Research Project Work Plan

for

Construction of Efficient, Cost-Effective and Sustainable Maintenance Facilities

SPR 792

Submitted by

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for

Oregon Department of Transportation
Research Section
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1.0 Identification

1.1 Organizations Sponsoring Research

Oregon Department of Transportation (ODOT)
Research Section
555 13th Street NE
Salem, OR 97301 Phone: (503) 986-2700

(If federal funds are used)
Federal Highway Administration (FHWA)
Washington, D.C. 20590

1.2 Principal Investigator (ODOT requests only one per institution or firm)

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1.1 Associate Investigator(s)

1.2 Technical Advisory Committee (TAC) Members

Lyn Cornell, Chair, ODOT Research Coordinator
Phone: 503 986-2853
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Bob Repine, Manager ODOT Facilities
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FHWA Rep - TBD

1.3 Friends of the Committee (if any)

Pat Creedican, District Manager, Reg 4
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1.4 Research Coordinator

Lyn Cornell, ODOT Research Section Phone: 503-986-2853

1.5 Project Champion

Bob Repine, ODOT Facilities Phone: 503-986-5791

2.0 Problem Statement

There are approximately 89 maintenance stations within ODOT, and a large assortment of other sheds, storage, and support buildings. Many of these maintenance stations are old, beyond their life expectancy, inefficient, or functionally obsolete (unable to accommodate larger-size, modern equipment). There is an urgent need to systematically replace these buildings to support the agency maintenance mission. A typical maintenance station can cost up to $8-$9 million, representing a significant capital cost burden over the next several years. The Facilities Leadership Team (representatives from all Highway Division Regions) has updated a 10-year plan prioritizing the renovation and replacement of maintenance stations (January 2014). The land purchase, design, and site preparation phase for one facility, and the construction phase of a second facility will be accomplished each biennium at funding of approximately $12 million. Further driving this effort are requirements for any new buildings constructed by authorized state agencies to exceed current building energy codes by 20% and for any public building costing over $1 million to devote at least 1.5% to green energy technology. ODOT facilities are also required to adhere to the

latest SEED rules.[1] It is the intent of ODOT to exceed these latest regulations. The work proposed herein will enable that effort to become a reality. A new maintenance station recently constructed in Sisters became the first in Oregon to incorporate renewable energy – in the form of geothermal heating and solar water heating. Even more sustainable and cost-effective solutions could have potentially been accomplished by utilizing high performance design practices, sustainably produced materials, increased insulation, more efficient lighting, water-saving techniques, waste reductions, etc.[1234] The goal of this research is to document and provide such information for ODOT decision makers to make the most efficient use of the funding for maintenance station buildings.

2.1 Background and Significance of Work

This project will provide ODOT with up-to-date information on current efficient, cost-effective, and sustainable construction practices and will provide guidance that will result in long-term cost savings by constructing new maintenance facilities that are functional, energy efficient, and low maintenance and that will have a lower impact to the land and surrounding environment in which they are built. It will also inform and support current efforts by ODOT to standardize building designs and present available options that are perhaps unfamiliar or unknown. In addition, it will provide a framework for retrofitting existing maintenance facilities that could be salvaged and improved, rather than replaced, thereby increasing their life expectancy. [2,3] In a broader sense, a wide-range of ODOT construction projects could benefit from the guidance provided by this project. The results of this research may also position ODOT to more effectively leverage federal funds as more funds are tied to the need for sustainable design and construction practices. Project results are also likely to have national implications for benefitting other states and federal facilities. If this research is not completed, facility upgrades and new construction may be done without the benefit of incorporating new technologies and current best practices, which will lead to higher systemic maintenance costs, system management inefficiencies, and environmental impacts related to energy and material use.

3.0 Objectives of the Study

The main goal of this research project is to produce guidance that provides ODOT with options for constructing high performance maintenance facilities that will: increase operational functionality, reduce environmental impact, increase energy efficiency, and lower life cycle costs. To reach this goal, the following objectives are proposed:

1) Continuously update the literature review over the course of the project to provide support for the recommended guidance on producing efficient, cost-effective and sustainable maintenance facilities
2) Conduct a modified Life Cycle Cost Analysis focusing on energy and materials for a base case (current maintenance facility slated for reconstruction) and for the recently constructed Sisters, OR maintenance facility.

