

## CHAPTER 1: STUDY OVERVIEW

In 1995, the departments of transportation of three Snowbelt states, Iowa, Michigan, and Minnesota, formed a consortium to study the feasibility of applying advanced technologies, particularly technologies already used in other industries for other applications, to state DOT maintenance vehicles to improve their performance, efficiency, and safety. Interest was especially strong in applying technologies that would enhance maintenance vehicles' winter ice and snow control performance and simultaneously provide data and tools for managing winter maintenance activities.

Advanced technologies have the potential to improve winter roadway maintenance activities in a several ways. One improvement may be cost savings. For example, the Iowa Department of Transportation expends \$60-70,000 per hour for snow and ice removal. If the use of advanced technologies reduces the amount of resources directed toward this effort by delaying the need to begin snow and ice removal for even one hour in each winter storm, there is a potential for large cost savings. The savings may offset the costs associated with the advanced technologies.

Another improvement may be the ability to provide management with more complete and detailed weather and road condition data to support maintenance management decisions. Many state departments of transportation are utilizing data recorded through roadway weather information systems (RWIS). These data include pavement, bridge deck, and sub-surface conditions, along with atmospheric condition data. However, although RWIS sensors provide accurate and timely data for specific locations, sensors are located several miles apart, and interpolation of recorded data between sites may not be accurate. If snowplow trucks are equipped with technology applications that measure and record data comparable with that collected by RWIS sensors, condition data may be collected over the trucks' network of roads and streets. The RWIS will provide data at RWIS sensor locations, and the moving snowplows will provide data for areas between those sensors, providing continuity of data all along a corridor or roadway section to help supervisors and equipment operators make better winter maintenance decisions and, ultimately, provide improved roadway conditions.

Finally, advanced technologies have the potential to improve communications with the traveling public, keeping travelers better informed of roadway and driving conditions. Winter driving can be a challenge, particularly during bad weather. Drivers struggle with slick roadway surfaces, poor visibility due to blowing and drifting snow, and traffic slowdowns. Today, there is not a complete system in place that measures these conditions and then shares descriptive information with the driving public. A snowplow equipped with technologies that record winter roadway friction values, pavement temperatures, visibility, and vehicle speed to improve maintenance operations can also provide descriptive information to the public in a credible, timely, and efficient format to help drivers make more informed trip decisions.

Cost savings, improved data, and improved communications are just three possible benefits of applying advanced technologies on winter maintenance vehicles. With these and other

possible benefits in mind, the consortium initiated a three-phase study, which has now become a four-phase effort:

- Phase I Establish desired snow plow functionality
- Phase II Develop a prototype vehicle in each state and conduct proof of concept
- Phase III Conduct field evaluation of selected technologies
- Phase IV Conduct a fleet evaluation in each state

## **STUDY CONSORTIUM**

The study is supported through a consortium of the Iowa, Michigan, and Minnesota departments of transportation, each of which has a reputation for embracing innovation in highway maintenance management, operations practices, and research; the Federal Highway Administration, which joined the consortium with the initiation of Phase II; and the Center for Transportation Research and Education (CTRE) at Iowa State University. CTRE is providing support staff to observe and document activities and coordinate study efforts.

A key element of the project has been the inclusion of private sector technology partners. Private partners were identified during Phase I activities and are now part of the consortium. In addition to the technologies they produce, these private partners have brought many assets to the project, including staff with specialized expertise, business connections, manufacturing facilities, and the potential to participate in funding and producing prototype and fleet vehicles in Phases II, III, and IV of the study. Consortium members include the following:

### **Public Agency Members**

Iowa Department of Transportation  
Michigan Department of Transportation  
Minnesota Department of Transportation  
Federal Highway Administration  
Center for Transportation Research and Education

