Concept Highway Maintenance Vehicle

Final Report: Phase One

April 1997

CTRE

Center for Transportation Research and Education

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The state Departments of Transportation (DOT) of Iowa, Michigan, and Minnesota formed a consortium to define and develop the next generation highway maintenance vehicle. The Center for Transportation Research and Education, an Iowa State University center, provided staff support to the concept highway maintenance vehicle project, which focused on winter maintenance activities. Phase I of the three-phase project focused on describing the desirable functions of a concept maintenance vehicle. Phase II will include the development, operation, and evaluation of prototype winter maintenance vehicles. Phase III is envisioned to be a comprehensive fleet evaluation of prototype winter maintenance vehicles. This report covers the activities of Phase I.

Phase I included conducting a literature review of materials related to winter highway maintenance activities, identifying ideal capabilities of a winter maintenance vehicle, inviting private sector equipment and technology providers to join the project and commit equipment and expertise for Phase II, and determining the specific equipment and technology to be included on the three prototype vehicles for the winter of 1996n1997. Phase I concluded by

establishing that assembling the three prototype vehicles would be beneficial to the project and to the three state DOTs.			
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CONCEPT HIGHWAY MAINTENANCE VEHICLE
FINAL REPORT: PHASE ONE

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ABSTRACT

The state Departments of Transportation (DOT) of Iowa, Michigan, and Minnesota formed a consortium to define and develop the next generation highway maintenance vehicle. The Center for Transportation Research and Education, an Iowa State University center, provided staff support to the concept highway maintenance vehicle project, which focused on winter maintenance activities. Phase I of the three-phase project focused on describing the desirable functions of a concept maintenance vehicle and evaluating its feasibility. Phase II will include the development, operation, and evaluation of prototype winter maintenance vehicles. Phase III is envisioned to be a comprehensive fleet evaluation of prototype winter maintenance vehicles. This report covers the activities of Phase I.

Phase I began with a literature review of materials related to winter highway maintenance activities. One hundred five articles were collected, which pertained to state of the art equipment, technologies, and research related to winter highway maintenance activities.

The ideal capabilities of a winter maintenance vehicle were identified through focus group activities. Five focus group meetings held in the three consortium states generated 600 ideas, which were later combined and organized into a list of 181 desired capabilities for the concept highway maintenance vehicle.

Private sector equipment and technology providers were introduced to the project and asked to join in the effort. These private partners committed to providing equipment and expertise for Phase II of the project, which will include producing and evaluating three prototype winter maintenance vehicles for the winter of 1996n1997, as well as additional prototype vehicles for the winter of 1997n1998.

The specific equipment and technology to be included on the three prototype vehicles for the winter of 1996n1997 was determined in cooperation with the three DOTs and the private sector partners. That equipment and technology has been listed in the Technology Abstract.

Phase I concluded by establishing that assembling the three prototype vehicles would be beneficial to the project and to the three state DOTs.

TECHNOLOGY DEFINITIONS

The following is a list of the equipment to be installed on the prototype vehicles. A longer explanation can be found in Chapter Six.

Truck - 50,000 pound gross vehicle weight (GVW), tandem axles.

Front Plow - Mounted in front of the vehicles. Down pressure applied by gravity.

Wing Plow - Mounted on the passenger side of the vehicles. Can be raised or lowered to plow the outside shoulder, wing snow down the foreslope, or bench plow high drifts.

Underbody Plow - Mounted under the vehicles. Down pressure applied hydraulically.

Global Positioning (GPS) Receiver - Rockwell International receiver mounted above the cab. Records vehicle's location every five seconds and stores it on the PlowMaster™.

PlowMaster™ - Rockwell International's PlowMaster, located in the cab, will store data collected by the vehicles. Data will be stored on a standard PCMCIA card, which can be removed from the PlowMaster for transfer of data to a personal computer.

Materials Applicators -

Iowa - Slip-in, single skid mounted liquid tank/Monroe Brute MSV heavy duty V-box spreader inside the vehicle's dump box. The anti-icing and pre-wetting systems, both with automatic granular reduction upon commencement of the liquid operation, will be controlled in the cab by a SYN/CON controller, provided by Bristol Company.

Michigan - Monroe Duz Mor chassis mounted V-box and permanent liquid tank. Anti-icing and pre-wetting systems use a Raven controller in the cab.

Minnesota - Slip-in, removable Tyler V-Blend salt/sand V-box inside the dump body. Divided spreader box allows operators to distribute any desired ratio of two materials. Anti-icing, pre-wetting, and spreader systems controlled in the cab by a Tyler Quantum Control.

Engine Power Booster - Fosseen Manufacturing's Hydrofire Fuel Injection System, incorporated into the fuel system, includes an eight gallon tank mounted behind the cab. Automatically injects a water/alcohol lubricant blend fuel additive at peak power requirements.

Friction Meter - Norsemeter Friction Meter is an additional single tire, which measures the friction of the road surface and records that information on the PlowMaster.

Pavement/Air Temperature Sensor - Sprague RoadWatch™ Warning System monitors the temperature of the pavement surface and air. The infrared sensors mount on the driver's side-view mirror and a two-inch digital gauge mounts in the cab. Pavement and air temperature readings will also be recorded by the PlowMaster.

Reverse Sensor - Global Sensor Systems Inc.'s Search-Eye Sensor System detects the presence of objects behind the vehicles, when in reverse, and automatically applies the brakes. The system consists of three sensors mounted on the rear of the vehicle, which are wired into the braking system.

Fiber Optic Warning Light System - Federal Signal's fiber optic warning light system uses a single light motor mounted in the cab to originate four solid or flashing warning lights which supplement the existing strobes and revolving beacon.

CHAPTER ONE: INTRODUCTION

A universal challenge facing highway agencies today is to simultaneously increase productivity, quality, and environmental sensitivity. These challenges are of major importance to three-quarters of the states' departments of transportation (DOT), who must face the perils of winter as they strive to provide uninterrupted mobility to the road user. Snow and ice control during winter storms includes highly complex tasks and long, stress-filled hours for equipment operators and their supervisors. Continued cutbacks in DOT staffs dictate that one equipment operator must be able to drive a snow plow truck and manage all of its ancillary equipment, whereas in the past there were two operators. These staff reductions come at a time when road users require greater mobility and an increased level of service for winter driving. Therefore, the concept highway maintenance vehicle project was undertaken as a three-phase project to re-engineer highway maintenance vehicles so that they include the newest technologies available, and better suit the needs of the operator and the highway agencies. This report summarizes the activities of Phase I, which involved determining the desired capabilities for a concept highway maintenance vehicle and predicting the feasibility of assembling prototype vehicles.

Snow and ice control operations could benefit greatly from improvements in state-of-the-art vehicle navigation systems, on-board computer applications, enhanced safety systems, and improved equipment operator efficiency. Advanced vehicle navigation systems can make equipment operations safer during times of poor visibility, often found during winter storms. Sensors and automated attachment controls could improve operator efficiencies (e.g., the equipment operator may be able to automatically set the most efficient underbody snowplow blade angle and down pressure by utilizing onboard computers and sensors). Sensors can record roadway surface temperatures and friction values. Computers may be able to determine optimal timing and application rates of chemicals and abrasives. Automatic vehicle location systems can track the progress of single vehicles and fleets. Computers, video cameras, and sensors could monitor vital signs of the major vehicle components and the ancillary snowplow equipment. By warning operators of abnormal conditions, costly and untimely breakdowns could be avoided.

THE CONSORTIUM

In recognition of the potential that exists when utilizing advanced technologies for highway maintenance activities, this project was initiated to define the desired vehicle and equipment capabilities, to develop and evaluate a prototype vehicle, and to produce vehicles for fleet applications. In order to initially focus on maintenance operations that are most under public observation, winter snow and ice operations received the first consideration for technology applications. However, the research team realized that many of the technologies adopted would also benefit other maintenance operations.

Phase I of the concept vehicle project—describing the desirable functions and evaluating prototype feasibility—was supported through a consortium of three "snowbelt" state DOTs: Iowa, Michigan, and Minnesota. Each of these DOTs have reputations for embracing innovation in highway maintenance management, maintenance operations practices, and research. Consequently, they formed the core and founding membership of the consortium. The Center for Transportation Research and Education (CTRE), an Iowa State University center, provided staff support to the consortium. The project definition and objectives paralleled the interests and experience of the CTRE's support staff. A key element of this project was the inclusion of private sector partners into the consortium. Private sector partners brought many assets to the project, including staff with specialized expertise, business connections, manufacturing facilities, and the potential to participate in the funding and production of both prototype and fleet vehicles in Phases II and III. Private sector partners and additional public sector members were invited to join the consortium.

The various consortium relationships were initially identified as follows:

<u>Initial Membership</u>

- Iowa Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Center for Transportation Research and Education—staff to consortium

<u>Other Potential Public Sector Participants or Observers</u>

- Federal Highway Administration
- Other state transportation departments
- Public works agencies
- Representatives of local government agencies

<u>Potential Private Sector Participants</u>

- Vehicle manufacturers
- Vehicle component manufacturers
- On-board vehicle tracking and communications manufacturers
- Technology manufacturers and integrators

THREE PHASE RESEARCH PLAN

The scope and breadth of a research project of this nature is difficult to totally define at the conception or initial stages. Many developments occurred as new technology and equipment options were identified for possible inclusion in the project. Each of those items needed to be properly evaluated and categorized with respect to its value and feasibility for the project. Furthermore, the inclusion of private sector partners added another level of unpredictability to the scope of the project in terms of what could be accomplished. A three-phase approach is being pursued with the most detail provided for Phase I. The ensuing phases are more broadly defined, because of their reliance on Phase I results. Phase I included developing a description of the desired concept vehicle functions and securing the involvement of private sector partners, Phase II will include prototype development and evaluation, and Phase III will include a comprehensive (fleet) evaluation.

Phase I: Identifying Desired Functions and Prototype Feasibility

Phase I identified the desired capabilities and formed public and private partnerships for assembling prototype concept highway maintenance vehicles. As an over-arching activity during Phase I, funding opportunities to carry the project into prototype production and fleet development were applied for once investigated.

The process of identifying the desired capabilities of this concept maintenance vehicle was very similar to the product development process used in the manufacturing community. This was the first time that several of the technologies had been brought together to increase the functionality of a highway maintenance vehicle and meet the needs of the equipment operator.

Because the process of incorporating new technologies into highway maintenance vehicles is similar to new product development, the process utilized was one used in the private sector called "Quality Function Deployment," (QFD). The process requires customer input before the product is designed and manufactured. The key is to identify the customers' expectations "in their own words" and not in the words of a marketer or engineer. Once the customers' expectations have been defined in QFD, a prototype concept design is assembled, tested, evaluated, and modified. The changes required to meet the customers' needs then occur and are included in the very first production models to be manufactured.

To capture customer input, each of the participating states conducted focus group activities to quantify the ideal capabilities of the concept maintenance vehicle. The ideas that were generated by the focus groups were recorded in a format called an affinity diagram, which was developed by Kawakita Jiro. The purpose of an affinity diagram is to generate, organize, and consolidate information concerning a product, process, or complex issue or problem. The focus groups for this project followed the affinity diagram process described in *Total Quality Transformation: Improvement Tools*. Ideas were generated, written on self-adhesive notes, and placed on the walls. After all ideas were generated, the ideas were grouped into logical categories and each group was labeled by the focus group. The focus groups then used relations diagrams to study the relationships among categories of the desired capabilities of the concept vehicle and to identify root causes and effects of problems. By identifying the relationships, the focus groups saw where to direct the resources of the organization when acquiring future vehicles. In general, all of the focus groups identified driver safety and snow plowing functions as high priorities.