3) Conduct a modified Life Cycle Assessment focusing on energy and materials for a base case (current maintenance facility slated for reconstruction) and the recently constructed Sisters, OR maintenance facility.
4) Develop a best practices guide incorporating results from Objectives 1-3 that will enable ODOT decision makers (e.g., design personnel, engineers, and facility managers) to specify the construction of new or reconstruction/remodeling of existing maintenance facilities that will lead to standards for improved efficiency, cost-effectiveness, and sustainability; focusing on energy and materials use across the facility life cycle.

3.1 Benefits

There are several benefits to ODOT and to transportation in general from the outcomes of this project. The current State Energy Efficient Design (SEED) program "require[s] that all state facilities constructed on or after June 30, 2001 exceed the energy conservation provisions of the Oregon Energy Efficiency Specialty Code by at least 20 percent."[1] Since ODOT must adhere to this regulation, one of the significant benefits of this research project is that we will provide several options as part of the best practices guide for the construction of new maintenance facilities to meet such regulations. Further Oregon State Law ORS 279C.527-528 states that any building costing over $1 million constructed by a public body must devote at least 1.5% of the total contract cost to the installation of green energy technology (GET) in the form of solar technologies or geothermal power. Because ODOT aims to exceed these requirements, the work proposed herein will enable decision makers to evaluate a suite of options to meet and exceed SEED requirements and ORS 279C.527-528.[5,6] It will also allow ODOT decision makers to make the most efficient use of the funding for maintenance station buildings and to justify that funding to stakeholders and to the Federal Government. An added benefit is that it will further ODOT's commitment to sustainability and allow them to be a leader in this area compared to other State DOTs.

4.0 Implementation

For this project, a final report will be provided that contains two distinct sections. The first section will be a traditional report that includes the literature review, current efficient, cost-effective, and sustainable construction practices, the methodologies used to conduct the research, and results of the LCC and LCA analyses, as well as the approach taken by the project team to develop the best practices guidance document. The second section of the final report will be the actual Best Practices Guide document. This will be produced in conjunction with ODOT technical staff so that its layout and formulation will be in a format familiar to ODOT personnel. Additionally, the project team will make a final presentation to the TAC and other interested parties at ODOT to inform them how the guidance document can be used and implemented. It is envisioned that this document will be made publicly available so that other agencies can benefit from the work developed under this project. Other State DOTs as well as counties with similar large facilities across the nation can benefit from this work.

5.0 Research Tasks

5.1 Expected tasks:

Task 1: TAC Meeting #1

Project kickoff meeting.

Time Frame: [1-3 Months after NTP]
Responsible Party: PI and Co-PI, ODOT Research Coordinator, TAC
Cost: $1,500
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes
TAC Action: Review and understand project research problem statement, research question, the limits of the research, and the project schedule. Advise ODOT Research Coordinator regarding any critical issues with the project's scope or schedule. Advise PIs regarding related professional practices, standards, methods and context for the project.
ODOT Action or Decision: Review TAC advice, discuss with PIs, and if necessary direct PIs to make changes to project documents.

Task 2: Draft Literature Review

The literature review will focus on current sustainability and green building practices and guidelines with specific emphasis on life cycle costs and environmental impacts of building energy and materials use, which are the overarching themes for this project. An ODOT intern already initiated a literature review on best practices for sustainable construction, which will be provided to the research team for resources, topics, and references. The literature review will draw information from many sources, including:

- Living Building Challenge
- LEED
- Government standards that ODOT is required to meet (SEED)
- Other federal sustainability standards
- Green Globes
- Other DOTs guidelines
- Software/databases: BIRDS/BEES (NIST), US LCI (NREL), *ecoinvent*, etc.
- Technical literature: journal articles, conference proceedings, etc.

