
- ☐ Additional information has been checked against standards (see Section 3.24).

1.0 Content and Organization

1.1 Sections To Be Included

The content of the report body may vary, depending on the nature of the research project. However, the final report must be organized into sections and chapters as follows:

Front Matter:
- Cover
- Technical Report Document Page
- Title Page
- Acknowledgements
- Disclaimer
- Executive Summary
- Table of Contents
- List of Tables
- List of Figures
- List of Acronyms (if required)

Body of the Report:
- 1.0 Introduction
- 2.0 Research Methodology
- 3.0 Results
- 4.0 Implementation and Technology Transfer
- 5.0 Conclusions
- 6.0 References
- 7.0 Appendices (if required)

If you feel that variance from this organization would better present your research, you must submit a written change of format request to the Manager of Research and the Project Champion as soon as possible.

The remaining sections in Chapter 1.0 describe the content requirements for each chapter of the report.

The following chapters in the Guide detail the format for you to follow in presenting your research. A **Sample Research Report** for further guidance is provided in the Appendix.

1.2 Cover

See example of a Report Cover in the **Sample Research Report**, in the Appendix. Submit a photo to be used, and MassDOT will create this cover page.

1.3 Technical Report Document Page and Abstract

Completion of the Technical Report Document is self-explanatory (see Table 1, and **Sample Research Report**). MassDOT will provide a Performing Organization report number (item 8) to be used. The "total number of pages" (item 21) is a count of all pages, beginning with the Technical Report Document Page through the final appendix page.

Each final report must contain an abstract within the Technical Report Document Page. **The abstract should be 200 words or less**. It should be self-contained, and it should require no reference to the report to be understood. The abstract presents the primary objectives and scope of the study. Describe specific techniques or methods only to the extent necessary for comprehension. Present your findings and conclusions concisely and informatively, with direct statements in complete sentences. Limit the use of bulleted or numbered lists, and do not use undefined terms, acronyms, reference citations, abbreviations, or equations.

The Transportation Research International Documentation (TRID) database uses this abstract to describe the research project.

Table 1: Technical Report Document

1. Report No. SPRII.**.**.*	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle		5. Report Date	
		6. Performing Organization Code	
7. Author(s)		8. Performing Organization Report No. UMTC-XX	
9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract An abstract of 200 words or less, suitable for use in computerized information storage and retrieval systems, should be presented. The abstract will be provided to the Transportation Research Information Services (TRIS) and the National Technical Information Service (NTIS). The abstract should use direct statements in complete sentences to describe the work scope and principal findings.			
17. Key Word		18. Distribution Statement	
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72)　　　Reproduction of completed page authorized

1.4 Title Page

List author name(s) and professional titles on the Title Page of the report, as shown in Figure 2. See the **Sample Research Report** in the Appendix for a specific example.

Graduate student authors who have made a meaningful contribution to the writing of the final report may be listed as co-authors on the Title Page. However, when students help with collection of data but do not contribute in any way to the preparation of the written portion of the final report, their data collection role would be mentioned in the Acknowledgements section, not on the Title Page.
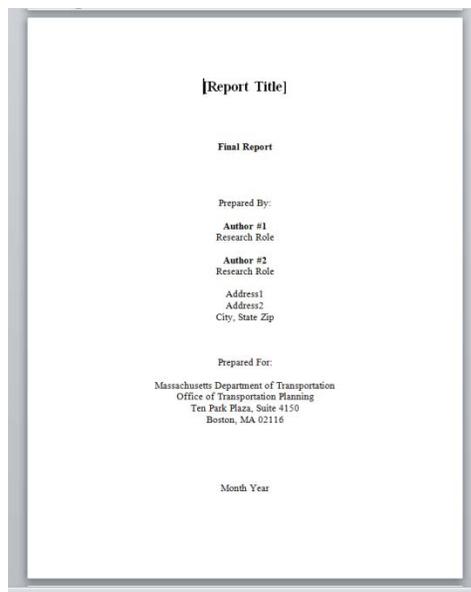
Figure 1: Final Report Title Page

1.5 Acknowledgements and Disclaimer Sections

The Acknowledgements section should include the following statement, before all other text:

Prepared in cooperation with the Massachusetts Department of Transportation, Office of Transportation Planning, and the United States Department of Transportation, Federal Highway Administration.

Following this statement, the authors may wish to acknowledge the efforts of their research team. Please see the **Sample Research Report** in the Appendix for an example.

The Disclaimer section should be word for word as follows:

The contents of this report reflect the views of the author(s), who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Massachusetts Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

1.6 Executive Summary

The Executive Summary should provide a stand-alone summary of the research report. As readers are more likely to refer to the Executive Summary than to the full report, recommendations should be supported within the Executive Summary.

Requirements of the Executive Summary:
- Provide the primary scope and objectives of the study.
- Provide a concise synopsis of the research issue.
- Convey the significance of the research.
- Convey the main findings or results, in a concise manner.
- Provide conclusions and recommendations of the research.

For consistency, the above points should match exactly those presented later in the final report.

This section should not contain:
- Unfamiliar terms that haven't been defined.
- Undefined acronyms.
- Reference citations.
- Displayed equations or lists.

The length of the Executive Summary should be approximately two to five pages.

If the research report contains many acronyms, provide a List of Acronyms at the front of the document (see Section 1.8).

The following paragraph should be included in the beginning of the Executive Summary, preceding any other text:

This study of [report title], was undertaken as part of the Massachusetts Department of Transportation Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

1.7 Table of Contents and Lists of Tables and Figures

The Table of Contents, List of Tables, and List of Figures are required chapters. All of these must be automatically generated so they can be updated as content changes are made during the review process, and in order to conform to Section 508 standards. See the applicable sections in Chapter 2.0, Required Format, for instructions on how to create these.

1.8 List of Acronyms (if required)

If many acronyms are used throughout the report, create a table containing a list of all acronyms used, with their titles spelled out in full. Otherwise, ensure that all acronyms are spelled out at least the first time they are used in body text.

1.9 Introduction

The Introduction is meant to paint a clear and concise overview of the research. As the opening chapter of the research report, this section should capture the attention of the reader and provide relevant detail.

Requirements for the Introduction:
- Provide a clear and concise overview of the research issue.
- Provide the historical background of the research issue.
- Convey the research goals and objectives.
- Convey the basic approach to the project, e.g., field study, case study, experiments, site testing, etc.
- List the main objectives of the research project and associated tasks (action steps).
- Unlike the Executive Summary, the Introduction does not include research results, conclusions, or recommendations.
- If the research included site testing, the Introduction should include a locus map, latitude and longitude in Massachusetts State Plane coordinates, and a detailed site map.

The following paragraph should be included in the beginning of the Introduction, preceding any other text:

This study of [report title] was undertaken as part of the Massachusetts Department of Transportation Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

1.10 Research Methodology

The Research Methodology chapter is meant to provide the reader with a detailed explanation of the methods used to conduct the research. The methods should be outlined in a clear and concise format, using tables and figures only when they will add depth to the text.

Requirements for the Research Methodology chapter:
- Detailed explanation of the research approach.
- Methods of data collection and analysis.
- Scope and limitations of the research project.
- Overview of research methods, including literature review, experiment design, field study/site testing detail, etc.
- Description of the materials and equipment utilized.
- Analytical procedures and evaluation methods.
- Criteria for measuring progress/success.

1.11 Results

The Results chapter is meant to highlight the outcomes of the research. This may include trends that were recorded or unexpected outcomes. As this chapter represents the fruits of the difficult research, care should be taken to provide a clear and inclusive picture for the reader.

Requirements of the Results chapter:
- Results of the research.
- Clear and concise picture regarding the outcomes and trends recorded.
- Tables and figures may be used to guide the reader toward important information.
  o If there is very little data or a lack of variation in the data, then a table is not necessary, as the information can be relayed in the text.
  o However, if the research is complex, dense, or shows great variation, then a table or figure may be helpful.
- Unexpected outcomes of the research.