Identification of desired highway maintenance vehicle and equipment capabilities was provided through focus groups consisting of DOT equipment operators, mechanics, equipment specification writers, maintenance managers, and maintenance supervisors. In addition, representatives from other professions who had an interest in the concept vehicle, such as law enforcement personnel and emergency responders, participated. These other representatives are on the outer edges of the highway maintenance activities and provided some of the most innovative input to the process. It was a project objective to identify the desired vehicle capabilities in "the voice of the customer," or in this case, in the voice of the equipment operator. CTRE utilized the services of a private sector group facilitator during the focus group activities. To remain efficient, the focus group sizes varied from 15 to 20 participants. Five focus groups were conducted in fall 1995 in the three consortium states, including Roseville, Minnesota; St. Cloud, Minnesota; Troy, Michigan; and two in Cedar Rapids, Iowa. The activities of the focus groups were documented to capture the entire list of ideas and function descriptions for the concept vehicle. As a result of the employee focus group activities, each partner state's DOT developed a prioritized list and a detailed description of the desired concept vehicle capabilities available for technology transfer applications.

Phase II: Prototype Evaluation

During Phase II of this project, manufacturers, system integrators, and the research team will develop one prototype concept vehicle in each of the three consortium states. An evaluation plan will be developed, and after the prototype vehicles have been built, they will be tested and the necessary or desired modifications will be made to improve the vehicles' design. The vehicles' performance will be evaluated using an evaluation plan which will be developed by CTRE and approved by the consortium. A recommendation to proceed to Phase III or to stop at Phase II will be provided at that time. Finally, task descriptions, a budget, and a schedule will be prepared for Phase III.

Phase III: Comprehensive Vehicle Evaluation

In Phase III, several vehicles will be built in each consortium state for fleet testing. Although building several vehicles implies a significant expense, these vehicles are likely to be standard design maintenance trucks with advanced technology systems incorporated into them. Therefore, instead of purchasing vehicles only for a test, the vehicles will be available, after testing, for standard maintenance operations in the participating states. It is anticipated that 30 concept vehicles will be built and deployed for use, testing, and evaluation by the consortium state DOTs. During Phase III, an evaluation plan will be developed and a thorough evaluation of the vehicle fleets will be made.

CONCLUSION

The schedule for completion of Phase I was driven by the desire to have prototype vehicles available for testing in winter snow removal operations during 1996n1997. In order to meet that schedule, the research team, including private sector partners and the original consortium state DOTs, had to evaluate the technical specifications and assemble the prototype vehicles. These tasks were completed in October 1996 and provided adequate time for development of prototype vehicles in the winter of 1996n1997. It appears feasible to continue prototype vehicle development for the winter of 1997n1998, and then proceed with fleet evaluation for the winter of 1998n1999. Many factors will influence this schedule, but the continued emphasis of the research team to keep the project on schedule will do much to accomplish this research project in a timely manner.

CHAPTER TWO: LITERATURE SEARCH

INTRODUCTION

A literature search of relevant materials was conducted utilizing different resources. The goal was to find materials related to state of the art technologies and research in the area of snow and ice removal. The search was carefully organized and documented to facilitate ease of both presentation and retrieval of materials. The following sections document how the literature search was conducted and the result of the search.

ORIENTATION TO THE IOWA STATE UNIVERSITY LIBRARY

The graduate research assistant assigned to the project and the principal investigator met with a library research assistant to become familiar with the different literature search tools available at the Iowa State University Library. The assistant helped to identify the numerous possible sources that would be available for searching. The assistant was available throughout the duration of this research project to act as a resource and to assist with the library search activities. Major subject areas were identified that helped focus the initial literature search, including a preliminary search of the following sources:

- Applied Science and Technology Index (ASTI) - Produced by the H. W. Wilson Company, this database contains citations and abstracts to applied science areas such as engineering, materials science, and biotechnology. It contains data from 1983 to the present.
- Compendex Plus - This database contains citations and abstracts to information related to engineering and contains data from 1980 to the present.
- National Technical Information Service (NTIS) - This database contains bibliographic descriptions of unrestricted technical reports from U.S. and non-U.S. government sponsored research about such subjects as engineering, mathematics, and business information. It contains data from 1983 to the present.
- Transportation Research Information Services database (TRIS) - Produced by the Transportation Research Board, this database contains document abstracts of published research literature in the areas of highways; rural, urban, and intercity transit; highway safety; railroad; maritime; and air transport. It contains data from 1983 to the present.
- Internet Resources - The Internet provides access to numerous transportation and government resources worldwide. It was used to identify possible sources of information.

REVIEW PERIODICALS

Periodicals can be a valuable resource to identify the activities that are being conducted by others with similar interests in a concept highway maintenance vehicle. The goal of this task was to identify information about current activities of universities, government agencies, research centers, and private sector researchers related to technologies which could be applied to maintenance vehicles. This directed the research team to others who were conducting similar activities, emerging technology and its application, and potential technology providers. The periodicals that appeared most frequently in the literature search were reviewed continuously. These included *Better Roads, Roads and Bridges, Public Works Journal, Civil Engineering*

News, Transportation Research Board publications, and NCHRP publications.

ORGANIZE DATABASE

It was important to identify which materials were relevant to the research activities and to ensure that the literature search was focused. The research team identified relevant technical subject areas, including on-board tracking systems, the latest snow and ice removal research activities, advanced military technology available to the public sector, current developments in the vehicle manufacturing industry, and potential funding sources for continuation of the project into Phase II and Phase III.

LITERATURE DATABASE DESIGN

The database was designed for the efficient querying and retrieval of both identified and collected materials. As various materials were identified, each was given a reference number and entered into the database as a “record.” Each record contained several pieces of information about the material, including title, author, publication title, page number, source where it was identified, and a brief description of the article. A sample record from the database can be seen in Figure 1-1.

The information entered into the database was used to identify materials that needed to be obtained. Records continued to be added throughout the literature search process. The final database was kept in electronic form and in print, with the intention of making it available for future literature searches.

SCHEDULE

A schedule was set for the literature search, including time for searching, reading, and database entry. This provided an opportunity to review the progress on an ongoing basis. Furthermore, by setting a library schedule, the research assistant was able to vary the literature search activities among library activities, database development, reading, and filing articles. Setting a schedule allowed the research assistant to vary the work load and allowed the principal investigator to assess and evaluate progress throughout the duration of the task.

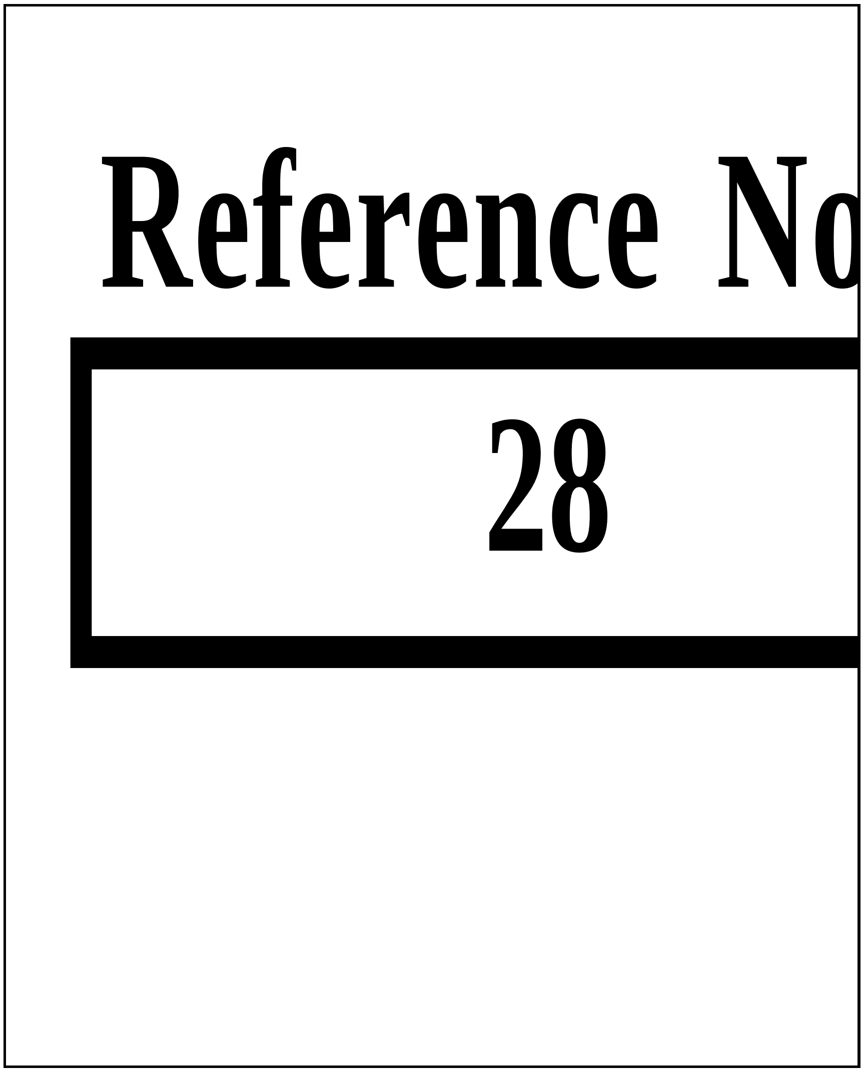

FIGURE 1-1 Example literature database input form.

IDENTIFY KEY DOCUMENTS AND ACTIVITIES

The research team identified the key documents and organizations that have the most potential to add value to the research activities, including:

- ·Types of snow plow blades
- ·Anti-icing and de-icing topics
- ·Various types of sensors, both for detecting roadway conditions and for detecting obstacles
- ·Technology transfer from defense industry to the public sector
- ·Alternative fuels
- ·Communications systems
- ·Economic analysis of snow removal operations

RESULTS OF LITERATURE SEARCH

Of the 600 plus references identified by the initial search, 130 materials were marked for retrieval. Some of the items could be obtained from the ISU library, but many had to be obtained through interlibrary loans or by contacting the publishing source directly. All of the materials were reviewed and rated as to their value to the project. The rating system consisted of a one to five scale, with five being the best. A complete list of the materials and their ratings can be seen in Appendix A.

CONCLUSION

The preliminary goal of the literature search was to determine the level of activity in the snow and ice removal arena. There were several activities in progress and many documents that described completed projects. The principal investigator was interested in focusing on successful ventures and determining their potential for this project. Many of the references were used to focus the scope of the project in the early stages, when ideas were being consolidated and a direction was being set. The area that seemed to be the least documented was economic evaluations. There were few documents that could specifically document the real savings from using advanced technologies. The research team was convinced that there were savings to be realized from the use of advanced technologies because of the continued and increasing use of some technologies by private sector businesses. For example, the trucking industry has continued to expand the use of Global Positioning Systems (GPS) for tracking shipments and equipment, determining optimum routes, and automating the administrative record keeping tasks. However, the literature search did not identify any reports from this sector of the economy that documented the benefits of using it. Common sense will tell us that it must be of value or private sector businesses would not continue to embrace its use. The private sector, however, is less likely to formally document its experiences because of the competitive environment in which they exist.

The most value derived from the literature was the identification of technologies that had already been developed. Sometimes these technologies were used in applications other than highway maintenance, but held promise for the concept highway maintenance vehicle. The more important references are described in Table 2-1.

