EXECUTIVE SUMMARY

This report documents Phase II activities of a potentially four-phase project. The goal of the project is to study the feasibility of using advanced technologies from other industries to improve the efficiency and safety of winter highway maintenance vehicle operations. State departments of transportation from Iowa, Minnesota, and Michigan initially formed the study consortium, and several private vendors have become project partners. The Center for Transportation Research and Education (CTRE) at Iowa State University is managing project tasks.

The primary goals for Phase II were to install selected technologies on three prototype winter maintenance vehicles, one in each of the consortium states, and to conduct proof of concept in advance of field evaluations planned for Phase III. Refer to Figure E-1 for a diagram of the study process, along with foundation statements.

PHASE II OBJECTIVES

A study team consisting of representatives from the consortium states, private partners, and CTRE directs study activities, and during Phase II the study team met regularly and participated in conference calls to oversee progress, monitor developments, and make joint decisions. Study team activities during Phase II are documented in Appendix A.

The study team developed the following objectives for Phase II:

- Install technologies, selected during Phase I focus group activities, on three snowplow trucks, integrating the subsystems into three working prototype winter maintenance vehicles, one in each consortium state.
- Conduct proof of concept for each of the technologies and for the data management process.
- Explore the comparison of data collected by sensor technologies to base data sources (part of proof of concept for several of the technologies).
- Document the cost of technologies implemented in Phase II.
- Solicit operator feedback about vehicle and technology performance.
- Integrate and format data collected by the add-on technologies for potential inclusion in DOT management systems.