Time Frame: [4 Months after NTP]
Responsible Party: PI and Co-PI
Cost: $15,000
Deliverable: Draft Literature Review
TAC Action: Read Draft Literature Review and advise ODOT Research Coordinator regarding any gaps in the literature.
ODOT Action or Decision: Review TAC advice, discuss with PIs, and if necessary direct PIs to make changes to project documents.

Task 3: Draft Research Methodology.

The project team will provide a draft research methodology specifically focusing on how the Life Cycle Inventory (LCI) and modified Life Cycle Cost Analysis (MLCC) (see Task 5 below) will be conducted. The team will outline limitations envisioned and provide a framework to accomplish both of these tasks given the two selected maintenance stations for the case study portion of the project. The project team will also detail how the results of the LCI and MLCC will inform decisions about information to include in the Best Practices guide. Specifically, results of Tasks 2 and 3 will highlight the relative advantages and disadvantages of various energy sources and building products that will form the basis of the best building technologies and practices to be documented in the second major section of the Final Report (Tasks 7 and 10).

Time Frame: [6-9 Months after NTP]
Responsible Party: PI and Co-PI
Cost: $5,000
Deliverable: Draft Research Methodology Report Section, Documentation of Institutional Review Board approvals for any work with human subjects.
TAC Action: Read Draft Research Methodology in preparation for TAC Meeting #2.
ODOT Action or Decision: Schedule TAC Meeting #2

Task 4: TAC Meeting #2

This TAC meeting is intended to set the course for the completion of the project. The TAC will review the draft research methodology from Task 3 and provide feedback for any corrections or additions that need to be made for successful completion of the project.

Time Frame: [9 Months after NTP]
Responsible Party: PI and Co-PI, ODOT Research Coordinator, TAC
Cost: $1,500
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes, meeting agenda
TAC Action: TAC review of Draft Research Methodology and Draft Literature Review. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. If possible, reach consensus regarding the content and methods contained in the draft research design. Advise ODOT Research Coordinator regarding project next steps.
ODOT Action or Decision: Review TAC advice. Assess project potential for successful completion. If necessary direct PIs to make changes to project documents. Provide formal acceptance of Draft Research Methodology. Authorize PIs to proceed with subsequent steps, notify by memo or email.

Task 5: Modified Life Cycle Cost Analysis

A modified life cycle cost (MLCC) analysis will be conducted on two comparable maintenance facilities: a base case and the recently constructed Sisters, Oregon Maintenance Station. The cost analysis will be done with a focus on construction and

operational costs. The two cases will serve as examples to show the differences between the cost of a conventional facility compared to the cost efficiency, i.e., savings realized, with features that were included in the Sisters facility (construction, maintenance, and daily operation). The two cases will also reveal how various energy efficiency opportunities, sustainable materials choices, and other design options could result in additional potential savings for future construction beyond what the Sisters maintenance station was able to achieve. The results from this analysis will be included in the Best Practices guidance document to inform future decision makers about the most cost-effective and innovative solutions to maximize energy efficiency and sustainable materials choices for new maintenance facilities. It is expected that both positive and negative attributes of different technologies will be realized in this task. In this case, those attributes will be highlighted to better inform future decision-making processes. In particular, decision makers will be more informed about the cost implications of various energy efficiency and sustainable materials technologies and practices, which will enable better understanding of the payback time and/or additional lifetime investment that may be required to implement more efficient, less impactful building products. The National Institute of Standards and Technology (NIST) Building Life Cycle Cost (BLCC) Programs will be referenced to provide a computational basis for the MLCC in this project. NIST provides BLCC5 software, an Energy Escalation Rate Calculator, Handbook 135, and annual supplements to Handbook 135 that will further inform this project.[7] Complementary information on LCC and low impact technologies are available from the National Institute of Building Sciences (NISB) Whole Building Design Guide.[8]

Time Frame: [16 Months after NTP]
Responsible Party: PI and Co-PI
Cost: $38,000
Deliverable: Progress updates will be documented in the quarterly project reports. A draft research note will be circulated to the TAC for review of the main outcomes from this task.
TAC Action: None
ODOT Action or Decision: Review

Task 6: TAC Meeting #3

This TAC meeting will be done following the completion of Task 5 to give the TAC an update on the progress and information learned during that task. The TAC will be asked to review the draft research note from Task 5. Their input on any updates to future directions will also be sought.