### **Private Sector Members**

Boyer Ford; *Minneapolis, Minnesota*  
Bristol Company; *Broomfield, Colorado*  
Component Technology; *Des Moines, Iowa*  
Federal Signal Corporation; *Tinley Park, Illinois*  
Force America; *Burnsville, Minnesota*  
Fosseen Manufacturing & Development Ltd.; *Radcliffe, Iowa*  
Global Sensor Systems; *Mississauga, Ontario, Canada*  
Innovative Warning Systems; *Minneapolis, Minnesota*  
Monroe Truck Equipment; *Monroe, Wisconsin*  
Navistar International Corp.; *Fort Wayne, Indiana*  
O'Halloran International; *Des Moines, Iowa*  
Raven Industries; *Sioux Falls, South Dakota*  
Roadware Corporation; *Paris, Ontario, Canada*  
Rockwell International; *Cedar Rapids, Iowa*  
Sprague Controls; *Canby, Oregon*

Tyler Ice (Tyler Industries); *Benson, Minnesota*  
Wired Rite Systems; *Santa Rosa, California*

A study team manages the study. The team consists of representatives from each of the state DOTs, the Federal Highway Administration, CTRE, and private sector partners. Private sector representatives vary due to reassignment of duties or completion of tasks.

## **STUDY PHILOSOPHY**

The foundational goals of the consortium were to select technologies that would, in a reasonably short time, improve functions as defined by the immediate customers (equipment operators, maintenance personnel, and decision makers), and have a reasonable cost-to-benefit ratio.

The study team developed direction for the study by developing mission statements, an approach to follow, and objectives to be achieved.

### **Agency-level Mission Statement**

Provide a uniform, predictable level of service for winter driving while managing assets effectively.

### **Project-level Mission Statement**

Develop a concept highway maintenance vehicle that will support equipment operators and fleet managers making more informed and cost effective decisions.

### **General Approach**

Bring technology applications from other industries to the highway maintenance vehicle.

### **Study Objectives**

The mission and approach statements led to the development of the following overall objectives for the four-phase study:

- Evaluate technology.
- Assess cost implications of technology applications.
- Develop benefit/cost analysis.
- Improve roadway safety for the driving public.
- Develop operator input and acceptance.
- Integrate data with DOT management systems.

- Develop “real time” data for storm management decisions.

## **Phase II Objectives**

Specific objectives for Phase II include the following:

- Integrate selected technologies onto three prototype winter maintenance vehicles, one in each of the consortium states.
- Conduct proof of concept. This may include subjective observation of the technologies’ performance as well as objective comparisons of sensor data with other source data.
- Document the cost of technologies provided in Phase II.
- Solicit operator input for the vehicle and technology performance.
- Integrate and format data on the vehicle for inclusion into DOT management systems.

## **STUDY APPROACH**

As described above, a four-phase approach was developed for the project. Phase I included developing a description of the desired concept vehicle functions and securing the involvement of private sector partners. Phase II included fabricating three prototype maintenance vehicles with add-on technologies and conducting proof of concept. Phase III will include conducting field evaluation and benefit/cost analyses of the add-on technologies. Phase IV will include conducting a comprehensive field evaluation of a fleet of 10 vehicles in each of the consortium states.