TABLE 2-1 Selected Literature

Ref. No.	Source	Subject
1	Roads and Bridges	International study tour sponsored by the FHWA brings both easy and complex solutions to domestic snow control problems.
2	NCHRP Research Results Digest	An NCHRP digest of the findings and recommendations of an international winter maintenance scanning tour conducted under the auspices of the FHWA's international programs and NCHRP Project 20-36, Highway Research and Technology - International Information Sharing.
10	TRB Maintenance Management Conference Proceedings 5	Automating maintenance scheduling and reporting including voice recognition software, pen based computers, bar-code scanners, and communication technologies.
25	Michigan Technology University	Explores new techniques of disbonding ice including pavement surface compositions, electromagnetic radiation, air and liquid jets, and acoustics waves.
29	Washington DC University Trans. Centers	Enhance the value of data received by the maintenance foreman for making decisions regarding winter highway maintenance using a microcomputer-based decision support system (DSS).
32	WELS Research Corp.	Development of user-friendly, artificial intelligence-supported weather prediction software. Seeks to integrate historical and current local weather information.
47	Better Roads	A discussion of salting and anti-icing techniques including temperature measuring devices attached to moving vehicles.
209	Better Roads	Cost reductions resulting from the Wisconsin Winter Weather System (WWWS) which allows for less use of salt by delaying applications until they are required for deicing activities.
233	South Dakota DOT	Snow plow light visibility and snow cloud reduction by using a variable angle snow plow.
242	Scranton Gillette Communications, Inc.	This report looks into how snow removal has moved from the mode of snow removal to that of prediction and prevention. There have been new developments in chemicals, equipment, and techniques, many of which are described.
247	Bundesministerium fur Wirtschafliche Angelegenheiten	New snow plow configurations that are hydraulically controlled for quick connect and disconnect features.
317	Stadden-K	This article discusses nationwide mobile messaging systems for trucking fleets. Mobile communications in trucks make drivers' lives easier, impress customers, and improve management efficiency.
342	Bristol Company	A press release for the SYN/CON FPS-1000-M Road Sensor that is truck mounted and displays the temperature of the liquid on the road and the freezing temperature of materials.
343	Traffic Technology International	An international review of road condition sensors, visibility sensors, thermal mapping, route optimization, pavement sensors, and variable message signs.
344	Traffic Technology International, Autumn 95	Pre-salting is effective where there is access to highly accurate road weather forecasts.
354	MNDOT	This paper discusses how reductions in roadway departure accidents

		can be achieved by integrating emerging sensing and control technologies into guidance control systems.
361	Finnish National Road Administration	This paper describes the principles of winter maintenance quality and road standards that the FinnRA has established.
363	Commonwealth of Pennsylvania, DOT	Field test performed in Pennsylvania of Tyler Ice's zero velocity spreader. Material savings and increased performance were documented.

There is a lot of activity in the area of snow and ice removal research and testing. The references in Table 2-1 are a representative sample of the types of activities and the institutions who are working in this arena. Although the references were not used specifically in this phase of the project, they were of considerable value in focusing on technologies that could be utilized on the first prototype vehicles developed. The reason that they were not used specifically in Phase I is because the objective of this phase was to determine the vehicle requirements. In later phases of the project, these and other references will be beneficial in establishing test procedures and in documenting the results as related to highway maintenance responsibilities.

CHAPTER THREE: IDENTIFY LIST OF DESIRED VEHICLE CAPABILITIES

INTRODUCTION

It was critical to the success of this research project to develop and prioritize a list of desired capabilities for the concept highway maintenance vehicle. Due to the newness of some of the technologies available, the process of identifying and prioritizing these capabilities was similar to the development process used by private industry to develop a new product. This project focused on the needs of the end users and then combined various techniques used in private industry to identify and prioritize a list of desired capabilities for the prototype vehicles. The general process followed was Quality Function Deployment (QFD), as described by L.P. Sullivan in an article in the June 1986 issue of *Quality Progress*. Part of QFD requires assembling the consumer's desires "in the voice of the consumer." During this research project, this was accomplished using affinity diagrams and relations diagrams, as described by QIP, Inc. and PQ Systems, Inc., in *Total Quality Transformation: Improvement Tools,* in 1994. The consumers in this case were the people who work with maintenance vehicles as a part of their everyday jobs: maintenance equipment operators, mechanics, and maintenance supervisors. The resulting list of desired vehicle capabilities was then used to identify technologies and equipment to be used on the prototype vehicles for Phase II.

QUALITY FUNCTION DEPLOYMENT

QFD is a process widely used in Japan for developing new products. QFD uses early consumer input to minimize the engineering and product manufacturing changes required after final production and distribution begins. The customers' needs are defined "in the words of the customer" and then incorporated into the initial design and modification phases, prior to manufacturing the final product. A prototype is then developed, tested, and evaluated by engineers as well as potential end users. These evaluations are used to make changes prior to final production. Through the use of this process, very few changes are needed after the product is released to the consumers. This research project identified the desired capabilities of a maintenance vehicle "in the words of the users" through focus groups and affinity diagrams and then evaluated the capabilities for possible inclusion on the prototype winter maintenance vehicles for Phase II.

FOCUS GROUPS

Background

Each of the consortium states participated in focus group activities which identified consumers' capability expectations of the concept highway maintenance vehicle. The focus groups were conducted according to procedures described in *Total Quality Transformation: Improvement Tools*. Its process for preparing affinity diagrams was followed in brainstorming and organizing initial ideas, and its process for relations diagrams was followed to identify relationships among those ideas.

Affinity Diagram

Affinity diagrams, originally created by Kawakita Jiro, are described in *Total Quality Transformation: Improvement Tools* as "the organized output from a team brainstorming session or a focus group session." An affinity diagram is made up of individual brainstormed ideas which are grouped together under common headings. The test lists three cases when affinity diagrams are useful:

The problem (or issue) is complex and hard to understand.

The problem is uncertain, disorganized, or overwhelming.

The problem requires the involvement and support of a group.

The process followed to create an affinity diagram includes choosing a leader, brainstorming ideas, organizing the ideas, drawing the diagram, and then discussing it. A complete listing and description of the seven steps, as described in *Total Quality Transformation: Improvement Tools*, can be found in Appendix B.

Each of the five focus groups for the concept highway maintenance vehicle used the seven step process with only slight modifications. In addition to stating the problem in the form of a question ("What should the capabilities of the future maintenance vehicle be?"), additional questions were used to stimulate the flow of ideas such as "What are the concerns you have with this project?" and "What are the problems you are facing today that seem impossible to solve?" Also, self-adhesive notes were used in place of index cards. This allowed the ideas to be displayed, and eventually arranged, on the walls for better visibility. As ideas were being grouped, if one idea fit into more than one group, a duplicate was made so the idea could be placed in both groups. Group names were written on different colored notes to distinguish them from ideas. The groups of ideas were attached directly to a poster-sized sheet of paper to complete the affinity diagram. A graphical version of the five affinity diagrams from the focus groups can be found in Appendix B.

After constructing the affinity diagrams, they were studied to gain a better understanding of the problem. This was useful in helping participants identify major areas of concern relative to snow and ice removal operations and the vehicle which performs those operations. The process of brainstorming, grouping the ideas, and naming the groups allowed the participants to identify the components involved with creating a better highway maintenance vehicle. The next step was to investigate the relationships among the groupings.

Relations Diagram

After each focus group finished their affinity diagram, it created a relations diagram, another tool described in *Total Quality Transformation: Improvement Tools.* A relations diagram charts the cause and effect relationships among the various groups which were created in the affinity diagram. Creating the diagram allows the participants to identify the root causes of the problem, which leads to the more efficient solutions.

Each group followinged the six step process found in *Total Quality Transformation: Improvement Tools*:

Clearly define the issue or problem

"Issues pertaining to the concept highway maintenance vehicle" was used as the problem statement.

Construct the diagram layout

The problem statement was written in the center of a poster-sized piece of paper and circled. Then each of the group names from the affinity diagram were written in boxes around the problem statement.

Analyze the relationships

The relationship of each group name was analyzed with respect to each of the other group names. If a cause-effect relationship did exist, a line was drawn between the two group names in question and the group determined which group was the cause and which was the effect. An arrow was drawn from the cause group to the effect group. Any two groups could have either one or no arrows joining them. This was continued until every group was compared to every other group. This was done in an orderly fashion to ensure that all possible combinations were analyzed.

Count the arrows

Once the analysis was complete, the number of arrows going into and out of each group name was counted. The numbers were labeled "in" and "out" and written above each group name on the chart. It was also possible to use a color coded system to differentiate between the number in and the number out.

Identify the root causes and effects

After counting the number of arrows into and out of each group, the root causes and root effects appeared as the groups with the highest number of "ins" and "outs." The root causes had the greatest number of arrows going out, and the root effects were the groups with the greatest number of arrows going in. The root causes and root effects were then identified on the diagram by a double box or by highlighting the boxes with shading. Typically, one root cause and one root effect were identified per five to seven groups on the diagram. In the case where there were many groups — 15 or more — the team chose to identify two or three root causes and root effects. In the cases where there were fewer groups, only one or two root causes and effects were identified. Each of the focus groups was allowed to determine the specifics about how they would identify the root causes and effects.

Study the final diagram

The final step was for each focus group to study its completed relations diagram. They discussed the diagram and the root causes and root effects. Participants frequently said that they saw the problem in a new way as a result of concentrating on the causes of the problem, rather than its symptoms.

The results of the relations diagram were then used within each state organization to focus on the main cause and develop a strategy for addressing that concern. In this research project, the results of the relations diagrams were used to determine and prioritize the technical capabilities that were of highest importance to the individual focus groups.

The figures 3-1 to 3-5 are the results of the relations diagram exercise generated by each of the focus groups. Note the similarity in the major issues identified by each focus groups.

Root Cause: Future Snow Removal
Root Effects: Public Acceptance and Procurement Concerns

FIGURE 3-1 Relations diagram from Cedar Rapids, Iowa focus group, September 7-8, 1995.

Root Cause: Safe Operations   Root Effect: Concerns

FIGURE 3-2 Relations diagram from Cedar Rapids, Iowa focus group, October 3-4, 1995.

Root Cause: Safety   Root Effect: Equipment

FIGURE 3-3 Relations diagram from Troy, Michigan focus group, October 19-20, 1995.

Root Cause: Advanced Plowing Technology
Root Effect: Truck Equipment

FIGURE 3-4 Relations diagram from Roseville, Minnesota focus group, October 9-10, 1995.

Root Cause: Emergency Mobilization Root Effect: Concerns

FIGURE 3-5 Relations diagram from St. Cloud, Minnesota focus group, October 11-12, 1995.

DOCUMENTATION OF RESULTS

Upon completion of the focus group activities, the products of the individual groups were combined into one database for analysis. Initially there were approximately 600 ideas recorded by the five focus groups. A three step process was utilized to incorporate all of the input ideas from each focus group into a single set of 183 desired capabilities. The three steps are represented graphically in Figure 3-6:

Step 1

All of the ideas were taken directly from the focus group activities and entered into one database for analysis. It was important to capture the "voice of the customer," the highway maintenance worker, in this step. The desired capabilities from each of the focus groups were categorized under the headings developed during the focus group activities.

FIGURE 3-6 Three step process flowchart.

Step 2

The ideas were then organized and placed into six major categories for analysis. These major categories were developed with the purpose of breaking the activities of the maintenance vehicle into logical sequences. The six major categories were:

- ·Administration
- ·At Rest
- ·Infrastructure
- ·Post Operations
- ·Pre Operations

·Roadway Systems Operations

The group headings assigned by the focus groups were removed at this time. They were kept, however, to show what the individual groups identified as their most significant concerns. The original ideas were used later in the process to assess the concept vehicle.

Step 3

The ideas under each major category were again regrouped to form minor categories. Inside each minor category, similar ideas were combined to eliminate repetition. These ideas then served as the desired capabilities for the concept maintenance vehicle that were evaluated and analyzed in the rest of the project.

A listing of the final 183 desired capabilities of the concept highway maintenance vehicle can be found in Appendix B.

CHAPTER FOUR: RESEARCH FUNDING SOURCES

INTRODUCTION

This report covers Phase I of a three phase research project with funding initially only secured for Phase I. In order to continue with the next two phases of the project, funding must be secured. Some of the resources required to develop the prototype vehicles will come directly from the vendors themselves. That funding will cover the equipment to be provided for the first round of prototype vehicles. However, some funding is still required for the technical support and for the ongoing expenses of the project.