Time Frame: [9 Months after NTP]
Responsible Party: PI and Co-PI, ODOT Research Coordinator, TAC
Cost: $1,500
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes, meeting agenda
TAC Action: TAC review of technical presentation on Task 5. Any updates to the draft research note will be made following the TAC advice. The ODOT Research

Coordinator will be advised of any critical issues with the project's research progress. The ODOT Research Coordinator will be advised of project next steps. *ODOT Action or Decision:* Review TAC advice. Assess project potential for successful completion. If necessary direct PIs to make changes to project documents. Authorize PIs to proceed with subsequent steps, notify by memo or email.

Task 7: Life Cycle Inventory

A Life Cycle Inventory (LCI) will be conducted on energy and materials use for two comparable maintenance facilities: a base-case and the recently constructed Sisters, Oregon Maintenance Station. The focus on energy will allow the development of quantitative data to illustrate the current base-case energy demands and how they have been met, in part, by measures implemented in the Sisters, Oregon facility. It will also enable the researchers to identify areas where improvements and recommendations can be made to increase energy efficiency. This will result in long-term cost savings and reduced environmental impacts for newly constructed facilities. Similarly, focusing on materials will allow the construction of new maintenance facilities to use the most environmentally friendly materials practical that also produce low-maintenance, long-life structures.

3.2.3.1 Energy Focus

The life cycle building energy inventory will consider the embodied energy of building products and operational phase energy use. Embodied energy is the energy invested into the conversion of materials into a final product and the transport of materials and products throughout the supply chain and during building construction. Information about building products (e.g., types, materials, and amounts) will be collected for the two case facilities in collaboration with ODOT. This information will be used to compile a material/supply chain energy inventory from LCI databases (e.g., within SimaPro LCA software). In some cases, LCI models may need to be constructed if standard databases are incomplete.

To complete the operational phase energy inventory, onsite energy assessments will be conducted at the two case facilities by the OSU Energy Efficiency Center (OSU EEC). The assessments will begin with the EEC team conducting a survey and baseline data collection, followed by a one or two day site visit, taking engineering measurements as a basis for assessment recommendations. The team will then perform a detailed analysis for specific recommendations with related estimates of costs, performance, and payback times. A report, detailing the analysis, findings and recommendations of the team will be compiled. Prior to the site visits, facility personnel will be asked about typical operations and energy, water, and waste (typically, it is simplest to get permission to obtain this information directly from the utility companies). During the visits, the team will tour the facility with ODOT personnel to learn more about the operations and ask questions to obtain clarification. Next, the team will collect required information, including measuring temperatures, pressures, power, and flow rates, as well as collecting operating schedules, statistics, and downtime reports. The team will need assistance from qualified personnel when measuring electrical loads and steam temperatures. Following the visits, the team will work with ODOT personnel

to clarify points about facilities. Based on this information, a report will be compiled that will detail information about facility energy use and potential areas of improvement, including information about potential savings and implementation costs.

3.2.3.1 Materials Focus

Both of the maintenance stations that are part of the case study will be assessed for all materials used in the construction of the maintenance stations and for any permanently attached materials to the building. The building plans and as-built drawings, along with visual inspections and interviews with appropriate ODOT personnel will aid in the development of the LCI of the materials used in both maintenance stations. Any removable items, such as furniture, support supplies, and tools, will be out of the scope of the LCI.

The computer software program, SimaPro will be used to input all of the LCI information from the materials used in the construction of the maintenance stations. The materials will be input in appropriate units to the software so that the appropriate amount (volume or mass) of all materials is correctly quantified. SimaPro software will then calculate a Life Cycle Assessment (e.g. impacts to the environment for the materials chosen) and a carbon footprint of materials used in both maintenance stations. The research team will identify any limitations of the program, which are only expected if a specific material cannot be located in the SimaPro database. If a material cannot be located an alternate will be decided after discussion with the ODOT Research Coordinator on this project. In some cases, material LCI may need to be created from literature information if no suitable alternate can be identified in commercially-available databases.