1.12 Implementation and Technology Transfer

The Implementation and Technology Transfer chapter will be based on the Implementation and Technology Transfer plan, as outlined in each agreement. This section is a critical component of the research report, as the information provided here will aid in the transfer of this knowledge.

The Implementation and Technology Transfer chapter will include:

- Lessons learned.
- Opportunities for technology transfer.
- An implementation plan for the research.
- Potential institutional barriers.
- Guidance for future planning, design, and deployment of research findings.
- Guidance for future training associated with this research.

1.13 Conclusions

The Conclusions chapter is meant to provide a summary of the research report and should include a more general overview of the research and the broader implications of the findings.

The Conclusions chapter will include:
- Conclusions and recommendations of the research.
- Strong connections between the evidence that has been collected and the recommendations that are being provided.
- Discussion of the findings of the research and the broader implications of said findings.
- Limitations of the research.
- Possibilities for future research.

1.14 References

Reference lists, unlike bibliographies, list only the sources cited in the text and are organized in the order of citation. Bibliographies generally include all sources consulted, not just those cited in the text, and generally are organized alphabetically. Reference lists are required for all research reports.

The References chapter demands absolute accuracy. Because references come from a wide variety of sources, definite rules for the identification of reference materials have been adopted and should be carefully observed. See Chapter 2.7 concerning the required format for references and how they must be cited in the body of the report.

1.15 Appendices (if required)

The Appendices chapter provides a space in the research report for addenda to the body of the report. The Appendices, while offering more flexibility in terms of formatting (as they are often protocols from other sources, etc.), should still be treated as part of the document. If the Appendices won't attach to the main document, please send as a separate pdf.

The Appendices will include:

- Relevant data summaries, graphs, and charts not used in the report.
- Lab reports.
- Non-standard protocols.
- Glossaries.
- Any other relevant information left out of the main body of the report.

Follow the required format for Appendix headings as described in Chapter 2.0.

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2.0 Required Format

Prepare your final draft report using Microsoft Word. MassDOT expects that draft final reports submitted will be complete, accurate, and fully formatted. Please thoroughly review your report prior to submittal. Chapter 4.0 on Manuscript Submittal contains additional information.

The Transportation Research Board (TRB) "Preparing Papers for Peer Review and Presentation," as well as the *Chicago Manual of Style* (visit http://www.chicagomanualofstyle.org/home.html), were generally referenced to develop these guidelines, with some differences. **If you feel that variance from the format in this Guide would better present your research, you must submit a written change of format request to the Manager of Research and the Project Champion as soon as possible.**

2.1 Manuscript Specifications

2.1.1 Length of Manuscript

Final reports will vary in length, based on the research conducted. There is no upper or lower page limit. However, write your report as clearly and concisely as possible.

2.1.2 Software to be Used

Please make every effort to prepare your report using Microsoft Word 2007 or later versions. Use of Microsoft Word 2003 or earlier versions frequently results in problems with formatting and editing the final report, and with addressing Section 508 compliance.

2.2 General Style

Generally, refer to the *Chicago Manual of Style* (http://www.chicagomanualofstyle.org/home.html) and Merriam Webster for style, usage, and spelling guidance. Avoid jargon and undefined acronyms. The writing style should be appropriate for a technical document: clear, concise, readable, and effective.

Before submittal, ensure that your entire document is written in one voice, without the use of first-person or second-person singular or plural, such as "I," "we," "us," or "you." Often, papers are written in stages by different authors. This can create issues with continuity and flow of the document. Review the report carefully for consistency and continuity.

Follow the instructions in this Guide and the **Sample Research Report** when building your final report. Style direction for formatting is provided throughout.

2.3 Organization of Final Report

The final report should be organized into the following sections:

- Cover
- Technical Report Document Page
- Title Page
- Acknowledgements
- Disclaimer
- Executive Summary
- Table of Contents
- List of Tables
- List of Figures
- List of Acronyms (if needed)
- 1.0 Introduction
- 2.0 Research Methodology
- 3.0 Results
- 4.0 Implementation and Technology Transfer
- 5.0 Conclusions
- 6.0 References
- 7.0 Appendices (if needed)

2.4 Page Setup

2.4.1 Margins

- Left 1.25 in., Right 1.0 in.
- Top 1.0 in., Bottom 1.0 in.
- Header 0.5 in., Footer 0.5 in.

2.4.2 Normal Style (Font and Alignment)

- Font should be Times New Roman.
- Text in body of report should be 12 point.
- Text should be left-aligned, not justified.

2.4.3 Pagination

Do not number either the Cover page or blank page that follows it. Beginning with the Technical Report Document Page and through all front matter, number pages continuously using lower-case Roman numerals, starting with i. At the Introduction, begin numbering with Arabic numerals, starting with 1. Use Arabic numerals to the end of the document, including Appendices.

Page numbering format:

- Insert page numbers using the Footer tab, placing them centered at the bottom of the page.
- The front matter of the document, from the Technical Report Document Page up to the Introduction, will have lower case Roman Numerals (i, ii, iii…).
- Start Arabic numerals (1, 2, 3…) with the Introduction (1.0), and continue through to the end of report, including all Appendices. Use Word's section breaks function to change page numbering style from Roman Numeral to Arabic.
- Do not include title, author name, date, logos, etc. on the top or bottom of any page.
- The following sections should begin on a right-hand page when printed (i.e., odd-numbered page):
  o Technical Report Document Page
  o Title Page
  o Acknowledgements and Disclaimer (these sections will be on the same page)
  o Executive Summary
  o Table of Contents
  o List of Tables
  o List of Figures
  o List of Acronyms
  o All Main Chapter Headings (1.0 to 7.0)
  o References
  o First page of each Appendix

- Insert blank pages as necessary to ensure that these sections begin on a right-hand page when printed. These blank pages should contain the sentence "This page left blank intentionally." in the center of the page (except for the blank, unnumbered page following the Cover).

2.4.4 Widows and Orphans

- Do not leave a single line of text at the top or bottom of a page. If necessary, move the associated paragraph to the next page.
- Do not insert a heading without text at the bottom of a page. Instead, move it to the next page by inserting a page break.
- Keep numbers or words that depend on each other for meaning on the same line by inserting nonbreaking spaces (Control+Shift+Space).

2.4.5 Paragraphs

Begin new paragraphs flush with the left margin; do not indent. Use an extra line space between paragraphs.

2.4.6 Headings and Subheadings

Clear and logical reading order is one of the most important parts of a successful final report. It is useful for all readers, and is also a requirement of 508 compliant documents. For this

reason, all reports must have clear chapter and subchapter headings, **not exceeding two levels of subheading**. For example, within Chapter 1 (1.0), there may be 1.1 and 1.1.1.

Create all of your report headings using the "styles" function in Microsoft Word. This step allows creation of a Table of Contents that you can then automatically update as page numbers shift during editing, and also makes the document Section 508 compliant. This section gives instructions on how to create headings using styles. See Section 2.10 for instructions on how to create your automated Table of Contents.

Main Chapter Headings

The following parts of the report are considered main chapters and should begin on the right-hand side of the report (odd-numbered pages) when printed. Begin each main report chapter on its own page. Insert blank pages to ensure that the chapter begins on the right-hand side of the printed report.

- Technical Report Document Page
- Acknowledgments and Disclaimer (on the same page)
- Executive Summary
- Table of Contents
- List of Tables, List of Figures, and List of Acronyms
- All Chapter Headings (1.0 through 7.0)
- First page of each Appendix

For main headings, use the following specifications. Format your first main heading and save its style as "MCRP Main Heading." See example in Figure 2.