PHASE II AND PHASE III FUNDING MECHANISMS

CTRE, the principal investigator, explored the funding programs that might be available to continue the research project for Phase II and Phase III. They focused on technology transfer and defense conversion technology along with other development and research programs. In addition, the principal investigator researched other funding sources during the technical literature search and contacted government agencies that are knowledgeable of funding sources. Private sector partner candidates were interviewed for possible financial participation in the concept vehicle project. This was accomplished at each of the meetings in Detroit, Michigan and in St. Paul, Minnesota. The steering committee was encouraged to keep current with resources that could provide avenues for funding and to relay them to the principal investigator for documentation and evaluation.

RECOMMENDATIONS TO THE STEERING COMMITTEE

The principal investigator recommended to the steering committee that a pooled fund study was appropriate for funding of Phase II activities and also appeared to be appropriate for Phase III. The recommendation for a pooled fund study included recommending Iowa as the lead state DOT. As the lead state, Iowa shall make the request to the Federal Highway Administration for Special Projects and Research (SP&R) funds, shall enter into a contract with the principal investigator, and shall administer the research contract.

MAKE OR ASSIST WITH FUNDING REQUESTS

The principal investigator prepared the scope of work and the budget requirements for Phase II of the research project. This request was for the time required to complete Phase II. The principal investigator provided the data to the Iowa DOT (lead state) for submittal to the Federal Highway Administration division office. The principal investigator delivered the data to the Iowa DOT on October 3, 1996, and the request was then forwarded to the division office of the Federal Highway Administration on October 9, 1996. Copies of the letter from the principal investigator to the Iowa DOT and the forwarding letter from the Iowa DOT to the FHWA can be found in Appendix C.

CHAPTER FIVE: SELECT PRIVATE SECTOR PARTNERS

INTRODUCTION

In order to facilitate private sector participation, steering committee members agreed to host a workshop. The vision of the steering committee was to use this workshop as a basis for reviewing the project with private industry and soliciting its interest. Ultimately, interested members of private industry would be invited to enter into a partnership with the state DOTs. The workshop was the first step in selecting private sector partners. The selected partners were then asked to join the consortium and assist with the effort to create prototype vehicles which address as many desired capabilities as possible. The partners also provided resources to the project in the form of technology, equipment, vehicle assembly, and staff time.

SOLICITATION OF INTEREST

The participating states were requested to submit the names of private sector contacts which may have an interest in the concept highway maintenance vehicle project. State maintenance engineers from the snowbelt states were also included as possible attendees. The ITS America membership directory and CTRE contacts were used to solicit additional names of technology personnel. All contacts were compiled into a database, and workshop invitations were sent to over 200 potential attendees.

ADVANCED TECHNOLOGY APPLICATIONS WORKSHOP

Forty-nine people attended the Advanced Technology Applications for Highway Maintenance Vehicles Workshop held in Detroit, Michigan on April 23, 1996. An agenda from the workshop, a list of attendees, and a workshop summary can be found in Appendix D.

The workshop began with an overview of the progress to date, and a presentation of the results of the focus group activities. The workshop attendees then participated in one of three discussion sessions: vehicle manufacturers, communication/technology providers, or equipment vendors. The sessions were designed to define the technologies available for prototype evaluation in the participating states. The minutes from each of the three breakout sessions can be found in Appendix D.

The workshop provided the snowbelt DOT maintenance engineers and research engineers an opportunity to meet with equipment providers and discuss the potential for advanced technologies on highway maintenance vehicles. The participation sessions allowed the private sector attendees to provide direction to the consortium DOTs. Furthermore, the technology and equipment providers were enticed by the opportunity to hear what the DOT equipment operators defined as improved vehicle and equipment capabilities.

IDENTIFY PRIVATE PARTNER PARTICIPATION

At the conclusion of the workshop, the representatives from private organizations were given "partnership interest" forms. These forms asked private companies to indicate the level of participation that they could supply in terms of time, equipment, technology, and funding. A copy of this form can be found in Appendix D.

ASSIGN PRIVATE SECTOR PARTNERS

Once the partnership interest forms were returned, the responding private sector partners were assigned to one of the state teams. The assignments were made according to the technology and equipment they could provide, their geographical proximity, and their familiarity with each state's DOT. Figure 5-1 shows the 10 initial private sector partners grouped into teams following receipt of the partnership interest forms after the Detroit workshop.

Additional companies expressed interest in the project after the initial private sector assignments were made. These companies were asked to complete partnership interest forms, were updated on the progress of the project, and were invited to attend the next project workshop.

FIGURE 5-1 Initial prototype teams for winter 1996n1997.

CONCLUSION

This portion of the project assured the valuable backing of private sector partners. By soliciting a large number of companies from various industries involved in snow and ice control, the concept vehicle project obtained the backing and support of private industry. The next step in the process was to determine which technologies could be utilized on the prototype vehicles.

CHAPTER SIX: DEVELOP DESCRIPTION OF SYSTEMS

At this point, the focus groups had provided a list of ideal features for a concept maintenance vehicle, and private companies had been introduced to the project and given the opportunity to indicate their level of interest in joining the project. The goal for Phase II of the project was to develop three prototype vehicles, one in each of the three participating states. This was the crucial point where the initial interest expressed by the private and public participants needed to be focused toward developing vehicle specifications and making commitments for providing equipment for the three prototype vehicles. A clear and specific understanding was needed of what the private companies would be able to provide for the three prototype maintenance vehicles for the winter of 1996n1997.

ST. PAUL WORKSHOP

In order to establish exactly what the private sector partners would provide for the prototype vehicles, a workshop was held for the three consortium DOTs and all interested private sector partners. On July 23n24, 1996, fourteen private companies and representatives from all three DOTs attended a two-day workshop held in St. Paul, Minnesota. The agenda was planned to provide a break between establishing the capabilities of the prototype vehicles and determining the budget. A copy of the agenda and a list of attendees is included in Appendix E.

The workshop had four goals:

- Determine the team members and their roles
- Develop the technical capabilities of the prototype vehicles
- Establish the prototype vehicles' development schedules
- Develop the prototype vehicle budgets

Technical Capabilities

The workshop convened by allowing each of the private sector partners in attendance to give a 10 minute presentation of the technology and equipment that their organization had to offer. Some of the private sector partners had already been assigned, according to their location and past association with the consortium DOTs, to one of the state teams and others were new to the project. A summary of these presentations can be found in the St. Paul workshop meeting minutes in Appendix E.

Next, the technology available from each state team's initially assigned private partners was compared for uniformity among the three state teams. Any deficiencies in comparable capabilities among states were corrected by allowing other vendors to provide the lacking technologies. Unique technologies, supplied by only one vendor, were considered for use on all three state trucks. One example of this is the Ethanol Injection Power Boost System developed by Fosseen Manufacturing and Development, Ltd. This is a new and unique product available only from Fosseen. They agreed to donate three systems, one to each of the three prototype vehicles.

After all three state prototype vehicle teams were organized with providers of similar equipment and technologies, the workshop adjourned for the day. However, each of the private sector partners and the DOTs were asked to determine cost estimates for the equipment that would be provided for the prototype vehicles and to have those estimates ready for the next morning. The cost estimates were to include a dollar value for the equipment that their organization would donate to the project and a dollar value for the amount that the project funding would cover. The agenda of the meeting was set specifically to give the project participants time at the end of the day to determine their organization's cost estimates.

Budget and Schedule

The second day of the workshop began with a discussion of the possibility of using equipment integrators. Although it was decided not to specifically designate an integrator for the prototype vehicles, it was decided that the Minnesota prototype vehicle would be assembled at Tyler Ice in Benson, Minnesota, and the Iowa and Michigan prototypes would be assembled at Monroe Truck Equipment in Monroe, Wisconsin. It was also decided at this point that the prototype phase of the project should be continued for a total of two winters. Instead of trying to implement a fleet of vehicles for the winter of 1997n1998, the prototypes would be further developed and tested, and the fleet could be implemented in the winter of 1998n1999. This was done to allow an extra year to integrate more of the desired capabilities into the prototype vehicles. The first prototype vehicles were only able to integrate technologies which were already available from industry. With the additional year, it will be possible to develop additional equipment to satisfy more of the ideal capabilities identified by the focus groups.

After the discussion of the prototype assembly locations, the budget estimates, which were requested the previous day, were provided by representatives from each organization and recorded. Two numbers were requested: the value of the technology and time the vendor was willing to contribute, and the amount that the project would need to fund. Following the budget discussion, a preliminary schedule for installation of the components was discussed. Dates were set for the availability of each component, and the target date for completion of the three prototype vehicles was set for November 1, 1996. The initial budgets and schedules for the three prototype vehicles can be seen in Table 6-1.

TABLE 6-1 Initial Prototype Providers, Budget, and Schedule

Item	Technology Provider	Provider Contribution	Project Contribution	Schedule
IOWA TEAM (Ames)				
50,000 GVW Truck, Plows, Box	Iowa DOT			10/01/96
Trip Master/AVL System	Rockwell			—
Two-way Communication	Rockwell			—
Material Application	Bristol	$12,500	$12,500	09/01/96
Incremental Power	Fosseen	1,500	Fuel	09/15/96
Friction Meter	Norsemeter	45,000	20,000	01/01/97
Surface Temp. Sensor	SXI	500		10/01/96
Vehicle Weight Sensor	SXI	1,500		10/01/96
	Sub Total:	$61,000	$32,500	

MICHIGAN TEAM (Cadillac)				
50,000 GVW Truck, Plows, Box	Michigan DOT			10/01/96
Fleet Advisor	Eaton	$25,000		09/01/96
AVL System/ Communications	Eaton			09/01/96
Material Application	Monroe	8,000		09/01/96
Incremental Power	Fosseen	1,500	Fuel	09/15/96
Friction Meter	Norsemeter	45,000	$20,000	01/01/97
Surface Temp. Sensor	SXI	500		10/01/96
Vehicle Weight Sensor	SXI	1,500		10/01/96
	Sub Total:	$81,500	$20,000	
MINNESOTA TEAM (St. Cloud)				
50,000 GVW Truck, Plows, Box	Minn. DOT			08/15/96
Data Logger	SXI	$25,000		10/01/96
AVL System	Tyler Ice	42,000		09/15/96
Two-way Communication	SXI			10/01/96
Material Application	Tyler Ice			09/15/96
Incremental Power	Fosseen	1,500	Fuel	09/15/96
Friction Meter	Norsemeter	65,000		01/01/97
Surface Temp. Sensor	SXI			10/01/96
Vehicle Weight Sensor	SXI			10/01/96
Air Foil	Monroe			09/01/96
	Sub Total:	$133,500	$0	
	Project Totals:	$276,000	$52,500	

IDENTIFY TECHNOLOGY TRANSFER OPTIONS

The research team has actively watched other industries and evaluated the technology applications that have a potential to work on the concept vehicle. The agricultural industry has been distributing chemicals in sensitive environmental settings and the technology utilized has merit for consideration. The transit industry has been a testing the use of engine power boosters for short term power requirements. Commercial vehicles have benefited from the use of Global Positionsing Systems (GPS) and Automatic Vehicle Location (AVL) in conducting management functions as well as providing improved service to their customers. In Europe, there have been technology developments and applications that have not yet been advanced in the United States. These are examples of advanced technologies, identified by the research team, which are being used successfully in other industries. The research team will use the concpet maintenance vehicle project to transfer several of these technologies into the winter snow and ice removal field.

Several of the technologies being implemented on the prototype vehicles were originally used for other applications, such as transit, with similar performance requirements. Those ideas were adapted by various companies and are being applied on the prototype vehicles. The other fields include transit and agriculture. The Ethanol Injection Power Boost System was originally developed by Fosseen Manufacturing for use on city transit buses. Likewise, some of the liquid and solid material spreaders were originally developed for agricultural use by Tyler Industries. The "PlowMaster™" system of GPS and data recording, being provided by

Rockwell International, will be adapted from their transit and agricultural product line.