The research team will also consult the Living Building Challenge and LEED to identify areas where improvements could be made on the selection of materials for future maintenance stations based on the information generated from the two case studies as part of this project. In particular, the Living Building Challenge Red List may identify potential pitfalls, hazards and opportunities regarding materials.

- ODOT will supply detailed plans for the Sisters Maintenance Station.
  The TAC will determine which older maintenance station we be used for comparison, such as the Corvallis Maintenance station, or another that makes sense within the same climate area. And ODOT will supply whatever plans they have for the chosen facility.

  Time Frame: 16 Months NTP
  Responsible Party: PI and Co-PI
  Cost: $70,000
  Deliverable: Draft Analysis Report Section
  TAC Action: Review and comment
  ODOT Action or Decision: Review

Task 8: Draft Final Report

A publication ready Draft Final Report in the prescribed ODOT report format will be done and submitted to the TAC.

Time Frame: [2 Months after completion of Task 5]
Responsible Party: PI and Co-PI
Cost: $7,500
Deliverable: Draft Final Report using ODOT's report template
TAC Action: TAC review and feedback to the ODOT Research Coordinator
ODOT Action or Decision: Review and counsel prior to TAC meeting

Task 9: Draft ODOT Research Note

Write 1000 to 1500 word summary of the research project. The summary will concisely document the research findings, value of the research to the agency, science and society, and any limitations on the use of the findings.

Time Frame: [3 Months after completion of Task 5 and 6]
Responsible Party: PI and Co-PI
Cost: $1,000
Deliverable: Draft ODOT Research Note using ODOT's report template
TAC Action: None
ODOT Action or Decision: Review and advise

Task 10: TAC Meeting #4

This TAC meeting will include a review of the Draft Final Report and Draft Research Note prior to the TAC meeting. The TAC will offer advice on the content and clarity of these work products. The TAC will also advise on post research implementation.

Responsible Party: PI and Co-PI, assisted by the ODOT Research Coordinator, TAC
Cost: $1,500
Deliverable: TAC meeting attendance, TAC meeting presentation, TAC Meeting Minutes
TAC Action: TAC review of Draft Final Report, and Draft Research Note. Advise ODOT Research Coordinator regarding any critical issues with the project's research design. Advise ODOT Research Coordinator regarding any required final edits to the Draft Final Report, and Draft Research Note.
ODOT Action or Decision: Review TAC advice. If necessary direct PIs to make changes to project documents.

Task 11: Final Report

Edit Draft Final Report to incorporate edits identified by the ODOT research Coordinator after the last TAC meeting

Time Frame: [1-3 Months after Data Collection]
Responsible Party: PI and Co-PI
Cost: $1,500

Deliverable: Final Report
TAC Action: None
ODOT Action or Decision: Review. Provide formal acceptance of Final Report. Publish Final Report on ODOT's research website

Task 12: Final Research Note

Edit Draft Research Note to incorporate edits identified by the ODOT research Coordinator after the last TAC meeting.

Time Frame: [1-3 Months after Data Collection]
Responsible Party: PI and Co-PI
Cost: $1,000
Deliverable: Final Research Note
TAC Action: None
ODOT Action or Decision: Review. Provide formal acceptance of Research Note. Publish Final Report on ODOT's research website

5.2 Reporting

All reports shall be produced in the standard ODOT Research Section report format provided to the Project Investigator by the Research Coordinator unless some other format is deemed to be more appropriate. The Project Investigator shall be responsible for submitting deliverables as professional-level written composition equivalent to the writing standards of peer-reviewed journals. These writing considerations include grammar, spelling, syntax, organization, and conciseness.

The Project Investigator, in consultation with the TAC and Research Coordinator, shall deliver to ODOT in electronic format the data produced during the project. The Project Investigator shall ensure the data is labeled and organized to facilitate future access. ODOT shall warehouse the data.