- Times New Roman, bold, 20 point.
- Aligned center, 0 in. left indent, 0 in. right indent.
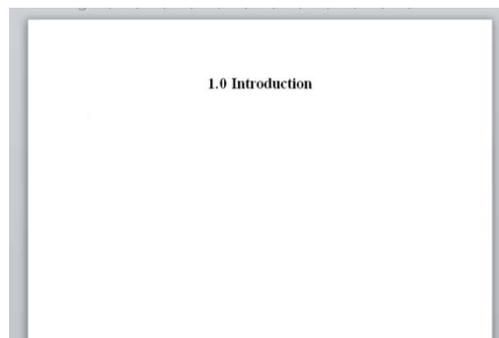- No hanging indent, single line spacing, 0 point before spacing, 24 point after spacing.

Figure 2: Example of Main Chapter Heading

Subheading Level 1

Format your first chapter subheading and save this style as "MCRP Heading 1." These subheadings do not begin on a new page or print on a right-hand page. Follow these specifications for Subheading Level 1, and see example in Figure 3:

- Times New Roman, bold, 14 point.
- Aligned left, 0 in. left indent, 2.5 in. right indent.
- No hanging indent, single line spacing, 30 point before spacing, 18 point after spacing.
- 0.5 point dotted border under text.
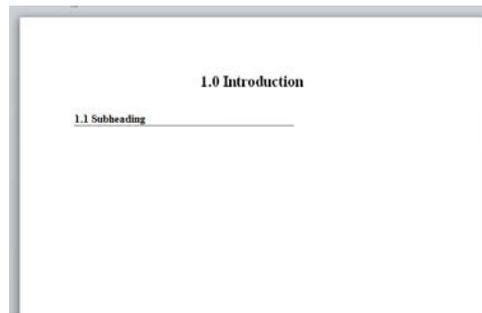
Figure 3: Example of Subheading Level 1

Subheading Level 2

For Subheading Level 2, if needed, use the following specifications. Format your first use of this subheading and then save this style as "MCRP Heading 2" in Microsoft Word. See example of Subheading Level 2 in Figure 4.

- Times New Roman, Bold, 12 Point.
- Aligned left, 0 in. left indent, 0 in. right indent
- No hanging indent, single line spacing, 18 point before spacing, 6 point after spacing.

Figure 4: Example of Subheading Level 2
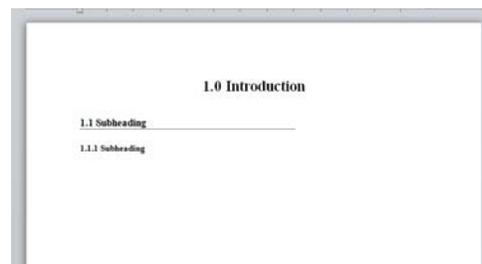
2.5 Bulleted and Numbered Lists

Be consistent with bulleted and numbering styles throughout the document. Use one style of numbered list and one style of bulleted list throughout the document. **Only use a numbered list if an order is implied within the list; otherwise, use a bulleted list instead.**

For numbered lists, use Word's automated numbering function to create the numbers, in order to ensure Section 508 compliance.

When you have created your first list, save this as a style called "List Paragraph" to ensure consistency and Section 508 compliance, and apply that style throughout.

2.6 Table Titles and Figure Captions

Create table titles and figure captions above a table or below a figure by right-clicking on the table or figure and then selecting "Insert caption." **Please note that table and figure headings should be no longer than five words**. Also see Section 2.9 for more instructions concerning how to insert and format tables and figures and to ensure they are 508 compliant.

For all table titles and figure captions, use the following specifications (see Figure 5):
- Title all tables and figures to identify their contents.
- Titles should be brief and concise, no more than five words. Align titles centered, above tables and below figures.
- Use Times New Roman, Bold, 11 point.
- Use "sentence case," capitalizing only the first word in the title, unless it's a proper noun..
- Do not use periods at the end of titles.
- If needed, enter any additional explanation about the table or figure, as well as source information, in one of two ways:
  - Add it as an asterisked note in Times New Roman, 10 point font, below the object
  - Explain it in the body text
- Allow Microsoft Word to automatically number tables and figures. They will be numbered 1, 2, 3, etc., with no additional numbers, periods, or dashes.
- After creating the first caption, save it as a new "style." Name the style "Table-MassDOT" and "Figure-MassDOT"; this will allow you to create a List of Tables and List of Figures that can be automatically updated when formatting the document.

Figure 5: Example of table placement and title

2.7 References and Citations

Citation and reference lists demand absolute accuracy in both content and format. The rules for the identification of references should be carefully observed. Use the TRB's resource for its Paper Authors for annual meetings, "Preparing Papers for Peer Review and Presentation at the TRB Annual Meeting," as a guide for formatting your reference list (http://www.trb.org/AnnualMeeting/AMPaperAuthorResource.aspx).

2.7.1 Reference List

- List all references used in the References chapter of the report, **numbered in the order in which they first appear in the report.**
- **Do not include references that were not cited in the report**; this is a reference list, not a bibliography.
- Do not repeat a reference in the Reference list or refer to it by the use of ibid, loc. cit., and so forth.
- Check the spelling of names, initials, and dates. Give the title of the article as it was published.
- Avoid use of unpublished references wherever possible.
- Print the names of journals, proceedings, bulletins, and books in italics; print the titles of papers in Roman; capitalize using heading style.
- Do not set off titles of articles in quotation marks.

2.7.2 Citations

- Cite a reference in body text by inserting the reference number at the end of the applicable sentence, using an Arabic numeral in italics and parentheses (see examples in Figure 6 and the Sample Research Report in the Appendix). For multiple references applying to the same sentence, list them in the order they are cited in the text. Note that this citation style differs from that of Chicago style.

- When the report is complete, do a final check to ensure that all citations agree with text and that all numbered citations agree with the reference list. Remember that text revisions may require renumbering of citations or other reference changes, and vice versa.

See examples of how to insert citations (Figure 6), and how to format typical references per TRB style (Table 2).
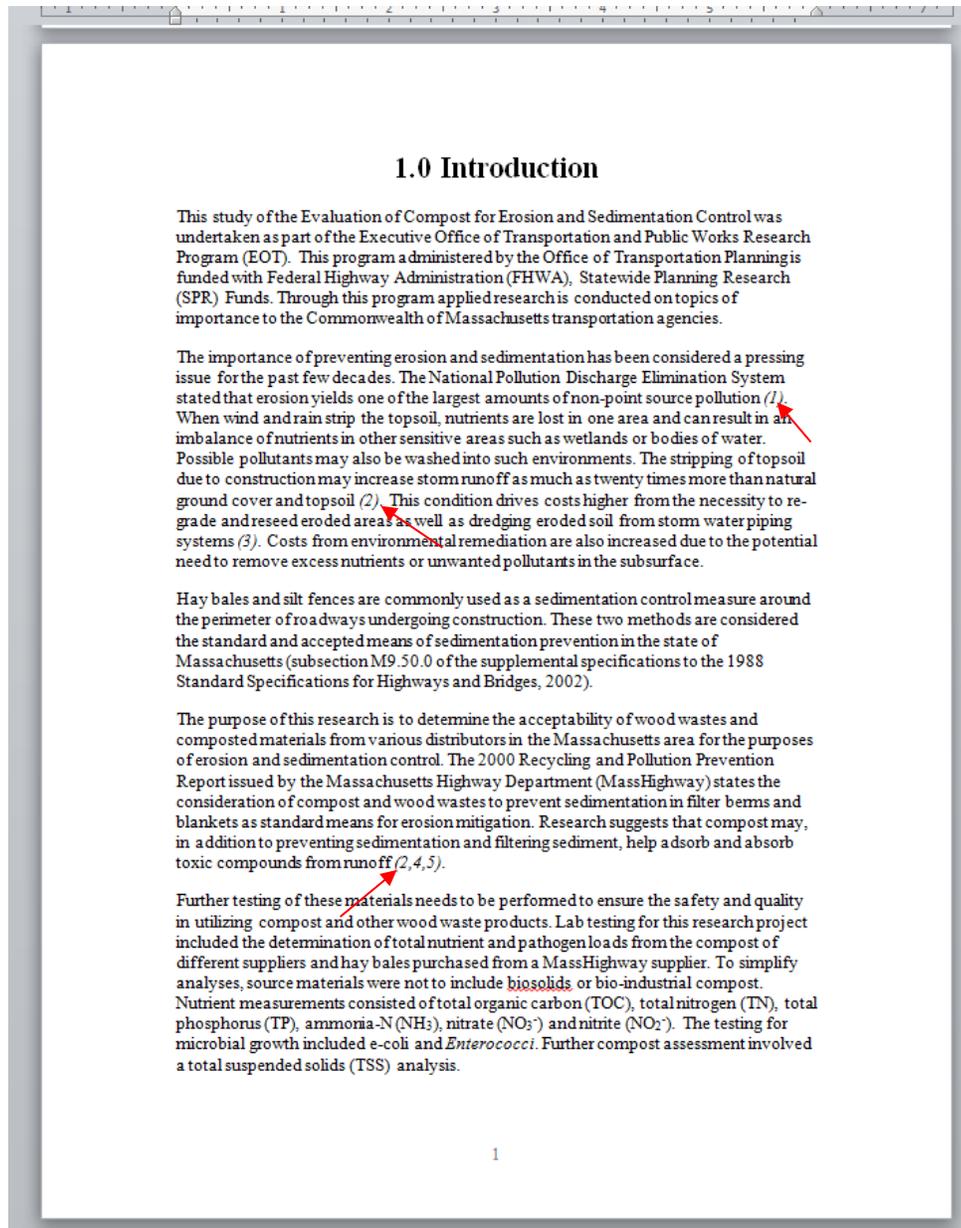