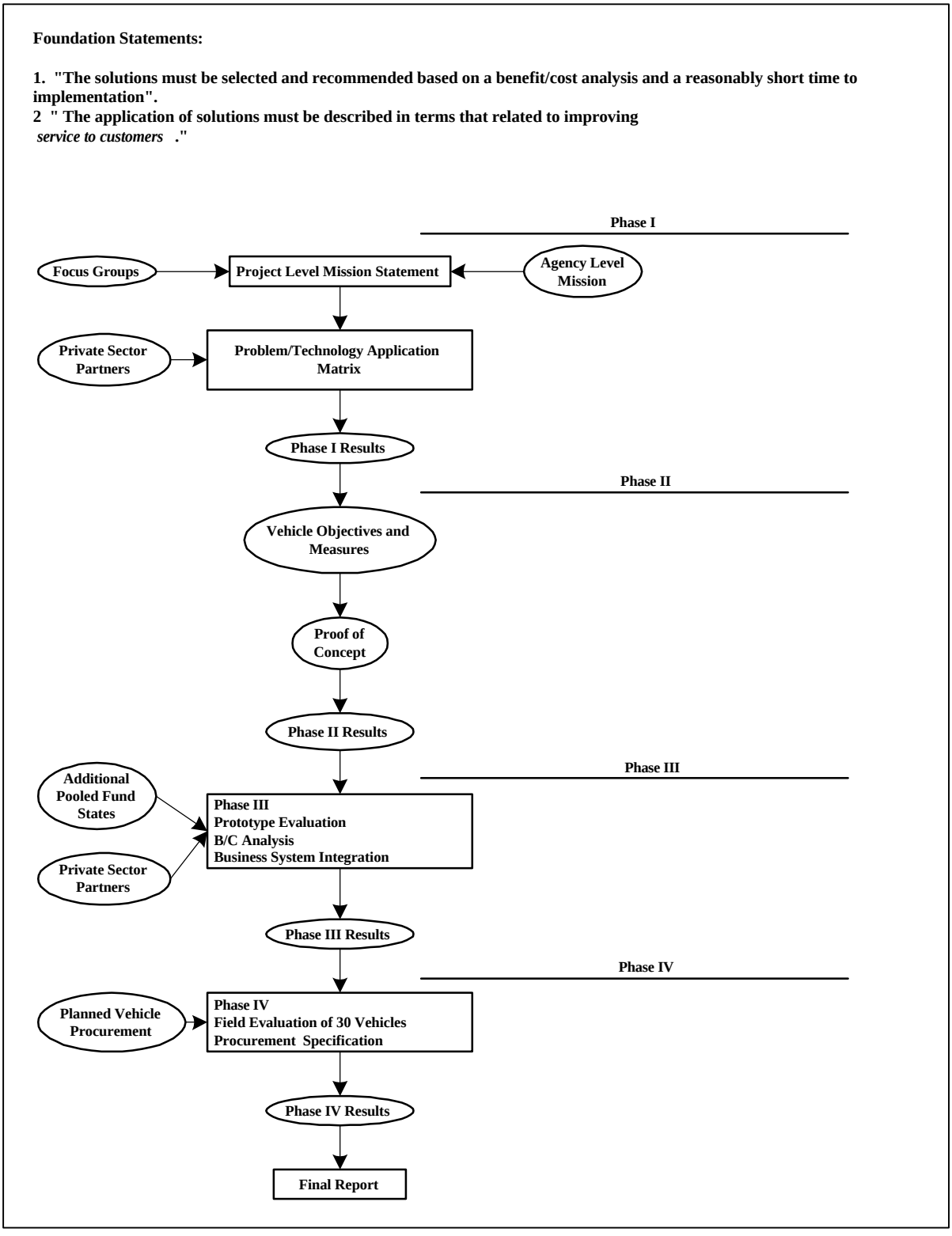

Figure E-1 Foundation statements and study process map

The study team approved a detailed Phase II work plan to guide CTRE's accomplishment of these objectives. Work plan tasks are outlined in Appendix B, along with references to sections of this report describing progress on and accomplishment of the tasks.

Objective 1: Install Technologies

The first objective of Phase II was to build three prototype winter maintenance vehicles by installing selected technologies on three basic state snowplow trucks. Many of the technologies, which were originally developed for applications in other industries, required special fabrication to fit on the trucks and operate effectively under harsh winter conditions. The friction meter offered the most significant installation challenges, and results were not entirely satisfactory. Iowa's installation interfered with full movement of the underbody blade; Minnesota's installation exposed the meter to excessive bouncing, as well as spray from the spreader; and Michigan installed its meter on a separate pickup-class truck. For the most part, however, the technologies were installed and operated on the prototype vehicles. Table E-1 points to the individual chapters in this report that discuss each technology in detail, including installation and proof of concept.

Table E-1 Technologies installed in Phase II

Technology Provider	Technology	Reference Name	Chapter Reference
DOT	Trucks, Plows, and Spreaders	Trucks, Plows, and Spreaders	5
Rockwell International	PlowMaster Computer	PlowMaster	6
Rockwell International	Global Positioning System	GPS	7
Roadware Corporation	Norsemeter ROAR Friction Meter	Friction Meter	8
Sprague Controls	Pavement/Air Temperature Sensors	Temperature Sensors	9
Fosseen Manufacturing	Engine Power Booster	Engine Booster	10
Innovative Warning Systems	High-Intensity Discharge Warning Lights	HID Lights	11
Global Sensor Systems	Reverse Obstacle Sensor	Reverse Obstacle Sensor	12

Objective 2: Conduct Proof of Concept

Proof of concept is simply a process that proves that an idea, or concept, is possible. Proving the possibility of deploying an advanced-technology winter maintenance vehicle required proving the feasibility of each add-on technology and of data management for the project as a whole. For each technology, then, CTRE first determined if the technology could be installed on the vehicle reasonably easily and then determined if the installed technology performed as expected and desired.

Table E-2 shows the results of the proof of concept activities. It lists the desired vehicle functions identified by focus groups in Phase I, the technology subsystems selected to fill those functions, whether the technology passed Phase II proof of concept, and modifications recommended for Phase III.

Table E-2 Proof of concept results

Function	Subsystem	Passed Proof of Concept	Modification for Phase III
Pavement Friction Condition	Friction Meter	Yes	Newer model
Ambient Conditions	Air and Pavement Temperature Sensor	Yes	None
Automatic Vehicle Location	Global Positioning System	Yes	DGPS
Apply Various Materials	Materials Applicators	Yes	Coordinate material applications with roadway conditions
Improve Vehicle Visibility	Fiber Optic Lights	Proof of concept not conducted	None
Provide Additional Horsepower during Periods of High Engine Demand	Power Booster	Yes	None
Rear Obstacle Alarm	Back-up Sensors	Proof of concept not conducted	None
Data Processing	Onboard Computer	Yes	Format data for reports
Data Communications (Real Time)	Cellular Data Communications	Proof of concept not conducted	Provide communication linkage to garages

The friction meter passed proof of concept under dry/wet road conditions but was not conducted under winter road conditions. Proof of concept for the fiber optic lights and back-up sensors was anecdotal only; methodical proof of concept will be conducted in Phase III along with evaluation of the systems. Real-time communications from the onboard computer to garages was not an objective in Phase II. Real-time cellular communications are planned for implementation in Phase III.

Objective 3: Compare Sensor Data with other Sources

Several of the add-on technologies on the prototype vehicles—GPS, air/pavement temperature sensors, friction meter—collect information about the environment, and it was important to proof of concept for those technologies to determine that the information they were collecting was reasonable. CTRE therefore compared data collected by the onboard sensors with known data.