ACCOMPLISHMENTS

In the time following the St. Paul Workshop, several changes and additions were made to the organization of the three prototype vehicle teams and the technologies and equipment being added. The final plans for the three prototype vehicles will accomplish the following desired capabilities from the list created in the focus groups and described in Chapter Three:

- Recording and downloading of vehicle activities
- Sense roadway friction conditions
- Sense roadway surface temperature
- Improve fuel economy
- Carry multiple materials
- Adequate horsepower for vehicle
- Distribute multiple types of materials
- Removable salt/salt brine dispensing system
- Backing sensor/monitors

REFINED VEHICLE DESCRIPTION

The following paragraphs describe the three prototype vehicles as planned for the winter of 1996n1997. Also, a final listing of the equipment, providers, and costs can be found in Table 6-2.

Truck

The base trucks used for each state's prototype winter highway maintenance vehicle will be provided by that state's DOT. They will be 50,000 pound gross vehicle weight (GVW) trucks with tandem rear axles. Iowa and Minnesota's trucks will have dump bodies, while Michigan's truck will have a chassis mounted liquid tank and granular bin.

Plows

Each prototype will be equipped with three plows: a front plow, a wing plow, and an underbody plow. The front plow will be capable of rotating side to side, with down pressure applied solely by gravity. The wing plows will be retractable and mounted on the passsenger side of the vehicles and will have down pressure applied solely by gravity. The wing plow on the Iowa prototype will be capable of raising and lowering for bench plowing. The underbody plows, or ice blades, will allow the operator to apply down pressure hydraulically, rotate its angle side to side, as well as adjust its vertical angle.

GPS Receiver

The GPS receiver will be provided by Rockwell International and will be mounted above the cab of the vehicle. This is technology that Rockwell has adapted from their transit, agricultural, and commercial vehicle product lines. The GPS will determine the location of the vehicle every five seconds, and that data will be recorded by the PlowMaster™.

PlowMaster™

The PlowMaster™ will be provided by Rockwell International, and is being adapted from their transit, agricultural, and commercial vehicle technologies. It will store the data being collected by the various sensors on the vehicle, as well as provide a display panel for the operator. The data will be saved in the PlowMaster™ on a standard PCMCIA (Personal Computer Memeory Card International Association) card, which can be removed and plugged into a personal computer for downloadinging the data.

Material Applicators

All three prototypes will be equipped with both liquid and granular dispensers, and each will be capable of pre-wetting, de-icing, and anti-icing functions. However, each of the three prototype vehicles will have their material application system provided by a different private sector provider; therefore, each system will be slightly unique.

Iowa

The Iowa prototype will use a slide-in, combination 5.2 cubic yard Monroe Brute MSV heavy duty V-box spreader and 900 gallon liquid tank which will ride inside of the dump body of the vehicle. The granular spreader will use a spinner spreader mounted on the rear of the vehicle. The anti-icing and pre-wetting systems will both have automatic granular reduction upon commencement of the liquid operation, and will be controlled in the cab by a SYN/CON on-board controller system from Bristol Company. The controller will be capable of storing up to eight combinations of varying liquid material, granular material, and gate openings, for pre-wetting and anti-icing applications. Within each of the eight combinations there can be up to six settings for granular and liquid outputs. There are six separate settings on anti-icing and six on pre-wetting to allow for varying level of service requirements and storm conditions.

Michigan

The Michigan prototype will use a 6.5 cubic yard Monroe Duz Mor, chassis mounted, self unloading V-box with a spinner spreader located in the center of the rear of the vehicle. Liquid materials will be held in a permanent 900 gallon tank mounted in front of the Duz Mor body. The pre-wetting and anti-icing system will use a Raven controller.

Minnesota

The Minnesota prototype will use a removable Tyler V-Blend salt/sand V-box which will ride inside the dump body of the vehicle. This divided spreader box will allow the operator to distribute any desired ratio of two granular materials. The truck will have a 900 gallon liquid tank. The anti-icing, de-icing, and pre-wetting functions will be controlled in the cab of the vehicle using a Tyler Quantum Control.

Engine Power Booster

Each prototype will have a Fosseen Manufacturing Hydrous-Ethanol Injection System. It automatically injects Hydrofire Fluid, a water-alcohol-lubricant blend fuel, whenever the engine needs more power. The Hydrofire Fuel improves engine combustion and reduces oxides of nitrogen emissions. The main system will be under the hood, attached to the fuel system, with an eight gallon fuel tank mounted behind the cab. It also includes a control box mounted in the cab which allows the driver to adjust the sensitivity of when the system is engaged. Fosseen has successfully installed this system on transit buses in the past.

Friction Meter

Each vehicle will have a Norsemeter Roar Friction Meter installed to measure and record the friction of the road surface. The meter consists of an actual tire which rides on the road and oscillates between traction and slippage and measures the friction curve of the road. This system will be operated from a display screen located in the cab. Data from the friction meter will be recorded by the PlowMaster™.

Pavement/Air Temperature Sensor

Each of the prototypes will have a Sprague RoadWatch™ Warning System to monitor the temperature of the pavement surface and the air. The infrared sensors will be mounted on the driver's side-view mirror, and a two-inch digital gauge will be mounted in the cab. The pavement and air temperature readings will be recorded by the PlowMaster™ system.

Reverse Sensor

The prototypes will be equipped with Global Sensor Systems, Inc.'s Search-Eye Sensor System. The system detects the presence of objects behind the vehicle and automatically applies the brakes when the vehicle is in reverse. The system consists of three sensors mounted on the rear of the vehicle, which are wired into the braking system. The Search-Eye Sensor System has been used in the past on school buses, waste managment trucks, and commercial delivery vehicles.

TABLE 6-2 Final Prototype Equipment, Providers, Budget, and Schedule

Item	Technology Provider	Provider Contribution	Schedule
IOWA			
50,000 GVW Vehicle, Front Plow, Underbody Plow, Wing Plow	Iowa DOT	$85,000	10/01/96
PlowMaster (GPS, Data Recording)	Rockwell International	70,000	10/01/96
Material Applicator	Bristol Company	12,500	09/15/96
Incremental Power	Fosseen	1,500	09/15/96
Friction Meter	Norsemeter	45,000	01/01/97
Surface/Air Temp. Sensor	Sprague	500	10/01/96
Vehicle Weight Sensor	Rockwell International	1,500	10/01/96
	State Total:	$216,000	
MICHIGAN			
50,000 GVW Vehicle, Front Plow, Underbody Plow, Wing Plow	Michigan DOT	$85,000	10/01/96
PlowMaster (GPS, Data Recording)	Rockwell International	65,000	10/01/96
Material Applicator	Monroe Truck Equip.	8,000	09/15/96
Incremental Power	Fosseen	1,500	09/15/96
Friction Meter	Norsemeter	45,000	01/01/97
Surface/Air Temp. Sensor	Sprague	500	10/01/96
Vehicle Weight Sensor	Rockwell International	1,500	10/01/96
	State Total:	$206,500	
MINNESOTA			
50,000 GVW Ford, V-Box, Front Plow, Underbody Plow, Wing Plow	Minnesota DOT	$85,000	08/15/96
PlowMaster (GPS, Data Recording)	Rockwell International	65,000	10/01/96
Material Applicator	Tyler Ice	7,500	09/15/96
Incremental Power	Fosseen	1,500	09/15/96
Friction Meter	Norsemeter	65,000	01/01/97
Surface/Air Temp. Sensor	Sprague	500	10/01/96
Vehicle Weight Sensor	Rockwell International	1,500	10/01/96
	State Total:	$226,000	
	Project Total:	$648,500	

CHAPTER SEVEN: PREDICT FEASIBILITY OF VEHICLE

INTRODUCTION

In cooperation with the private sector partners, the state partners collaborated to define the systems and subsystems and the budget for initial prototypes to be developed for each of the participating states. The discussion and consensus building occurred during the joint meeting held in St. Paul, Minnesota, on July 23n24, 1996. During that meeting and subsequent conference calls, all of the participating partners assured themselves and each other that the concept maintenance vehicle was worthy of the investments to continue development of prototype vehicles.

The commitment and excitement associated with this project continued to build and develop as it was discussed in several national level meetings during the fall of 1996 and at the international Transportation Research Board (TRB) meeting held in Washington, D.C. in January 1997. The consensus was to utilize existing technology products, readily available from the private sector partners, for the first vehicles that will be evaluated during the winter of 1996n1997, and to research other technologies for the prototypes that will be evaluated during the winter of 1997n1998. The initial technologies are generally management tools, and there is a commitment from the entire team to provide technology advancements that help the equipment operator, the mechanic, and the garage supervisors with their everyday assignments.

IDENTIFY PRODUCTION ELEMENTS AND COSTS

The consortium determined what the production elements would be and developed cost figures for the chosen elements. At that stage of the project, the consortium knew the equipment that would be on the vehicles, the technology that would be implemented, the funding available, and the extent of participation from the private sector partners. The desired capabilities were developed using focus groups in the participating states and by inviting private sector technology providers to the Detroit meeting, as described in Chapter Three and Chapter Five. The technology selected for implementation in the first prototype vehicle was determined at the St. Paul meeting as well as the decision to develop a second set of prototype vehicles for the winter of 1997n1998. The cost of the vehicle had been established in the St. Paul meeting, and a funding request was developed as discussed in Chapter Four. Using this information, the steering committee developed the desired production elements and the associated costs.

COMPARE TO TECHNOLOGY AVAILABLE

During the summer of 1997 (between the first and second winters of prototype vehicles), additional technologies will be investigated for their possibilities of accomplishing more of the original 183 desired capabilities (explained in Chapter Three and found in Appendix B). An area of particular interest will be on technologies which assist the vehicle operators. At several stages, the list of 183 desired capabilities will be compared to the technology available or under development. If desirable technology features are not available or are in the development stages during the assembly of the first prototype vehicles, provisions will be made to incorporate them into the next winter's vehicles. The second winter's vehicles will focus more intently on the needs of the vehicle operators and on safety elements in addition to the management-related technologies.

ESTABLISH PRODUCTION TIMELINES

One objective of the St. Paul meeting was to establish a reasonable timeline for the assembly of the three prototype vehicles. Consideration was given to the existing production schedules and commitments of the manufacturers. It was important to remember that the private sector partners would be contributing resources to the project and that they would also have many other projects that would compete for their time. The time frame for the planning and assembly of the vehicles would occur during the busiest time of the year for many of the technology providers and needed to be taken into account when setting time lines and completion dates. The private sector partners provided direction to the rest of the steering committee on product availability. They also provided valuable insight into industry practices and the commitments that could be formalized. The first winter prototype vehicles were scheduled to have the new technology and equipment added and to be ready for use by November 1996. The state DOTs were to make the vehicles available in August to the equipment installation locations at Monroe Trucking in Monroe, Wisconsin, and at Tyler Ice in Benson, Minnesota.

SPECIFY PRODUCTION TEAM AND LOCATION

The production elements, associated costs, desired technology, and production timelines had been defined at this point (Chapter Six). The consortium then designated two production teams for assembly of the vehicles. Iowa and Michigan were scheduled to have their plows and spreaders installed on their prototypes at Monroe Trucking in Monroe, Wisconsin. Minnesota planned to have their assembly done at Tyler Ice in Benson, Minnesota, where they had cooperated on previous research projects. The steering committee conducted project meetings at each location and toured each of the facilities. Both Monroe Truck and Tyler Ice are fully equipped to accomplish the equipment assembly and will be able to overcome the unpredictability of installing prototype equipment. The committee was impressed with each of the facilities and has confidence in their ability to assemble the vehicles.

TECHNICAL REPORT

A technical report was not written to document the feasibility of developing a concept vehicle. As the steering committee worked together during the entire process and private sector partners were added to the consortium states, there was continuous reassurance that the technology elements could be provided and had been successfully used in other applications. The time to assemble the vehicles for the winter of 1996n1997 was very short. Considering the coordination and assembly time required, the research team committed their time to the assembly task. The technologies to be provided for the first prototype vehicles were already proven in other applications and were logical technology applications to be used in the snow and ice removal operations. As technology applications are considered for the winter 1997n1998 prototype vehicles, there may be more emphasis placed on assisting the needs of the operator. It will be important that the feasibility of the vehicle and additional technology applications is documented and that the relationship with the state DOTs' business plans are established before moving into the Phase III of the research project: providing a fleet evaluation in each of the participating states.