Figure 6: Example of citations within body

Table 2: Guide for references*

Type of Reference	Example
Periodical	Sansalone, M., J. M. Lin, and W. B. Streett. Determining the Depths of Surface-Opening Cracks Using Impact-Generated Stress Waves and Time-of-Flight Techniques. *ACI Materials Journal*, Vol. 95, No. 2, 1998, pp. 168–177.
Proceedings	Leadabrand, J. A., and L. T. Norling. An Example of Soil-Cement Treatment. 2nd Int. Conf. on Soil Mech. and Found. Eng., Rotterdam, The Netherlands, Proceedings Vol. 4, 1956, pp. 62–84.
Unpublished Papers	Corbett, J. J. Toward Environmental Stewardship: Charting the Course for Marine Transportation. Presented at 83rd Annual Meeting of the Transportation Research Board, Washington, D.C., 2004.
Abstract	Directional Signing on Metropolitan Freeways. Automobile Club of Southern California, Los Angeles, CA, July 3, 1963, 11 pp. *Highway Research Abstracts*, Vol. 34, No. 6, June 1964, p. 10.
Corporate author	Automotive Safety Foundation, *Traffic Control and Roadway Elements: Their Relationship to Highway Safety,* Washington, D.C., 1963.
Government Report	Von Quintus, H. L., and A. L. Simpson. *Documentation of the Backcalculation of Layer Parameters for LTPP Test Sections*. Publication FHWA-RD-01-113. FHWA, U.S. Department of Transportation, 2002.
TRB Publication	Dewan, S. A., and R. E. Smith. Creating Asset Management Reports from a Local Agency Pavement Management System. In *Transportation Research Record: Journal of the Transportation Research Board*, *No. 1853*, Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 13–20.
Book	Newland, D. E. *Random Vibrations: Spectral and Wavelet Analysis*. John Wiley & Sons, Inc., New York, 1998.
Part of book only	Newland, D. E. [name of chapter or section]. In *Random Vibrations: Spectral and Wavelet Analysis*. John Wiley & Sons, Inc., New York, 1998, pp. [xx–yy].
Highway Dept. report	New York Dept. of Public Works. Asbestos Admixture in Asphalt Concrete. Physical Research Proj. No. 11. *Engineering Research Series*, Research Rept. RR60-5, Dec. 1960.
Congressional document	U.S. Cong., 77th 2d SESS., Committee on Roads, Proposed Highway to Alaska. Hearings … on H.R. 3095, a bill authorizing the construction of a highway to Alaska, Feb. 4, 5, and 6, 1942. U.S. Govt. Print. Office, Washington, D.C., 1942, 151 pp.

Type of Reference	Example
Websites and Electronic Sources	References to websites should include corporate or personal authors, title of document, date of document (if available), web address (complete URL), and date accessed by the author. For example, a periodical article: Nemmers, C. Transportation Asset Management. *Public Roads Magazine*, July 1997. www.tfhrc.gov/pubrds/july97/tam.htm. Accessed Jan. 13, 2002.
CD-ROM (same format as printed version, but add CD-ROM)	Solaimanian, M., J. Harvey, M. Tahmoressi, and V. Tandon. Test Methods to Predict Moisture Sensitivity of Hot-Mix Asphalt Pavements. In *Moisture Sensitivity of Asphalt Pavements*. CD-ROM. Transportation Research Board of the National Academies, Washington, D.C., 2004, pp. 77–110.
Program Manuals, Tapes or other documentation for models	*MINITAB User's Guide 2: Data Analysis and Quality Tools*. Minitab, State College, PA, 2000, pp. 27–52.

*Source: TRB, *Preparing Papers for Peer Review and Presentation at the TRB Annual Meeting*, updated June 14, 2016, http://www.trb.org/AnnualMeeting/AMPaperAuthorResource.aspx.

2.8 Metrication

Use the same abbreviations for measurements throughout the report. Refer to Sections 10.52 and 10.53 in the *Chicago Manual of Style* (http://www.chicagomanualofstyle.org /16/ch10/ch10_sec052.html) for instructions and a list of the most common technical and statistical abbreviations.

2.8.1 Equations

Create all equations as part of the text. Alternatively, submit them as embedded images within the text. Explain and identify each variable and constant in the equation. Cite the source for equations as well. Be sure that all symbols, Greek letters, and mathematical signs are exact, defined, and absolutely unambiguous; for example, carefully distinguish the following:
- All capital and lowercase letters
- Capital O ("oh"), lowercase o ("oh"), and 0 (zero)
- Lowercase l ("el") and number 1 (one)
- Letter X, Greek chi (χ), and multiplication sign ×
- Prime ´, apostrophe ', and superscript one [1]
- English and Greek letters such as:
  - B and beta (β), upper- or lowercase k and kappa (κ),
  - n and eta (η), v and nu (ν),
  - u and upsilon (υ), u and mu (μ), and
  - Upper- or lowercase p and rho (ρ), and w and lowercase omega (ω).

Follow these instructions regarding equations:
- Show the relative positions in equations and formulas of all subscripts, superscripts, fractions, and operators.
- Give units of measure common to the field of research reported.
- Most projects will involve the use of the U.S. Standard units of measure in the conduct of the research and the reporting of research results.