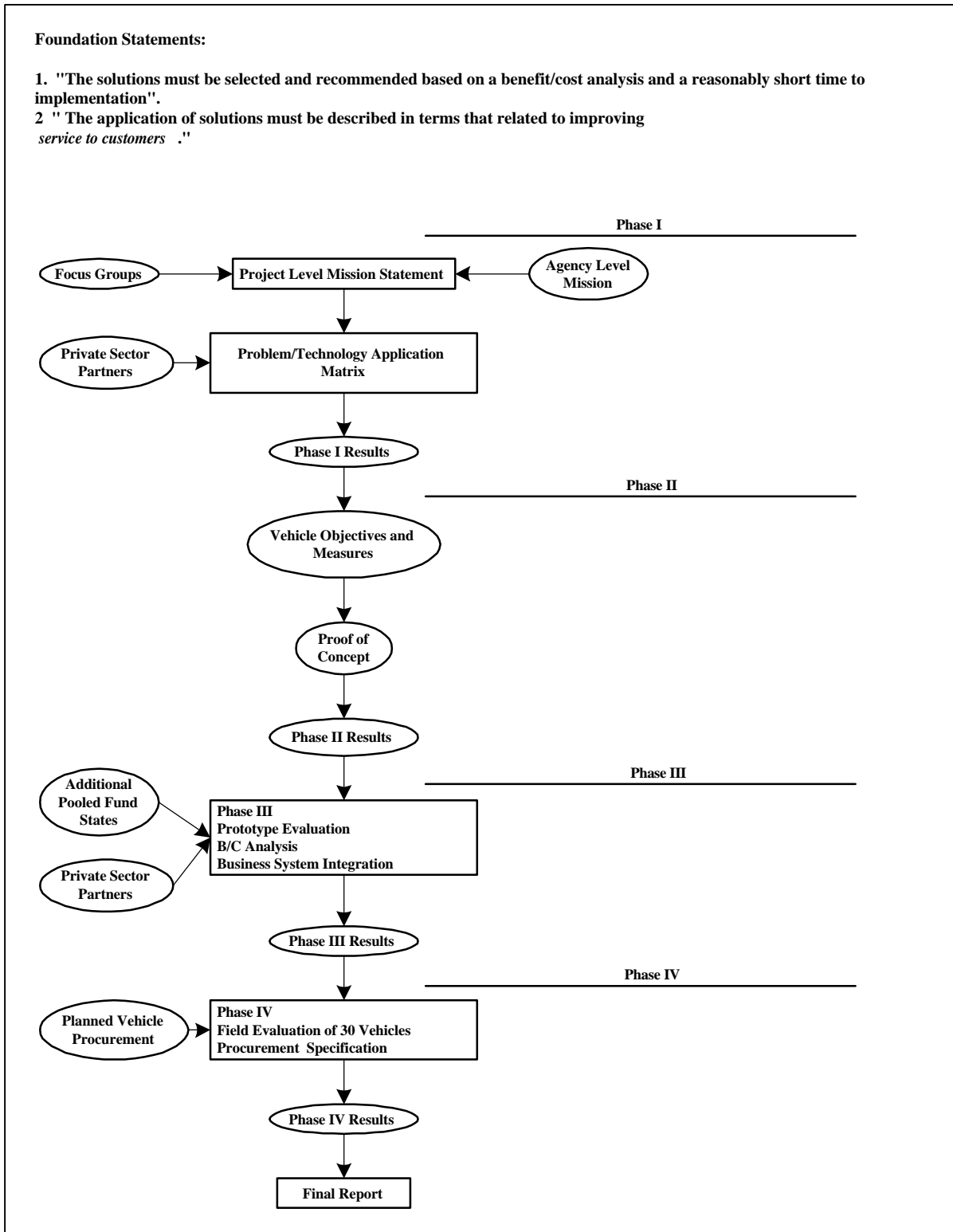
The process map in Figure 1-1 illustrates the progression of the study from Phase I, when the desired functions of the specially-equipped vehicles were determined, to the vision of the Phase IV field evaluation on a fleet of similarly equipped vehicles in each state. The schedule for these phases is graphically presented in Figure 1-2.