CHAPTER EIGHT: COST EFFECTIVE ANALYSIS

INTRODUCTION

A cost effective analysis was not completed at this time. As stated in the previous chapter, the assembly time was very short for the winter of 1996n1997, and the efforts of the research team were focused on assembling the vehicle. The cost effectiveness of the technologies provided was discussed internally with the research team and the steering committee throughout the Phase I process and the development of the prototypes. Also, the enthusiasm and generosity of the private sector partners at the Detroit and St. Paul workshops served as one indication of the economic feasibility of proceeding.

Furthermore, one benchmark for a cost analysis of the project is the number of new trucks purchased each year in the three consortium states (Table 8-1). Although the figures in Table 8-1 are only from the three consortium state DOTs, they demonstrate the potential market for new and innovative maintenance vehicle equipment.

TABLE 8-1
Estimated Annual Maintenance Vehicle Purchases for Three Consortioum States

State DOT	Tandem Axle Trucks	Single Axle Trucks	Total Trucks
Iowa	60	20	80
Michigan	2	10	12
Minnesota	15	15	30
Three state total	77	45	122

PRIVATE SECTOR PARTNER INPUT

The technologies to be used on the first prototype vehicles are off-the-shelf technologies currently utilized in other industries and applications. The private sector partners were very supportive and enthusiastic regarding the application of their existing equipment and technology for snow and ice removal operations. This was especially evident when each of the private sector partners not only evaluated its decision to continue involvement with the research project, but contributed equipment and technology with little cost to the project. This support from the private sector partners was more than enough to convince the research team to proceed with developing prototype vehicles.

PROTOTYPE VEHICLE INPUT

As the prototype vehicles are developed and move into evaluation in real world maintenance functions, their increased effectiveness will be documented. The first winter of prototype vehicles will show how the technologies can contribute to maintenance operations and to management functions by reducing some of the operator’s tasks, improving safety for the operators, and collecting data for management systems. The prototype vehicles will demonstrate the capabilities and potentials of the advanced technologies and allow cost effectiveness evaluations to be performed on the technologies.

DEPARTMENT OF TRANSPORTATION BUSINESS PLAN

One of the primary goals for the concept vehicle is to efficiently supply useful information to each state's business plan. The consortium state DOTs will consider the prototype vehicles' ability to assist their business plans when deciding to continue from Phase II (prototype vehicles) to Phase III (fleet evaluation). The work scope for Phase II of this research project includes tasks that will look at the business plans of the state DOTs and show the potential for integration into these plans with the data collected by the prototype vehicles. If a business plan does not include a formal maintenance management system, one will be presented by the research team that can be used for alternative evaluations. A separate investigation will be conducted to look at this potential.

VEHICLE USER INPUT

The input from the vehicle user will be critical to the evaluations in Phase II. If the vehicle does not help the users conduct their daily work assignments better or provide for increased safety, then the value of the advanced technologies, as applied to the snow and ice operations, will be questioned. As Phase I of the research project is completed, the entire consortium is convinced that the added value will be apparent as prototype vehicles are evaluated first during the winter of 1996n1997, and then again in 1997n1998, when additional technologies are tested. The Phase II work plan requires a process to solicit input from the vehicle users in a manner that will be compatible with each user's work time and assigned duties.

CHAPTER NINE: CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

Phase I of the research project included determining the desired capabilities of the prototype vehicle, selecting private sector partners to assist the consortium states, and developing a budget and time line for providing a prototype maintenance vehicle for each of the consortium state DOTs.

PHASE I CONCLUSIONS

Phase I of the research project met the goals and objectives that were established and was successful in bringing this part of the three phase research project to completion. The desired vehicle capabilities were established and the "voice of the user" was recorded using nominal group techniques.

The private sector partners were selected during the two meetings held in Detroit, Michigan and in St. Paul Minnesota. It was during these two meetings that the desired maintenance vehicle capabilities were determined and the technologies for evaluation were committed to the project. It was also agreed by the steering committee that two winters of prototype vehicle evaluation would be needed, first during 1996n1997, and then again during 1997n1998. The second winter of prototype vehicles will include the results of the evaluations conducted for the first vehicles plus additional technologies as they are identified and or developed in further research efforts.

The desired capabilities for the vehicle were defined, and it was decided to use off-the-shelf technology for the first prototypes. This is technology that has been utilized in other industries and applications. These technologies should accomplish nine important items from the list of desired vehicle capabilities described in Chapter Three and found in Appendix B:

- Record and download vehicle activities
- Sense roadway friction conditions
- Sense roadway surface temperature
- Improve fuel economy
- Carry multiple materials
- Adequate horsepower for vehicle
- Distribute multiple types of materials
- Removable salt/salt brine dispensing system
- Backing sensor/monitors

The budget and schedule were established and involved input from all steering committee members. The critical input was provided by the private sector partners, who made the commitment of technology elements and resources to complete the assembly of the vehicles.

The time frame for completing the first prototype vehicles for the winter of 1996n1997 was fairly short. The desired equipment and technologies were established during the workshop in St. Paul, Minnesota, and the vehicles were anticipated to be available in November 1996. The research team committed their efforts to getting the vehicle on the road during the time frame defined. As a result, some of the more rigorous evaluations of feasibility and cost effectiveness were moved into the next phase of the research project. Throughout the process, the private sector partners assured the steering committee that there was justification to pursue this research project and that the technology applications from other industries proved the point. As proof of their commitment, the private sector partners contributed the technology, equipment, and resources needed to assemble the prototype vehicles.

RECOMMENDATIONS FOR PHASE II

It is the recommendation of the research team that the project continue into Phase II and assemble prototype vehicles for evaluation. There is interest and commitment from both the consortium states and from the private sector partners to continue.

Two winters of prototype vehicles are recommended. The first vehicles will be evaluated during the winter of 1996n1997. They will utilize the available technologies that were identified by private sector partners in Phase I of this research project. Because of the short time frame between defining the ideal vehicle capabilities and assembling the vehicles for evaluation, some technologies in the development stage or that can be refined from existing technologies are not available at this time. They would potentially be available for evaluation during the winter of 1997n1998. Furthermore, the technologies to be used for the first vehicles are largely for management applications and there is a great desire by the steering committee to provide technologies that will help the vehicle operators. These technologies can potentially be available for the second winter of prototype vehicles.

Phase II of the concept maintenance vehicle may need a larger pool of supporters. Phase I was supported by the consortium states and has met the objectives and requirements that were established. The next phase will have a longer duration, will require more in-depth evaluation and analysis of the data that are captured, and will benefit all of the snowbelt states. Because Phase II is larger in scope, there should be a bigger support base. Funding requests should be submitted to secure funds from broader based programs.

The data that are developed from the technologies applied to the prototype vehicles will be evaluated in Phase II. In addition, there will be an evaluation of the feasibility and cost effectiveness to carry the research project into a broader application, a fleet evaluation in each of the consortium states.

FOREIGN TECHNOLOGY APPLICATIONS

Wilfrid Nixon from the University of Iowa performed a study for the concept vehicle project, *Foreign Technology Applications for the Winter Maintenance Concept Vehicle*. The entire report (without appendices) can be found in Appendix F. The study identified foreign technologies which may be useful for consideration on the concept vehicles. The study focused on seven technology areas taken from the focus groups and included a report of recommendations for the concept vehicle project:

- The concept vehicle should be equipped with a front universal attachment hitch and a universal hydraulic power hitch of the type commonly used in Europe. Various plow and broom attachments for the hitch should also be obtained and evaluated.
- At least one of the highly sophisticated chemical delivery systems used overseas should be obtained and used as part of the concept vehicle project. Ideally, more than one such system should be evaluated.
- With regard to Roadway Weather Information Systems (RWIS) and GPS systems, it was felt that better technology is available in the U.S. than overseas. However, the highway GPS technology found in the U.S. is primarily found in the trucking industry and may require some refinement for winter maintenance activities.
- There are some good cab ergonomics concepts from overseas which could be incorporated into the concept vehicle. The recommended approach is to share these concepts with U.S. manufacturers and allow them to develop them for the concept

vehicle.
·Automated plow operation is one of those areas which is clearly not at a level where full deployment is possible. Further, the cutting edge of the technology for this field is based in the U.S. The best approach is probably to work with the researcher in this area to incorporate appropriate instrumentation into the concept vehicle as deemed desirable.
·There are a number of works in progress on vehicle visibility both in the U.S. and overseas. These include reducing the snow cloud created by the plow, adding reflective surfaces to the vehicle, improving vehicle warning lights, and adding rear warning systems to the vehicles. Again, the recommended approach is to work with those involved in these projects to field test concepts under active consideration as part of the concept vehicle project.
·Although the technology for friction measuring devices is being developed in Europe, their technology is already being tested in the U.S., including tests being conducted by the Minnesota DOT. There are currently three European manufacturers of friction measuring devices. The concept vehicle could be an ideal test bed for such equipment, provided it can be made small enough to fit beneath the subframe.

It is the recommendation of the project team to attempt to implement any recommendations from Mr. Nixon's report which are not already planned the first winter of prototype vehicle development.

CHAPTER TEN: IMPLEMENTATION PLAN FOR PHASE II

INTRODUCTION

During the completion of Phase I of this research project, it became apparent that one winter season would not be adequate for evaluation and data collection activities. The schedule for providing the prototype vehicles by November 1996 dictated that the technology to be implemented needed to be readily available. This limited the technology applications for the prototype to those described earlier in the report.

The research team was not comfortable with the fact that some of the desired vehicle capabilities defined in the focus groups were unable to be addressed on the first prototype vehicles. For example, there were several capabilities related to aiding the work of the operator, such as automating the CDL inspection process, that were not available immediately but could be in the near future. Some improvements or refinements in the technology will be available within the next year. The research team would like the opportunity to analyze these advancements in a prototype vehicle environment.

As a result, the research team agreed that there should be two winters of prototype vehicle activity. The implementation plan for Phase II will therefore include the winters of 1996n1997 and 1997n1998. A copy of the Phase II Work Plan has been included in Appendix G.

PHASE II

Winter 1996n1997

The initial technologies that were selected in Phase I will be installed on the three prototype vehicles. Any modification or adjustments required to fit the technology to the vehicle will be documented along with the location of the devices.

The reliability of the technology will be evaluated during this winter period. Some of the newer technologies being tested have not been subjected to the harsh environment of snow and ice removal. The intent is to test the performance and reliability of this equipment and if necessary, recommend remedial measures to assure reliability in the future.

The research team will document the validity and repeatability of the measurements taken. If the data captured on the moving vehicles are to be of value, they must be consistent and predictable under a given set of conditions. This activity will determine if the data repeat themselves on a reliable basis and if trends in the data can be identified.

There is a great need to find out what the operators of the prototype vehicles experience. We must determine if this technology made a difference in their job assignments. In order to avoid burdening the operators with a lot of written questions, telephone interviews will be used with a standard set of questions. The questions will be developed by the principal investigator and reviewed by the research team before they are used. The interviews will ideally occur within one week after an operator uses the prototype vehicle. From these surveys, an interim report will be made which describes the operators' reactions to the prototype vehicles.

Summer 1997

There has always been the understanding that these prototype vehicles and other vehicles that will follow it will be functional for all roadway maintenance activities and not just snow and ice removal. The time between the winters of 1996n1997 and 1997n1998 will provide the opportunity to test the prototype vehicles in other settings such as edge rutting, pavement patching, etc. The research team will determine tasks for review, schedule activities to observe, and record relevant data. Also, an interim report documenting the evaluation of the prototypes will be prepared.

After winter evaluation of the first prototype vehicles and before the modification of the prototype vehicles for 1997n1998, there will be new or improved versions of technologies which will need to be incorporated into the new prototypes. The research team will continually solicit information from the vendors and evaluate the appropriateness of the technologies. The experiences from the first prototypes will be evaluated and recommended changes will be made for the next prototypes.