2.8.2 Abbreviations, Acronyms, and Symbols

Follow these instructions:
- Fully define abbreviations, acronyms, and symbols by writing out the full names, followed by the abbreviations in parentheses the first time they are used in the report (see examples in Figure 7).
- Thereafter, use only the abbreviated term, without parentheses.
- If many acronyms are used throughout the report, create a List of Acronyms in the front matter.
- Because the Executive Summary may be used as a stand-alone document, acronyms defined in this section should be defined again in the body of the report.
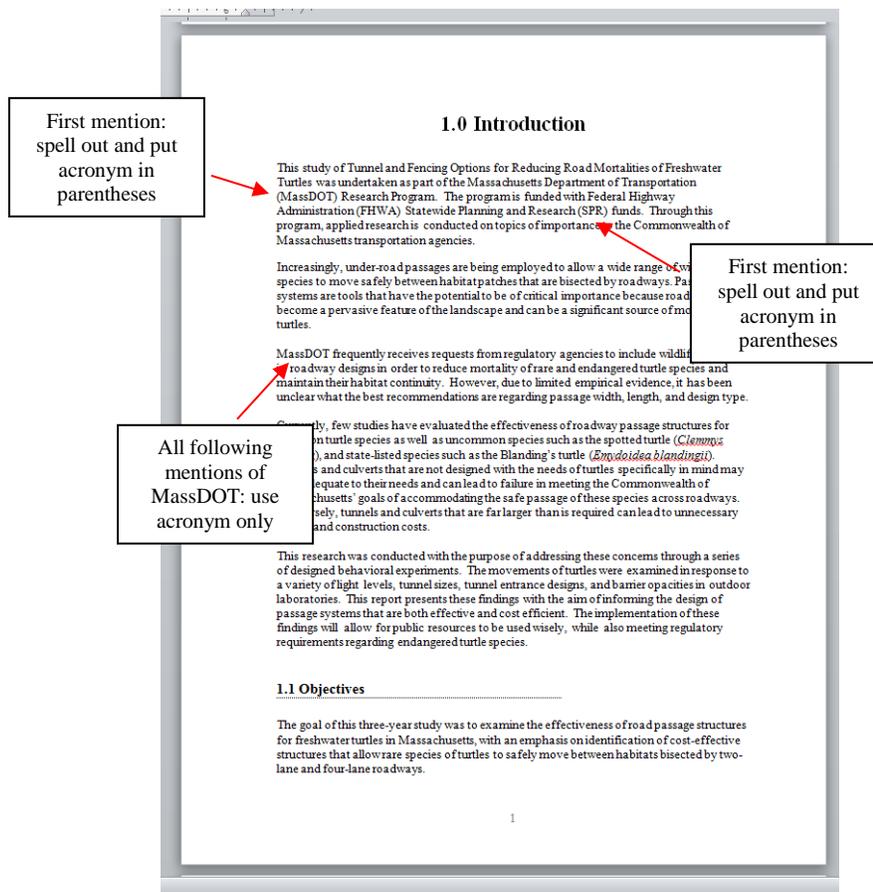
Figure 7: Examples of acronyms

2.9 Tables and Figures

The purpose of tables and figures is to relay supplemental, not duplicate, information in a clear format. See Section 2.6 for detailed steps on how to create table and figure captions.

2.9.1 Section 508 Compliance

All tables and figures must comply with Section 508 standards by the use of "alt text." Right-click the table or figure to navigate to "Properties." Within Properties is the "Alt Text" section, which provides the reader with additional information about the table or figure. **The "Alt Text" section must be completed for each table and figure;** otherwise, the document is not 508 compliant. Entering the title of the table or figure is the minimum action required, but more information should be included if further clarity is necessary.

2.9.2 Tables

Tables present short descriptions or numerical listings that are more clearly presented in tabular rather than bulleted or narrative format. They should be self-explanatory and should supplement, not duplicate, information given in the body of the report.

Follow these instructions regarding tables (see Figure 8 for example):
- Provide tables embedded in the text of the document, by using the "Insert Table" function in Word. Do not break a table across two pages; insert a page break to keep the table on one page. Large tables of two or more pages should be in an appendix.
- Allow Microsoft Word to number all tables consecutively with Arabic numerals, using the "insert caption" option (see Section 2.6).
- Title all tables to identify their contents, keeping the title to no more than five words. Center the title above the table and use sentence case, no period (see Section 2.6).
- Use a dash (-) for empty cells in a table, indicating its meaning in a footnote (e.g., missing data, data not available or not applicable).
- Check the accuracy of all totals included in tables.
- Refer to each table by number at the appropriate places in the text (e.g., "Table 1 shows a list of …."); do not hyperlink the text reference to the actual table.
- Tables should immediately follow their first textual reference, appearing on the same page wherever possible.
- Use tables of comparable size and scale when they are intended to be compared.
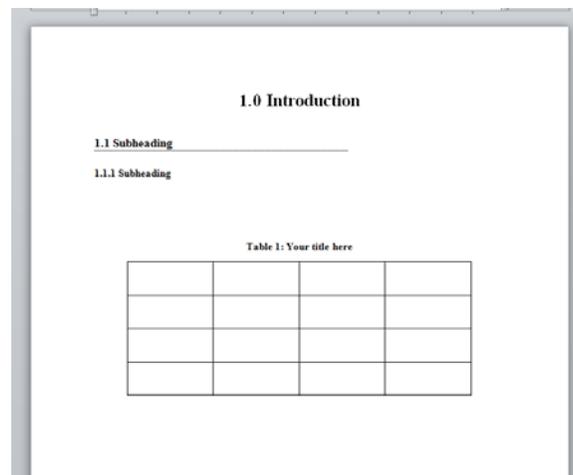
Figure 8: Example of table placement and title

2.9.3 Figures

Figures are photographs, drawings, charts, graphs, and other objects that supplement the body of the final report. They should convey information clearly and completely. Lettering and numerals must be of adequate size and clarity to be easily read.

To ensure Section 508 compliance, figures should be free of all "floating objects." For example, if arrows or text boxes are used, those objects should be "grouped" within the main figure as a single object.

Follow these instructions for figures:
- Provide figures (including photographs) embedded within the text of the document.
- Figures must use the "in line with text" text wrapping style.
- Allow Microsoft Word to number all figures consecutively with Arabic numerals, using the "Insert Caption" option (see also Section 2.6).
- Caption all figures to identify their contents, limiting caption to no more than five words. Center the caption below the figure, using 11 point font and no period.
- Cite the outside source of the figure if applicable, either in the body text or as a footnote below the figure but above the caption (see also Section 2.6).
- Use figures of comparable size and scale when they are intended to be compared.
- Use abbreviations, numerals, and capitalization consistent with body text.
- Figures should immediately follow their first textual reference, appearing on the same page wherever possible.
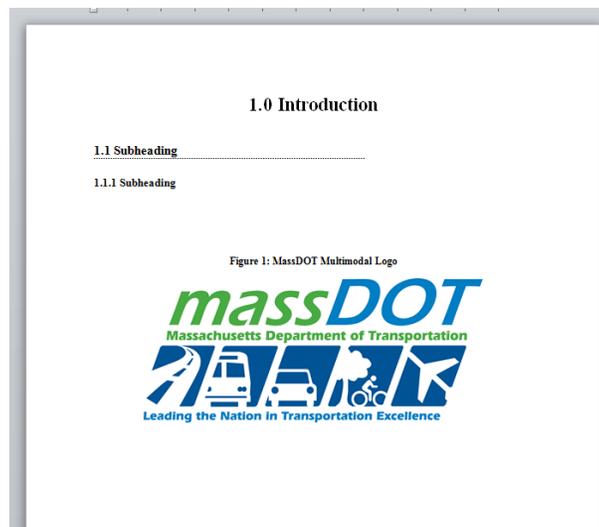
Figure 9: Example of figure placement and caption

2.10 Creating an Automated Table of Contents

In order to comply with Section 508 regulations, all headings must be created using "styles" in Microsoft Word. Heading styles create an organized and logical reading order for all readers, and are particularly critical for people using screen reader technology. This step will also permit the creation of an automatically generated Table of Contents (TOC), which can

can be automatically updated to reflect correct page numbers and section headings as the final report is edited.

To create a TOC that can be automatically updated, assign a "style" to each heading that is meant to be represented in the TOC (see Section 2.4.6). Assign a style to the following headings:

- Technical Report Document Page
- Title Page
- Acknowledgements and Disclaimer (Assign both a style so they are represented separately in the TOC)
- Executive Summary
- Table of Contents
- All Chapter Headings and up to two levels of subheadings (e.g., 1.1, 1.1.1)
- References
- Appendices

To create a new style that can be used for the TOC, begin by formatting all headings. Once the headings have been formatted, begin creating "styles" for each:

- Highlight the heading and then right-click the highlighted heading.
- Scroll down to "Styles" and choose "Save selection as a new style."
- Name the style using the conventions in Section 2.4.6.