Latitude/longitude readings collected by the onboard GPS at mileposts and compared to known milepost latitude/longitude references were found to be reasonably accurate. Air and pavement temperatures reported by the onboard sensors and compared to temperatures collected by other temperature sensors at the same time and location were found to be reasonable. Friction meter readings on dry/wet pavement were compared to friction data collected by ASTM E-274 equipment at the same time and location and found to be reasonable. Unfortunately, not enough friction data were collected under winter roadway conditions to determine that they were reasonable.

Objective 4: Document Cost of Technologies

CTRE documented the initial development costs for add-on technologies installed on the prototype vehicles, as well as for some technologies not implemented in Phase II. Potentially high development costs for the prototype vehicles were partially avoided by the state DOTs because private vendor partners provided technologies. Phase II installation and operations activities prompted some vendors to significantly modify their product (e.g., the friction meter), and these modifications may significantly reduce ultimate production costs.

Objective 5: Solicit Operator Input

As with many new ventures, successful implementation of the prototype maintenance vehicles depends on acceptance, even ownership, of the project by the people working with them every day: snowplow operators, mechanics, and supervisors. Therefore, operators, mechanics, and supervisors have been involved in this project from the beginning. They were central to Phase I focus group activities that determined the desirable functionalities for a high-technology maintenance vehicle. In Phase II telephone surveys, they provided feedback about their experiences with the prototype vehicles during 1997-1998 winter maintenance activities.

Each of the prototype vehicles was assigned to active duty and used for snow and ice control on roads in Michigan, Minnesota, or Iowa. The winter of 1997-1998 was unusual for its relatively few snow storms, but feedback regarding the vehicles' operations during those events was helpful. Generally, the operators' favorite feature was the automatic material spreaders.

They found the onboard computer display easy to read and use and reported difficulties with the friction meters. Operator feedback is summarized in Figure E-2.

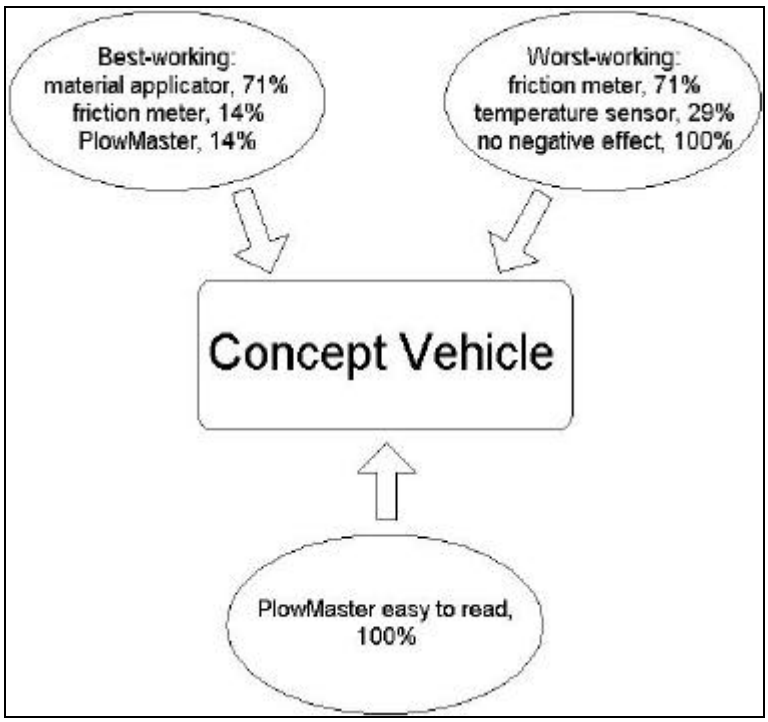

Figure E-2 Equipment operator feedback

Objective 6: Integrate and Format Data

The success of this project depends, in large part, on operators' and managers' ability to access data collected by the prototype vehicles' add-on technologies. Vehicle operators want immediate access to understandable environmental information (temperatures, friction, etc.) and information about the status of the technologies themselves (plow positions, engagement of power booster, etc.) to help them with their immediate maintenance operations. Managers want access to both kinds of information to support local and regional winter maintenance activities and to incorporate into various management systems.

During Phase II, data integration and management was conducted at two levels. First, the onboard computer collected data from the add-on technologies, formatted the data in common formats, interpreted data into understandable terms for the operator's in-cab display, and stored the data on removable Personal Computer Memory Card International Association (PCMCIA) cards for delivery to CTRE. Second, CTRE performed several data management activities

related to proof of concept (e.g., compared the onboard data to data from known sources) and to the possible future integration of onboard data into state DOT management systems. These activities involved translating data into meaningful terms (e.g., GPS latitude/longitude to milepost, vehicle speed to distance traveled, etc.) and developing programs for organizing and plotting the data. These activities provide the foundation for real-time data communications planned for Phase III and, eventually, the possible incorporation of data into management systems.