A plan to correlate the prototype data with base data will be developed. For example, the pavement temperature recordings will require validation with other pavement temperature recordings. Comparison tests will be designed and implemented. It is also the desire of the research team to compare the results of the Norsemeter friction meter to the values determined by the Law Trailer, currently used by the Iowa DOT.

Development of the concept maintenance vehicle so far has included input from equipment operators, mechanics, managers, and maintenance supervisors, as well as technologies that are available off-the-shelf. This approach is often referred to as a “bottom-up” approach to technology advancement. But there needs to be given equal consideration to a “top-down” approach. This approach will consider how the data can be used in state DOT maintenance management systems, and what the data architecture should be to ensure compatibility with other DOT systems. It will also determine the logical data transfer points from the vehicle to the rest of the DOTs’ business processes. The top-down approach to development will include the input from top management personnel in the overall process. The top-down approach will be discussed, and an approach to implementing it will be developed for consideration by the research team.

Winter 1997n1998

The same steps will be taken during the winter of 1997n1998 that were taken during the winter of 1996n1997. The technology applications for the second set of prototypes will be documented and any modifications to the original vehicles recorded.

The reliability of the technology will be evaluated during these winter periods. Some of the new technologies have not been subjected to the harsh environment of snow and ice removal. One intent of the prototypes is to identify failures caused by the environment and recommend remedial measures to assure reliability in the future.

The research team will document the validity and repeatability of the measurements taken. If the data captured on the moving vehicle are to be of value, they must be consistent and predictable under a given set of conditions. This activity will want to determine if the data repeat themselves on a reliable basis and if trends in the data can be identified.

There is a great need to find out what the operators of the prototype vehicles experience. Can we answer the question, “Did this make a difference in their job assignment?” To prevent burdening the operators with a lot of written questions and answers, the research team will develop a standard set of questions to ask the individual operators and then conduct an interview over the phone. This interview will ideally occur early in the week after an operator uses the prototype vehicle. If there is a need to use different or additional questions from the first questionnaire, they will be used.

PHASE III

The final phase of this research project is to conduct a fleet evaluation in each state. This evaluation is envisioned to include 10 vehicles in each of the participating states, a total of 30, that are equally designed with advanced technologies and applications. The technologies used will be the ones that have been utilized during the prototype development and evaluation tasks.

An implementation plan will be developed and used for this fleet evaluation. Several vehicles that are working together give a better evaluation of the overall benefits gained from advanced technology applications than does a single prototype vehicle.

FINAL REPORT

A final report will document the implementation and evaluation of the two winters of prototype maintenance vehicles. The first prototypes will be evaluated during the winter of 1996n1997, and the second prototypes will be evaluated during the winter of 1997n1998. That report will be presented to each of the participating state DOTs and each of the research team partners.

Bibliography

Nixon, Wilfrid A. *Foreign Technology Applications for the Winter Maintenance Concept Vehicle*. Iowa Institute of Hydraulic Research, University of Iowa, 1996.

Sullivan, L.P. "Quality Function Deployment," *Quality Progress*. June 1986, pp 39-50.

QIP, Inc. and PQ Systems, Inc. *Total Quality Transformation: Improvement Tools*. 1994.

Appendix A

Literature Search

Appendix B

Identify List of Desired Vehicle Capabilities

AFFINITY DIAGRAM PROCESS

Source:
QIP, Inc. and PQ Systems, Inc. *Total Quality Transformation: Improvement Tools*. 1994.

Choose a Group Leader.

The group leader is responsible for leading the group through the steps to make the affinity diagram.

State the Issue or Problem.

Before beginning, the group should state the issue or problem to address. It is often useful to state the problem in the form of a question. For instance, "what are the barriers to the implementation of a total quality program in our organization?"

Brainstorm and Record Ideas.

Brainstorm ideas concerning the problem statement. Brainstorming for ideas to make an affinity diagram uses a mixture of traditional brainstorming and the Crawford slip method. In traditional brainstorming, each person says ideas aloud. Ideas are given by each person in the group until no one has anything else to add. In the Crawford slip method, ideas are recorded on index cards, slips of paper, or sticky notes in silence. There is no verbal exchange among team members. Brainstorming for the affinity diagram is a mixture of these two approaches.

Each person writes his or her idea on an index card (slip of paper or sticky note) while saying it aloud to the team. The process goes around the group with each person giving one idea at a time (one idea per card). The process continues until all the ideas had been expressed. The same rules for brainstorming should be observed: no criticizing, everyone has equal opportunity to express ideas, quantity over quality, and encourage piggy-backing.

As each team member records an idea on a card, the cards are piled in the middle of the table.

Move the Cards Into Like Piles.

Spread all the cards out on top of the table so every team member can see them. Team members walk around the table, grouping the cards into like piles. Cards that are alike are said to have "mutual affinity." It is important that the cards are grouped into like piles in silence. There should be no talking among group members.

Cards can be moved among piles any number of times. Cards that do not seem to fit into any pile may be grouped into a miscellaneous pile. Usually between seven and ten piles will emerge but this is not a restriction. Grouping is finished when most of the members are no longer moving cards from pile to pile.

Name Each Pile With a Header Card.

Name each pile of like cards through group discussion. The group leader reads all the cards in each pile aloud. The group then decides on the best name for the pile based on the content of the cards. Sometimes one of the cards in the pile becomes the header card (or name card) for the pile. The team leader then writes the name on an index card and places it on top of the pile. The name of the card should be a short phrase, not a single word. Single word names tend to lose the meaning of the pile. This process is repeated until all the piles are named. If there is a miscellaneous pile, the members should review the cards to see if any of them fit into one of the named piles. Move any such cards to the named pile; name the remainder "miscellaneous."

Draw the Affinity Diagram.

Tape the cards on a flip chart or butcher paper to display them. Position the header cards at the top of the piles. Draw a circle or square around each group of like cards. Also, label and date the finished diagram.

Discuss the Piles.

The team should now discuss the piles and individual items within the piles and how they related to the problem. The piles are studied to gain a better understanding of the problem.

The affinity diagram is useful in helping a group to identify major topics of concern relating to a problem. The process of brainstorming, grouping like cards, and naming the piles allows the group to participate in the identification of the components that make up an issue. They can then study the components and gain a better understanding of the problem.

Appendix C

Research Funding Sources

October 3, 1996

Lee Smithson
State Maintenance Engineer
Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010

Dear Lee:

I am sending you the scope of work and the budget that is to be used for our submittal to request a pooled-fund study. The process to be followed is attached to this letter and consists of Page 136 of the RAC handbook, section 7.5.2.1 entitled, "Regional Pooled-Fund Process Summary."

The work plan was distributed last month and all of the comments received have been incorporated into this work scope. I know there is an interest in the other states to see this pooled-fund study established so that it is available for travel reimbursement.

The travel budget line item may need to be adjusted upward in the future when other states join the research team and want to use the project for project travel.

If you have any questions, please let me know and I will respond immediately. It would be helpful to keep a project file of all the submittals for this pooled-fund study, and I will be willing to keep a copy on file in our office.

Thanks, Lee.

Sincerely,

Duane E. Smith, P.E.
Associate Director for Outreach
Center for Transportation Research and Educ.
Iowa State University

Appendix D

Select Private Sector Partners

ADVANCED TECHNOLOGY APPLICATIONS
FOR
HIGHWAY MAINTENANCE VEHICLES
Detroit, Michigan
AGENDA
April 23, 1996

8:00	**Welcome**	Dr. Tom Maze Director, CTRE Iowa State University
8:10	**Opening Comments**	Larry Brown State Maintenance Engineer Michigan Department of Transportation
	Workshop goals	Duane Smith Principle Investigator, CTRE Iowa State University
8:30	**Project background**	Lee Smithson Deputy Director, Maintenance Division Iowa Department of Transportation *European / Japanese Research Trip*
9:30	**Break**	
10:00		Wilfrid Nixon University of Iowa *European Research Activities*
10:30	**Project Status**	Duane Smith
11:30	**Lunch**	
12:30	**Breakout sessions**	
	Vehicle Manufacturers	Tom Van Epps, Moderator, Michigan DOT
	Equipment Vendors	Lee Smithson, Moderator, Iowa DOT
	Communications/	*Technology* Dave Johnson, Moderator, Minnesota DOT
3:00	**Break**	
3:30	**Breakout Session Reports**	Session Moderators
4:00	**Adjourn**	

CONCEPT HIGHWAY MAINTENANCE VEHICLE WORKSHOP SUMMARY

Detroit, Michigan, April 23, 1996

INTRODUCTION

On April 23, 1996 the State DOTs of Iowa, Minnesota and Michigan held a workshop for the *Advanced Technology Applications for Highway Maintenance Vehicles* in Detroit, Michigan. The workshop is to be incorporated into the Concept Highway Maintenance Vehicle Project, currently sponsored by a three state consortium. The vision of the consortium is to use this workshop as a basis for reviewing the project with private industry and soliciting their interest. Ultimately, interested members of private industry would be invited to enter into a partnership with the State DOTs. The workshop is the first step in selecting private sector partners. The selected partners will be asked to join the consortium and assist with the evaluation and feasibility of the technical requirements. The partners may also provide resources and contribute funds to the project.

BACKGROUND

In response to the need of providing the driving public with quality service in a climate of declining budgets and manpower, the State DOTs of Iowa, Michigan and Minnesota assembled a consortium to research the feasibility of applying advanced technology to the highway maintenance vehicle. The Center for Transportation Research and Education (CTRE), an Iowa State University center, provides support for this research project.

The intent of the Concept Highway Maintenance Vehicle project is to incorporate technology into the functions of the maintenance vehicle. By adding technology such as vehicle trip recorders, pavement temperature sensors and state of the art snow removal equipment, the project aims to increase the efficiency of maintenance operations.

Each of the three participating states held focus groups to determine the technical requirements for the maintenance concept vehicle. In all, five focus groups were held, two each in Iowa and Minnesota and one in Michigan. Attendance at these focus groups consisted of maintenance vehicle operators, mechanics, maintenance engineers, and emergency responders. The purpose of the focus groups was to identify possible requirements of a new generation maintenance vehicle by those who are most knowledgeable about these requirements, the users. The ideas generated at each of these focus groups were recorded and a composite list was generated. A list of these ideas was distributed at the workshop.

The Concept Vehicle will initially be evaluated as a snow and ice removal vehicle. However, since all maintenance operations are eventually expected to benefit, all maintenance applications will be examined. Three prototype vehicles are planned to be tested during the winter of 1996-1997. After the evaluation of the prototypes, the vision is to produce 10 vehicles for each participating state DOT. These fleet vehicles will be evaluated during the winter of 1997-1998.

WORKSHOP DESCRIPTION

The workshop presented an overview of the progress of research, and the results of the focus group activities. Technology providers and integrators learned what the DOT equipment operators defined as improved vehicle and equipment requirements. These providers and integrators participated, along with agency personnel, in a one of three breakout sessions that provided direction to the consortium states. The three sessions were:

·Vehicle manufacturers
·Communication/technology providers
·Equipment vendors

In these smaller sessions, questions were asked of the participants to identify technologies available for prototype evaluation and any problems that could occur in implementing these technologies. The results of these sessions are summarized in the following section. At the conclusion of the workshop, attendees were asked to indicate their interest in joining the consortium as a private sector partner.

Invitation Procedure

The participating states were requested to submit the names of interested private sector contacts with interest in the Concept Highway Maintenance Vehicle. State maintenance engineers of the snowbelt states were also included as possible attendees. The ITS America membership directory and CTRE contacts were used to solicit additional names of technology personnel. All contacts were compiled into a database, and the invitation brochure was sent to over 200 contacts. Of the 200 contacts, 49 people registered for the conference.