To create the automated TOC, follow these steps:

- Place your cursor on the page where you want to insert the TOC.
- Select References > Table of Contents > Insert Table of Contents:
  - Make sure the boxes for "Show Page numbers" and "Right-align pages" are selected.
  - Under Tab Leader, select a dotted line (…..).
  - Under Formats, select "From Template" from the drop-down menu.
  - Deselect the box that says "Use hyperlinks instead of page numbers."
  - Under Options, select the TOC levels that you will be using. To do this, first select "Reset" to remove any existing choices. Then find the styles you created for your headings, and enter 1, 2, and 3 under the Main Heading and subheadings respectively. Make sure these are the only styles selected, or unwanted text will appear in your TOC.
  - Under Table of Contents > Modify, select TOC 1 and ensure that Times New Roman 12 point is the font to be used; select Modify > Style and name the style MCRP TOC. This saves your TOC style and adds it to your quick style menu.
- Select OK when ready.
- To update the TOC when the report is done, click the TOC and select References > Update Table > Update entire table.

An example of a TOC is shown in the **Sample Research Report** in the Appendix.

2.11 List of Tables and List of Figures

The process for creating the List of Tables and the List of Figures is similar to that of the TOC. These lists provide readers with the titles of all tables and figures within the report.

Use the Insert Table of Figures function in Word to create lists of tables and figures. This step will ensure that after the report is edited, the List of Tables and List of Figures can be automatically updated during the report editing process to reflect the correct page numbers of each table and figure.

3.0 Section 508 Compliance

3.1 Introduction

Federal Section 508 standards make technology accessible for people with mobility, auditory, and visual disabilities. As a state agency, MassDOT must comply with these standards for all information made available in electronic form, in order to provide access to every citizen of the Commonwealth. Therefore, **all final reports published by MassDOT must comply with Section 508 standards.**

It is your responsibility to ensure that your draft final report is fully accessible prior to submittal. Note that it is much easier to create a Section 508 compliant document if you start incorporating the requirements from the beginning, rather than when the final report is fully prepared.

Section 3.2 provides summary guidance for ensuring that your Microsoft Word report meets accessibility standards. For each standard, see applicable sections of Chapter 2.0 for more detail on how to meet that standard.

Microsoft Word versions 2010 and later have an "accessibility checker" function that can be found under File > Information > Check for Issues > Check Accessibility. Further guidance on accessibility is provided by Microsoft at Microsoft.com Online Accessibility Center, https://www.microsoft.com/enable/.

For more information about the federal Section 508 standards, visit the GSA's Section 508 website at https://www.section508.gov/ or the United States Access Board website at https://www.access-board.gov/.

3.2 Section 508 Standards

3.21 Document Layout and Formatting
- The entire document is formatted using Style elements (e.g., Heading 1, Heading 2, Normal, List Paragraph).
- The document does not use flashing/flickering text or animated text/images.
- Word's automatic page numbering function is used (as opposed to manually typed page numbers).
- Any footnotes, if applicable, have been created through Word Footnote linking.
- The use of color is avoided wherever possible. If it is needed, it is accompanied by alternative descriptions.
- Automated bullet or numbering styles have been used (as opposed to manually added characters.

- All tracked changes have been accepted or rejected, and the Track Changes function has been turned off.
- Comments been removed and formatting marks have been turned off.
- Document has been reviewed in Print Preview for a final visual check.
- All URLs contain the correct hyperlink and display the fully qualified URL with the "http" prefix (e.g., http://www.section508.gov).
- All URLs have been checked to ensure they lead to the correct web destination.

3.22 Document Images (Including Figures)

- All images, grouped images, and non-text elements that convey information have alternative text (Alt Text) descriptions. For figures, this includes at minimum the figure caption.
- Complex images (charts and graphs) are accompanied by descriptive body text immediately preceding the image, and followed by figure captions.
- The document is free of background images and watermarks.
- The image text-wrapping style "In Line with Text" is used for all images.
- Multiple associated images on the same page (e.g., boxes in an organizational chart) are "grouped" as one object.
- All multilayered objects have been "flattened" into one image and use one Alternative Text (Alt Tag) for the image.
- The document is free of text boxes used for simple graphics.

3.23 Document Tables

- Tables have been inserted to create a tabular structure (rather than use of tabs or spaces).
- All tables have a logical reading order from left to right, top to bottom.
- Data tables have the entire first row designated as a "Header Row" in Table Properties.
- All tables are free of "merged cells."
- All tables are described in body text, and titled and numbered using a defined table style.
- In Table Properties, "Allow row to break across pages" is unchecked.

3.24 Additional Standards

- The document file name reflects the content of the document; e.g., "RAP final draft report 6-1-16."
- The document utilizes Times New Roman font.
- The Document Properties (Subject, Author, Title, Keywords, and Language) are accurately completed.
- The Tables of Contents for the report and for figures and tables are automatically generated and were all created using TOC styles in Word.
- A separate accessible version of a portion of the report has been provided when there is no other way to make the content accessible (e.g., organizational chart).

4.0 Manuscript Submittal

All final reports must be submitted to MassDOT in final draft form a minimum of three months (90 days) prior to the end of your contract.

Submit the document as a final report, even though edits and changes may be made following submittal. All efforts should be made by your research team to provide a document with the highest possible quality and accuracy.

MassDOT reserves the right to withhold final payment for the research if the final report has not been received by the due date, or if questions arise regarding quality or accuracy.

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5.0 Appendix: Sample Research Report

The following pages are excerpts from two sample research reports to illustrate the guidelines in Chapters 1 through 3.

Evaluation of Portable Road Weather Information Systems

Charles D. Baker, *Governor*

Karyn E. Polito, *Lieutenant Governor*

Stephanie Pollack, *MassDOT Secretary & CEO*

U.S. Department of Transportation
Federal Highway Administration

massDOT
Massachusetts Department of Transportation

Technical Report Document Page

1. Report No. n/a	2. Government Accession No. n/a	3. Recipient's Catalog No. n/a	
4. Title and Subtitle Evaluation of Portable Road Weather Information Systems		5. Report Date June 2016	
		6. Performing Organization Code n/a	
7. Author(s) Russell Tessier		8. Performing Organization Report No. UMTC-16.03	
9. Performing Organization Name and Address 309G Knowles Engineering Building, University of Massachusetts, Amherst, MA 01003		10. Work Unit No. (TRAIS) n/a	
		11. Contract or Grant No. 73160	
12. Sponsoring Agency Name and Address Massachusetts Department of Transportation Office of Transportation Planning Ten Park Plaza, Suite 4150, Boston, MA 02116		13. Type of Report and Period Covered Final Report June 2016	
		14. Sponsoring Agency Code n/a	
15. Supplementary Notes n/a			

16. Abstract

Recent advances in weather sensing technology, cellular communications, and solar panel technology have enabled the development of portable road weather information systems (RWISs). In this project, a full analysis of the state of the art for these types of systems was performed, providing insights into best practices. Two prototype portable systems based on commercial weather sensors, cellular communications equipment, and solar energy were developed and tested to better understand the challenges and tradeoffs of RWIS design. The prototype systems were deployed on roadways in the Commonwealth of Massachusetts and evaluated for ten months. As a result of testing, three additional RWIS units were developed for roadway use. This report provides a comprehensive look at the background, decision making, and lessons learned from these research activities. The availability of the five systems created for the project for continuous use in winter road monitoring will benefit the Commonwealth for years to come.