5.3 Safety and Related Training

Prior to accessing ODOT right-of-way (ROW), all personnel who will work on ODOT ROW shall complete safety training appropriate to the work to be performed within the ROW. The Project Investigator shall notify Project Coordinator in writing (email accepted) prior to the first day of work within the ROW that all project personnel who will access ODOT ROW have been trained. Until all ROW work is completed, the Project Investigator shall notify Project Coordinator in writing (email accepted) annually that an active safety training appropriate to the work to be performed within the ROW has been completed by all personnel who will work on ODOT ROW.

6.0 Time Schedule

This section specifies the time line for the project, listing the task headings and showing monthly and/or quarterly time blocks in which each task will be

accomplished. Also shown are interim and final deliverables. (A sample matrix is shown below.)

Task	2015						2016												2017					
	FY16												FY17											
	Jul - Sep			Oct - Dec			Jan - Mar			Apr - Jun			Jul - Sep			Oct - Dec			Jan - Mar			Apr - Jun		
1: TAC Meeting #1					T																			
2: Draft Lit Review							*																	
3: Draft Res. Meth.									*															
4. TAC Meeting #2										T														
5. Mod. LCC																			*					
6. TAC Meeting #3																T								
7. LCI																					*			
8. Draft Final Report																					R			F
9. Research Note																						R		F
10: TAC Meeting #4																								T *

*Deliverables
R - Draft report submitted for ODOT review.
F - Revised report submitted to ODOT for publication. End of contract.
T – TAC meetings

Generally, we schedule 3 months between draft report submittal and report submittal for publication.

7.0 Budget Estimate

An itemized budget for the project is included here showing expenditures for each task by fiscal year and in total.

Task	FY16	FY17	Total
1:TAC Meeting 1	$1,500		$1,500
2:Literature Review	$15,000		$15,000
3:Draft Research Methodology	$5,000		$5,000
4:TAC Meeting 2	$1,500		$1,500
5:Modified Life Cycle Cost Analysis	$28,000	$10,000	$38,000
6:TAC Meeting 3	$1,500		$1,500
7:Life Cycle Inventory	$31,865	$38,133	$70,000
8:Draft Final Report		$7,500	$7,500
9:Draft ODOT Research Note		$1,000	$1,000
10:TAC Meeting 4		$1,500	$1,500
11:Final Report		$1,500	$1,500
12:Final Research Note		$1,000	$1,000
Total for tasks (Contract amount)	**$84,367**	**$60,633**	**$145,000**
Support/management (ODOT completes)			
Total for ODOT (ODOT completes)			

1. *State Energy Efficient Design (SEED) Program: Guidelines for Oregon Administrative Rules Chapter 330, Division 130*, Oregon Department of Energy, January 2007, http://www.oregon.gov/energy/CONS/SEED/docs/Guidelines.pdf, accessed February 12, 2015.

2. *Living Building Challenge 3.0, A Visionary Path to a Regenerative Future*, International Living Future Institute, http://living-future.org/lbc, Accessed November 5, 2014.

3. Kibert, C.J., Sustainable Construction Green Building Design and Delivery, John Wiley & Sons, Inc., New York 2008.

4. *OSU Energy Efficiency Center*, Oregon State University, http://eec.engr.oregonstate.edu/, Accessed November 5, 2014.

5. "1.5 percent of Green Energy Technology for public buildings: Projects Reported in 2015," http://www.oregon.gov/energy/docs/reports/legislature/2015/GET_Rept_FINAL.pdf, accessed September 22, 2015.

6. Oregon Laws 2015, https://www.oregonlegislature.gov/bills_laws/lawsstatutes/2015orLaw0424.pdf, accessed September 22, 2015

7. *Building Life Cycle Cost Programs*, U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, http://energy.gov/eere/femp/building-life-cycle-cost-programs, accessed September 23, 2015.

8. Fuller, S., "Life-Cycle Cost Analysis (LCC)," http://www.wbdg.org/resources/lcca.php, last updated June 28, 2010, accessed September 23, 2015.