### **Phase I: Establish Vehicle Requirements**

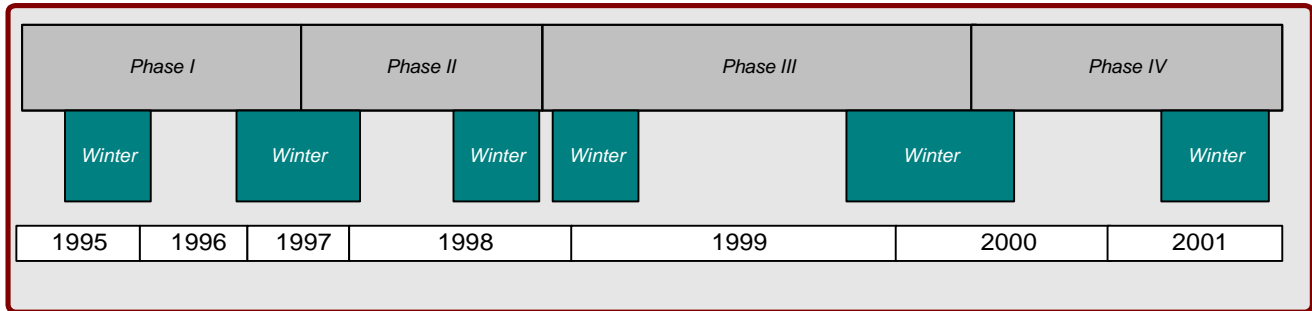
The objective of Phase I was to identify the desired functionality of winter maintenance vehicles and to enlist private sector partners to join the consortium. This phase began with a review of literature related to winter highway maintenance activities. One hundred and five articles were collected pertaining to state-of-the-art equipment, technologies, and research on winter highway maintenance activities.

**Foundation Statements:**

1. "The solutions must be selected and recommended based on a benefit/cost analysis and a reasonably short time to implementation".
- 2 " The application of solutions must be described in terms that related to improving service to customers ."



**Figure 1-1 Study process map**



**Figure 1-2 Four-phase time line**

The ideal capabilities (or functionality) of a winter maintenance vehicle were identified through a total of five focus groups that met in the three states. Focus groups were comprised of the “customers” or end users of winter maintenance vehicles: equipment operators, mechanics, area supervisors, law enforcement, emergency responders, resident and central maintenance office engineers, and equipment managers. More than 600 ideas for vehicle functions were generated, organized into a list of 181 desired capabilities, and categorized into six major groups of functions:

- Administration
- Vehicle at Rest
- Infrastructure
- Pre-operations
- Roadway Systems Operations
- Post-operations

Ideas from the focus groups were prioritized, resulting in the following desired functionality for the three prototype vehicles:

1. Sense pavement surface (friction) condition.
2. Sense roadway surface and air (ambient) temperatures.
3. Record and download vehicle activities (vehicle location).
4. Provide adequate horsepower (improve engine performance).
5. Carry and distribute various types of materials.
6. Sense obstacles behind the vehicle (rear-obstacle alarm).
7. Provide removable salt/salt brine dispensing system.
8. Improve fuel economy.

Private sector equipment and technology providers were then introduced to the project and asked to join in the effort. The private partners listed on page 10 committed to providing equipment and expertise for the duration of the study. Although the overall goal was to implement equipment that would perform the functions identified in the focus groups, the technologies provided by vendors did not exactly match the desired functions in every case. For example, no technology was provided to “improve fuel economy,” but fiber optic lights were provided to improve vehicle visibility in snow and fog. See Table 1-1 for a complete list of technologies selected for integration on the prototype vehicles during Phase II.

Phase I has been completed. A more detailed discussion of the work done in Phase I can be found in the report, Concept Highway Maintenance Vehicle, Final Report Phase One, dated April 1997. The report is available at CTRE and online at [www.ctre.iastate.edu/projects/convehcl/](http://www.ctre.iastate.edu/projects/convehcl/).