17. Key Word Road weather information system, RWIS, road condition sensor, weather sensor, portable		18. Distribution Statement unrestricted		
19. Security Classif. (of this report) unclassified	20. Security Classif. (of this page) unclassified		21. No. of Pages 82	22. Price n/a

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

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Evaluation of Portable Road Weather Information Systems

Final Report

Prepared By:

Russell Tessier
Principal Investigator

309G Knowles Engineering Building
University of Massachusetts
Amherst, MA 01003

Prepared For:

Massachusetts Department of Transportation
Office of Transportation Planning
Ten Park Plaza, Suite 4150
Boston, MA 02116

June 2016

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Acknowledgements

Disclaimer

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Executive Summary

This study of the Evaluation of Portable Road Weather Information Systems was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Effective highway winter maintenance programs, specifically snow and ice operations, depend on timely and accurate information to make good decisions relative to the placement of anti-icing and deicing chemicals. Weather indicators, such as pavement temperature, air temperature, precipitation type and intensity, and other variables, are used in the decision process. Currently, the Commonwealth of Massachusetts has invested in a series of permanently placed road and weather information systems (RWISs) throughout the state. These 27 RWIS stations have been strategically placed to cover the interstate highway system. These stations are considered vital to snow and ice operations. With increased sensitivity to environmental concerns, many other areas in the state are without monitoring capabilities. These permanent RWIS sites require power and communication cables at their sites.

The purpose of this project was to evaluate portable (e.g., trailer-based) RWISs to determine their suitability for use in Massachusetts. RWISs collect information such as pavement temperature, air temperature, precipitation type and intensity, and other variables and make them available to users via standard web browsers. In the early stages of the project, an effort was made to identify portable, commercially available RWIS technologies designed to capture and analyze weather data to help determine the appropriate application of sodium chloride, magnesium chloride, and any other deicers used in winter operations. This effort involved a complete literature survey of portable RWIS applications used by other state DOTs.

Following a full literature search, the development of two fully functional prototype RWISs based on weather sensing technology from two different companies (Vaisala, Inc. and High Sierra Corporation) commenced. One system was constructed using sensors from Vaisala, while the other system was constructed using sensors from High Sierra. Following initial data analysis and comparison, the RWISs were moved to roadsides in the Commonwealth for an extended test under winter driving conditions. As part of the project, the results of the field tests in terms of portable RWIS reliability, accuracy, and cost were assessed. Subsequently, three additional Vaisala-based RWISs were constructed and delivered to MassDOT for roadside use.

As a result of project research activities, the state of the art in portable RWIS technology has been assessed and a fleet of portable RWISs has been created for MassDOT use. These systems provide an understanding of weather indicators used in the winter maintenance/snow and ice decision process. Data collected from the RWISs have the potential to assist MassDOT in making decisions to apply sodium chloride, magnesium chloride, and any other

deicers used in winter operations, which, in turn, help achieve broader safety, fiscal, and sustainability goals.

In conclusion, the project team's effort to build practical, easy-to-use, and accurate portable RWIS units has resulted in five deployable systems that are highly accurate. The systems have been tested on roadways for an extended period of time (nearly 12 months) to determine their long-term effectiveness. Future work could involve increasing the portable RWIS fleet size beyond five and examining new energy and communication alternatives for the portable RWISs. It is the team's belief that portable RWISs can serve a vital role in providing roadway information for roads in isolated locations in the Commonwealth. Only cellular communication capabilities are required in the deployed location to transfer collected data. The availability of portable RWIS information can assist MassDOT in deploying road maintenance teams in a more efficient and cost-effective manner.

Table of Contents

[shows portions of the Table of Contents and Lists of Tables and Figures for those pages included in sample]

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List of Tables

List of Figures

1.0 Introduction

This study of the Evaluation of Portable Road Weather Information Systems was undertaken as part of the Massachusetts Department of Transportation (MassDOT) Research Program. This program is funded with Federal Highway Administration (FHWA) State Planning and Research (SPR) funds. Through this program, applied research is conducted on topics of importance to the Commonwealth of Massachusetts transportation agencies.

Weather conditions have a significant impact on road safety as well as roadway and highway maintenance operations. Costs associated with winter road maintenance are very high. Winter road maintenance alone accounts for about 20% of state DOT maintenance budgets *(1)*. State and local transportation agencies spend more than $2.5 billion each year on snow and ice control operations, and more than $5 billion to repair weather-damaged roadway infrastructure *(1)*. Snow and ice control techniques involve the application of millions of tons of salt to road surfaces each year. The usage of salt causes corrosion, affects vegetation, and has detrimental effects on the environment *(2)*. It is desirable for transportation agencies to find sustainable and cost-effective techniques for better roadway maintenance throughout the year, especially during winter months. Transportation agencies nationally and internationally are working on employing such techniques to improve operations related to road management, road safety, and emergency management. Real-time weather information also increases the preparedness of travelers for driving in inclement weather conditions.

Road weather information systems (RWISs) play a significant role in providing weather and surface conditions to transportation agencies to monitor weather events. Using this information, roadway operators can efficiently plan road operations, reduce chemical, sand, and salt usage, and provide a better level of service by using anti-icing practices. A RWIS consists of pavement sensors and meteorological sensors to determine road condition and weather events. The weather and pavement condition data collected by the weather sensors is typically processed using sophisticated technology in the RWIS and sent on a network for weather forecasting and pavement condition monitoring. Traditionally, most RWISs have been employed in the field as permanent fixtures. In contrast, a portable RWIS consists of trailer-mounted equipment that can be strategically relocated to different monitoring sites.

1.1 Problem Statement

Weather forecasting and roadway condition monitoring are of paramount importance for roadway safety and operational decision making. These actions require collection of accurate, real-time atmospheric data. Both current and historic atmospheric data greatly affect the decision-making processes of weather forecasting, road maintenance, construction projects, rescue operations, and the installation of future permanent RWISs at planned sites. The accuracy of the data collected by the weather sensors and the placement of these sensors are critical issues. Pertinent weather information can either be directly obtained or

extrapolated to a central location by a permanent RWIS. However, there are concerns that make permanent fixtures prohibitive. These concerns include cost, accessibility to sites, site terrain, and permitting issues. Under these circumstances, portable RWISs are an attractive solution to transportation agencies due to their mobility and ease of relocation. Portable RWISs are cost-effective systems and can be used to monitor specific weather conditions for a specific duration at the site of deployment.

This research project involves development of multiple portable RWISs to be used by MassDOT. These systems have the potential to assist MassDOT in making decisions to apply sodium chloride, magnesium chloride, and other deicers used in winter operations. The systems should help achieve broader safety, fiscal, and sustainability goals. The project involves deploying trailer-based RWIS systems in the field for monitoring weather data. These systems are tested for accuracy and feasibility. Weather data is visible on vendor websites. A full literature survey of the state of the art in RWIS usage and portable RWIS technology is also provided.

1.2 Research Objectives

The following goals have been achieved in the completion of this project:

- Examination of the state of the art in RWIS usage in both domestic and international environments.
- Evaluation of best practices in the existing use of RWIS equipment.
- Identification of portable, commercially available RWIS technologies designed to capture and analyze weather data and pavement data. This action involves selection and evaluation of sensors that are suitable for the portable RWIS. Non-invasive pavement sensors are typically suitable for a portable weather station.
- Development of two portable RWIS prototypes consisting of weather-sensing equipment procured from two different manufacturers, and identification of issues involved in building and using these systems. The systems are contrasted for their usability, accuracy, and maintenance.
- Analysis of the results of field tests of the two prototypes. The results obtained from the prototype RWISs are compared and documented.
- Construction of three additional portable RWISs for delivery to MassDOT.

1.3 Report Outline

The remainder of this report is organized as follows. Chapter 2 reviews the state-of-the-art in worldwide RWIS use, with a specific focus on portable RWISs. Chapter 3 describes the equipment used to build the five portable RWISs developed for this project. Each weather sensor is described in detail along with a discussion of trailer requirements. A comparative analysis of results obtained from the systems and results collected from a stationary weather system is provided. In Chapter 4, recommendations for further use of the portable RWIS and

the development of additional systems are provided. Chapter 5 provides conclusions for this project.

[Sample page wth example of figure]

Fixed Automated Spray Technology. Several domestic departments of transportation *(34)(35)* have explored the use of fixed automated spray technology (FAST) in conjunction with RWISs. These systems either automatically enable the deployment of anti-icing chemicals or enable their application after interpretation of RWIS data by a human operator. A recent study from North Dakota determined that an automatically enabled system is 95% reliable *(34)*. Pavement condition and temperature values are read from environmental sensors (see example of Buxton Bridge in Figure 2.7), and a computer algorithm can then trigger spraying. A significant reduction in motor accidents was recorded after the installation of the system on two bridges in 2002. The specific algorithm parameters can be triggered using the Vaisala ScanWeb interface. A second study *(35)* determined that the use of FAST can be cost beneficial if used with supporting RWISs. According to the report, proactive treatment is best performed with automated systems that enable spraying after the evaluation of road surface condition. Experiments with calcium chloride applied at a rate of 8 gallons per use were particularly effective. Nebraska has a similar FAST deployment on a bridge that is part of an interstate highway *(36)*. An RWIS at the location collects air and surface temperature, precipitation, dew and freezing points, and wind speed and direction. A fixed automated spray system that uses a deicing chemical is then deployed under likely icing conditions. It is not clear if the spraying is triggered automatically or manually.
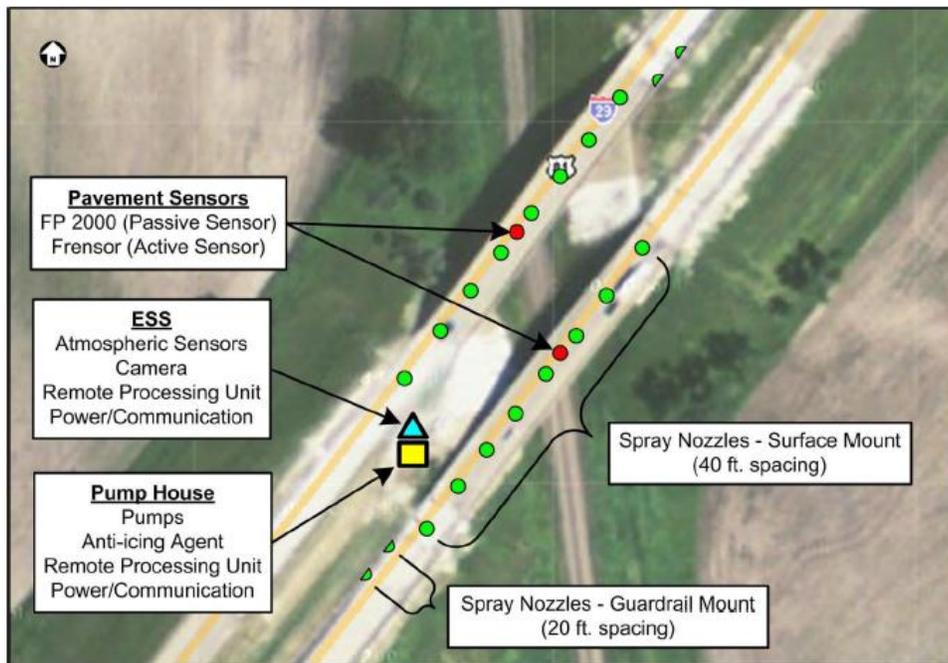

Figure 2.7: I-29 Buxton Bridge FAST system components

Load Restrictions for Roadways. RWIS data has also been used to develop a set of load restrictions on roads for trucks and other vehicles at different times of the year *(37)*. RWIS data is used to evaluate the amount of frost on pavement under various climate conditions. An evaluation of this data and a series of physical measurements determined a correlation between these RWIS parameters and measured frost depth. This information was then used to estimate the impact of thawing to help estimate load restrictions on trucks and other vehicles

[Sample page with example of table]

Table 2.1: Summary of documented portable RWISs

Label	Location	Company	Sponsor/Standard	Commun.	Power	Sensors	Cost per unit
P1	Kansas/Colorado	High Sierra 5721	NTCIP	unclear	Traffic cabinet	Pavement temp., precipitation, road surface	$2,800, not including traffic cabinet cost
P2	Texas	High Sierra 5470	NTCIP	Ethernet	Traffic Cabinet	Water level, flood data	$28,800 total. 5470 and software costs $12,150
P3	Manhattan, Kansas	High Sierra 5470	NTCIP	Ethernet	Traffic Cabinet	Flood, wind, road surface status, rain gauge	$28,800 total. 5470 and software costs $12,150
P4	Iowa	Vaisala MAWS/WXT520	Aurora/Clarus	Cellular	Solar/battery	Wind, air, and surface temp., rain, pressure	$3,000
P5	Missouri	Vaisala	n/a	n/a	n/a	n/a	$21,000
P6	Utah	Vaisala/Campbell	n/a	Cellular	Solar/battery	Wind, temp., rain, humidity, pressure	$14,000
P7	Nevada	n/a	n/a	Cellular/WIFI	Solar/battery	Camera/flow detector	$18,000 (not including trailer)
P8	Florida	n/a	n/a	Radio	Solar/battery	Undefined weather	n/a

Several commercial offerings have served as the basis of portable RWIS installations that have been deployed by transportation departments.

Systems based on the High Sierra 5721. This road sensor station *(54)* is a NTCIP-compliant system used to warn of icing conditions on roadways. As seen in Figure 2.9, the system contains a signal processing unit, a road surface wet/dry/ice sensor, and an optional embedded road temperature sensor. Power and communications capabilities are obtained

[Sample References page]

6.0 References

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3.0 Methodology

This chapter first provides an overview of the SPFs and the safety modeling procedures for urban and suburban arterial intersections in the 2010 HSM. Such an overview makes this report self-contained and helps readers understand the discussions in Chapters 4 through 7. Since the HSM safety predictive models urban and suburban arterial intersections are all based on Negative Binomial regression, this chapter also includes a summary of the Negative Binomial regression model.

3.1. SPFs for Urban and Suburban Arterial Intersections in the HSM

The *Highway Safety Manual* (HSM) was initially published by AASHTO in 2010. It includes a series of methods for predicting crash frequencies for different transportation facilities. The method for urban or suburban arterial intersections is given in Eqs. (1) and (2):

$$N_{predicted\_int} = C_i \times \left(N_{bi} + N_{pedi} + N_{bikei} \right) \tag{1}$$
$$N_{bi} = N_{spf\_int} \times (CMF_{1i} \times CMF_{2i} \times \cdots \times CMF_{6i}) \tag{2}$$

where,

$N_{predicted\_int}$ = final predicted average crash frequency of an intersection for a selected year;

N_{bi} = predicted average crash frequency of an intersection (excluding vehicle-pedestrian and vehicle-bicycle collisions);

N_{pedi} = predicted average crash frequency of vehicle-pedestrian collisions;

N_{bikei} = predicted average crash frequency of vehicle-bicycle collisions;

N_{spf_int} = predicted average crash frequency of an intersection (excluding vehicle-pedestrian and vehicle-bicycle collisions) satisfying the base conditions defined in the HSM;

$CMF_{1i}, \cdots, CMF_{6i}$ = intersection crash modification factors; and

C_i = calibration factor for use in a particular geographical area.

N_{spf_int} in Eq. (2) is often referred to as the Safety Performance Function (SPF). In this particular case, this SPF predicts the average crash frequency involving only vehicles for an intersection under the base conditions defined in the HSM. To account for intersections that do not satisfy the base conditions, a set of CMFs is provided in the HSM. As shown in Eq. (2), the original average crash frequency, N_{spf_int}, is multiplied by these CMFs to adjust for those non-base conditions. In the 2010 HSM, N_{spf_int} is separated into N_{bimv} and N_{bisv} as shown in Eq. (3), and they are further described in Eq. (4). Two different sets of SPFs are provided for N_{bimv} and N_{bisv} in the HSM, respectively *(1)*. Each set consists of SPFs for 3ST, 3SG, 4ST, and 4SG intersections.