**Phase II: Develop Prototype Vehicles and Conduct Proof of Concept**

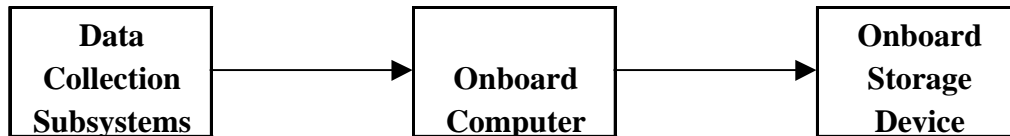
The object of Phase II was to build three working prototype vehicles, one in each consortium state, integrating selected advanced technology subsystems; conduct proof of concept to demonstrate that the integrated technologies performed satisfactorily on the maintenance vehicles; and prepare for field evaluation of the prototype vehicles in Phase III. Manufacturers and system integrators worked with the study team to develop the prototype vehicles. Technology providers for some of the components varied from state to state, but, with the exception of the friction meter, the functions of the prototype vehicles were identical. (Michigan did not install the friction meter on its prototype vehicle; see chapter 8.) The study team selected technology for the winter of 1997-1998 and documented equipment names and model numbers, technology providers, and descriptions of the technology capabilities. Adjustments and modifications were made when the technologies were incorporated onto the prototype vehicles. CTRE documented these adjustments and modifications, along with the challenges involved with locating the technology components on the vehicles and during troubleshooting activities.

Table 1-1 lists the desired vehicle functions identified in Phase I, associated technology subsystems, and level of integration of the subsystems on the prototype vehicles during Phase II.

**Table 1-1 Phase II level of integration of desired functionality on prototype vehicles**

<b>Function</b>	<b>Subsystem</b>	<b>Level of Integration</b>
Measure Pavement Surface Condition	Friction Meter	Complete
Measure Ambient Conditions	Air /Pavement Temperature Sensors	Complete
Automatic Vehicle Location	Global Positioning System	Complete
Improve Engine Performance	Power Booster	Complete
Apply Various Materials	Materials Applicators	Partial
Improve Vehicle Visibility	Fiber Optic Lights	Complete
Rear Obstacle Alarm	Backup Sensors	Complete
Data Processing	Onboard Computer	Complete
Data Communications (Real Time)	Data Communications	Phase III installation

Proof of concept is simply a process of proving that an idea, or concept, is possible. The “concept” to be proved in this study is that advanced, existing technologies (e.g., air/pavement temperature sensor, global positioning system (GPS), onboard computer system) can be adapted for use on a snowplow vehicle. Figure 1-3 provides a simple schema of the relationship among the onboard technologies, or subsystems.



**Figure 1-3 Phase II prototype vehicle system architecture**

To conduct concept, the study team’s goal was to run the add-on technologies while the prototype vehicles performed routine maintenance operations, and generally observe that the technologies functioned as expected. Proof of concept was conducted during winter operations in 1997-1998. For example, the temperature sensors collected data; the GPS collected location/time data; the onboard computer collected data, translated them to common formats, and stored them on removable PCMCIA cards; data were provided to vehicle drivers via a user friendly in-cab display; and, when CTRE converted and displayed the data, they appeared reasonable and suitable for incorporation into management systems. See Table 1-2.

**Table 1-2 Proof of concept results**

<b>Function</b>	<b>Subsystem</b>	<b>Passed Proof of Concept</b>	<b>Modification for Phase III</b>
Measure Pavement Surface Condition	Friction Meter	Yes	Newer model
Measure Ambient Conditions	Air and Pavement Temperature Sensors	Yes	None
Automatic Vehicle Location	Global Positioning System	Yes	DGPS
Improve Engine Performance	Power Booster	Yes	None
Apply Various Materials	Materials Applicators	Yes	Coordinate material applications with roadway conditions
Improve Vehicle Visibility	Fiber Optic Lights	Not conducted	None
Rear Obstacle Alarm	Backup Sensors	Not conducted	None
Data Processing	Onboard Computer	Yes	Format data for reports
Real-time Data Communications	Data Communications	Not conducted	Provide communications linkage to garages

A user manual was produced for the prototype maintenance vehicles, with documentation regarding operation and troubleshooting of the technological components. Each of the three state DOTs received a user manual specific to its vehicle, and a master manual is kept on file at CTRE.

A form was developed for DOT personnel to document problems, repairs, and maintenance on each prototype vehicle. Phone interviews were conducted with equipment operators to document equipment performance and user acceptance. Information from these interviews was entered into a database for analysis and comparison. As a result, the following desired functionality was identified for implementation in Phase III:

1. Provide additional weather data sources.
2. Provide a collision avoidance system.
3. Provide a differential global positioning system (DGPS).
4. Provide cellular telephone/radio communication linkage.
5. Trace roadway surface chemicals locally, regionally, and/or statewide.
6. Develop material distribution intelligence (using algorithms based on surface trace data, air/pavement temperatures, pavement friction, and weather forecast).
7. Display data on area-specific maps.

### **Phase III: Conduct Field Evaluation of Selected Technologies**

The general objectives of Phase III will be to establish the specific vehicle functionality and related technology to be evaluated in this phase, conduct a benefit/cost analysis for each technology, estimate the time to implementation, conduct field evaluations, and produce data flow and decision process maps that integrate the concept vehicle functionality into management systems. Phase III will answer these questions:

- Which technologies will be implemented?
- What are the benefits/costs of each technology?
- What is the expected time to implementation?

Phase III tasks will include the following:

- Describe the vehicle and systems to be considered.
- Develop proof of concept for additional technologies and onboard intelligence.
- Develop a field evaluation plan for three prototype vehicles and conduct the evaluation.
- Obtain additional state partners (pooled fund).
- Obtain additional private sector partners.
- Develop a benefit/cost evaluation and conduct benefit/cost analysis.

- Develop a time-to-implementation projection.
- Develop data flow maps and suggest a method(s) to integrate the data with existing and planned state systems.
- Develop information flow process maps and suggest a method(s) to integrate the information with existing and planned management systems.

#### **Phase IV. Conduct Fleet Evaluation in Each State**

The objective of Phase IV is to conduct a field evaluation of 30 vehicles equipped with the functionality selected in Phase III and to develop a draft vehicle procurement specification. The evaluation will be based on the evaluation plan developed in Phase III. In Phase IV it is envisioned that a fleet of 10 vehicles in each consortium state will be equipped with the selected advanced technologies. Although equipping 10 vehicles implies a significant expense, the vehicles themselves will be standard design maintenance trucks that are part of each state's annual equipment program. Therefore, instead of purchasing vehicles only for a test, the vehicles will be available after testing for standard maintenance operations in the participating states. The only equipment costs directly attributable to this project, then, will be the costs of add-on technologies.

#### **A VISION FOR THE FUTURE**

The scope of this study is limited to several prioritized functionalities determined primarily in the Phase I focus groups. However, the proof of concept demonstrated in Phase II, the prototype vehicle evaluations in Phase III, and the fleet evaluations in Phase IV will establish a methodology for determining the feasibility and cost-effectiveness of incorporating additional advanced technologies on maintenance vehicles. Consider the possibilities:

- Automated chemical and abrasive distribution systems activated by measuring the conditions of the roadway surface.
- Automated data collection that interfaces with DOT management systems, including maintenance, pavement, bridge, and equipment management systems along with personnel and purchasing systems.
- Specific winter maintenance strategies for local conditions.
- Analysis of the applied chemicals and roadway conditions to ensure effectiveness.
- Heads-up displays for equipment operators so they don't have to look away from the road to see the gauges.
- Geographical information systems (GIS) integrated with GPS to map roadway condition data and other maintenance information.

- Collision avoidance systems that allow equipment operators to know when there is a stalled vehicle or other obstruction in the way while conducting snow and ice removal duties during inclement weather conditions.
- Systems that provide accurate and “real time” condition reports to the driving public.

These few examples illustrate the potential that exists when we look into other industries and look at other technology applications that can be imported into winter maintenance decision-making processes and public information systems.