Structure of Workshop

The conference began with a welcome message from the director of the Center for Transportation Research and Education, Dr. Tom Maze. Larry Brown, the State Maintenance Engineer for Michigan, also added welcoming comments. Duane Smith, CTRE, then provided a description of the workshop goals described earlier. Lee Smithson, Iowa DOT, made a presentation on his trip to Europe and Japan and highlighted snow maintenance equipment in use. Wilfrid Nixon, University of Iowa, summarized his European research activities. His presentation included information on current types of snow removal equipment and stressed the European desire for interchangeable parts. Duane Smith then summarized the consortium’s progress on the Concept Highway Maintenance Vehicle research project.

Following lunch, participants selected and attended one of the three breakout sessions described earlier. Each group was led by a moderator from one of the three consortium states. Questions were asked in each group to determine the feasibility of private sector partnerships and of the technology requirements of the Concept Vehicle.

The goal of the workshop was to solicit interested private sector partners to join the three state consortium and participate in the development of prototype vehicles. At the conclusion of the workshop, those in attendance were asked to respond to an interest form included in the materials distributed at the workshop.

WORKSHOP RESULTS

The workshop was very informative for both the public and private sector participants. The private sector seemed to respect the insight of the requirements of a maintenance vehicle as they have been defined by the actual users. The public sector was encouraged that this concept vehicle project was worthy of continuing and that there was support to keep it active. There was a lot of informal conversations throughout the workshop and many ideas were exchanged along with lots of information. The objective of the workshop was accomplished when the participants responded that they now understood the concept vehicle project and would support it with their background knowledge and with the technology available. Many of the private sector participants indicated that they would be responding to the workshop by filling out the

"Partnership Interest Form."

CONCLUSIONS

The workshop was a success. There were many ideas exchanged between the participants. The private sector participants pledged their support of the project and this was an encouragement for the public sector and the consortium states to continue to pursue development of a prototype vehicle for the winter of 1996-1997.

GROUP SESSION MINUTES: EQUIPMENT PROVIDERS

Attendance:

Lee Smithson	Iowa DOT	Moderator
Michael Sherfy	Iowa DOT	Recorder
Chris Monsere	CTRE	Recorder
Ray Lutz	Sweson Spreader	Participant
Ron Colgin	National Automated Highway System Consortium	Participant
Tom Meszler	Oakland County Road Commission	Participant
John Robertson	Monroe Truck Equipment	Participant
Greg Krahenbuhl	Monroe Truck Equipment	Participant
Dave Pomplun	Crysteel Truck	Participant
Dan Bouwman	Truck and Trailer Specialties	Participant
Mark Kreuzfeldt	Tyler Ice	Participant
Jack Doherty	Bristol Company	Participant
Tom Borgmeyer	Missouri Highway Department	Participant

Lee Smithson, the moderator, asked questions to encourage discussion of the issues. The question asked are in bold, followed by the subsequent discussion.

Who has been involved in a public-private partnership?

Most participants had not been involved in any formal private-public partnerships. Most had, however, worked with public agencies in some manner. Dave Pomplun cited his company's involvement in providing the Minnesota DOT with an innovative joystick for controls. Mark Kreuzfeldt stated that his company, Tyler Ice, partnered with the Minnesota DOT to develop a zero velocity spreader. The partnership consisted of a trial and error type development of the spreader. Ron Colgin's company, National Automated Highway System Consortium (NAHSC), is a partnership between public and private industry. Ray Lutz stated that for industry to be willing to develop new products, there has to be a receptive market (the DOTs). Lee Smithson responded by saying that government agencies need to develop innovative funding methods to allow purchase of new equipment.

What obstacles to partnerships do you anticipate?

One of the hurdles cited by most participants was that the public agencies do not offer any loyalty in return for the investment made by the private company in partnerships. The private company may develop new products using their own money, but the public agencies will still request bids at the end, leaving the initial company having invested money but not necessarily guaranteed results from their investment. Many participants said they could give examples where this had occurred to them. Michael Sherfy cited examples at the Iowa DOT where the low bidder was not awarded the contract because of an inferior product. He stated that the Iowa DOT is looking to support the private sector and develop working relationships. Later, most participants suggested that the public agencies could avoid the loyalty issue by paying for development of hardware up front. Most did not expect any long term loyalty, because of how the business is structured. Ron Colgin stated that, in the defense industry, this is a common procedure. He said that the government agency will typically pay for development cost, then request bids for the implementation of that new technology. Jack Doherty suggested that the States need to get together and decide which technologies are applicable to the concept vehicle.

How should partners be established?

Most participants agreed that the key to the entire partnership was the inclusion of a system integrator. The integrator would have to assemble all of the various technologies on the maintenance vehicle. Ron Colgin mentioned that in his experience, the system integrator has to be a paid position. The systems integrator has to be proactive and develop a standards program. Dave Pomplun suggested that there should be written specifications for “trickle down” warranties so that the system integrator would not be responsible for failures of others’ products.

***Summary**:*

·State partners need to rank concepts.
·State partners need to identify all components on the maintenance vehicle.
·States need to agree on whether one state builds three vehicles or three states each build one.
·System integrator is a paid function who will establish a working relationship with component vendors and provide direction in the installation of the components.
·State partners need to establish an expert task group to test protocol and provide a cost/benefit analysis.

GROUP SESSION MINUTES: COMMUNICATIONS AND TECHNOLOGY

Attendance:

Dave Johnson	Minnesota DOT	Moderator
Tim Simodynes	CTRE	Recorder
Gary Nourse	3M	Participant
Robert Hart	Surface Systems, Inc.	Participant
Jeff Skorupski	Eaton Corporation	Participant
Pete Francis	Delco Electronics	Participant
John O'Doherty	Michigan DOT	Participant
Wilfrid Nixon	University of Iowa	Participant
Kevin Wald	Tyler Ice	Participant
Gil Boettcher	Roadware	Participant
Larry Brown	Michigan DOT	Participant
Tom Maze	CTRE	Participant
Oscar Villalvazo	Rockwell International	Participant
Duane Smith	CTRE	Participant
Roemer Alfelor	Cambridge Systematic	Participant
Ed Noteboom	Eaton Corporation	Participant
David Backus	Global Embedded Technologies	Participant
Tommy Viner	National Automated Hwy Sys Consortium	Participant
Max Donath	CAMDAC, University of Minnesota	Participant
Allen Lorenc	Rawson Control Systems, Inc.	Participant
Dana Albers	SXI Technologies	Participant
Mike Kistner	Dana Corporation	Participant
Robert Larsen	E-Systems	Participant
Mike Dergance	Eaton Trucking Information Services	Participant

Dave Johnson, moderator, asked questions to encourage discussion of the issues. The topics and questions presented by the moderator are shown in bold, followed by the discussion.

Who has been involved in a public-private partnership?

Various participants had been involved in public private partnerships. Gary Nourse, 3M, stated that they had been involved with the Minnesota DOT's "Guidestar" project. They developed SMART programs for implementation on maintenance vehicles for the purpose of aiding plow drivers. Honeywell had also been added as a sponsor on this co-funded project. Nourse stated that the "Guidestar" project took longer than usual because of the involvement of lawyers. Robert Hart, Surface Systems Inc., had developed a new sensor in conjunction with the New York Department of Transportation. Hart stated that there was a formal written agreement as a part of that partnership. Jeff Skorupski, Eaton Corporation, asked who would own the patent if something valuable was created from the partnership. Tom Maze, CTRE, stated that government agencies usually have the rights, but they seldom pursue patents. Robert Hart then advised that partnerships should be developed for ongoing returns, and not just for short term solutions.

Why implement all emerging technologies into one super truck?

Tom Maze stated that these technologies may be implemented differently in each of the three states. Dave Johnson said that this is an opportunity to combine multiple technologies. John O'Doherty stated it could work in the U.S. like it worked in Japan and Europe. Wilfrid Nixon, University of Iowa, explained that Europe and Japan do not have the same level of competition which lowers prices and challenges businesses. Kevin Wald said that his company, Tyler Ice, should be able to provide some engineering and evaluation assistance, but he wondered what could be done by the winter of 1996-97. Gil Boettcher, Roadware, and Pete Francis, Delco Electronics, both stated that they would like to have the states set specifications for the technologies, then they could estimate a cost for design and production. They would also like to know approximate quantities which the states would like to purchase.

Integration of technologies and agreement between public and private industry

Oscar Villalvazo, Rockwell International, said that in order to decide issues about the integration of technologies the states will have to decide if they are altering an existing truck or constructing a new one. This issue will decide who leads the integration process. Kevin Wald mentioned that his company produces zero velocity spreaders that the Minnesota DOT likes, but they are not purchasing a significant quantity. Another problem he identified is that there is very little incentive for operators to try new technologies.

The group then reviewed the focus group ideas:

Remote Controlled Vehicle

Kevin Wald stated that this was probably too great of a liability for the states. Oscar Villalvazo said that at the focus groups, this included using aircraft for obtaining weather data.

Auto Recording

The private sector consensus was that anything is possible, but the cost cannot be determined until industry is told which data needs to be collected. Larry Brown, Michigan DOT, said that he would like to know where maintenance vehicles are and what tasks they are performing, and knowing once every thirty minutes would be sufficient. Duane Smith said public and private partnerships will be crucial for working out details such as these.

Communications between DOTs and other public agencies

It was explained that technology for these applications currently exists, and it is up to the public sector to decide what they want and what they can afford. Dave Johnson stated that he would like to see dispatchers from the DOT and the Highway Patrol both know the location of maintenance vehicles. Oscar Villalvazo mentioned that some new communication capabilities may require modifying existing communication infrastructures. Dave Johnson added that this topic also includes communicating to the public. Max Donath, University of Minnesota, added that the Internet is a viable means for communicating with the public.

Cab Controls

Wilfrid Nixon pointed out the concern that the current controls often force operators to look away from the road to tell which button or lever their hand is on. Some possible solutions to this problem include voice activation and heads-up displays. Voice activation of controls is difficult because of various drivers' voices and habits, including listening to the radio. Also, heavy equipment is usually not controlled by voice because it is too risky. Other operations, such as operating the radio, may be more practical. Existing heads-up display products are somewhat limited, but there are some interesting applications such as bed tilt angle, blade pressure, and feedback to the driver showing which button or lever is being touched. Equipment providers would probably be eager to showcase their products in these areas.

Environmental Sensors

Roadway friction measurement is a very real possibility. Bob Hart stated that the detection of the thickness of ice will be possible soon. He also stated that image processing is also emerging. Kevin Wald stated that real time sensing is extremely difficult over 35 mph. Oscar Villalvazo added that thermal mapping could help. Dave Johnson stated that it would be helpful for the DOTs to have some Measures of Effectiveness (MOEs) for quantifying the benefits and justifying the costs of these technologies. Larry Brown, Michigan DOT, listed some MOEs such as material usage, overtime pay, and inches of snow; however, he said they do not have any base data.

Monitoring the Operator

Max Donath stated that studies have been done and are currently in progress about monitoring driver performance and driver fatigue. Tom Maze said that he is aware of some research in this area and it is probably not possible to implement anything by the fall of 1996.

Notification and Mobilization of Drivers

Duane Smith explained that this area is concerned with the time involved with getting the drivers, preparing and warming the truck, and loading the materials. Larry Brown explained that their road observer now carries a cellular phone and directly calls the drivers in.

Summary

Several points arose throughout the discussions:

- The integrator must take responsibility for the overall integration and the method of implementing the technologies into a maintenance vehicle.
- Private industries can develop almost any technology that the state DOTs want. However, they need to know what the DOTs want, the potential size of the market, and how much they are willing to pay.
- New technologies must be categorized by those which may be implemented by the fall of 1996, and those which may be implemented by the fall of 1997.
- Need a measure of evaluation and an ability to compare results to baseline data.

GROUP SESSION MINUTES: VEHICLE MANUFACTURER

Attendance:

Thomas Van Epps	Michigan DOT	Moderator
Roxanne Getzen	Michigan DOT	Recorder
Karin Katch	Michigan DOT	Recorder
Ron Zietell	Oshkosh Truck Corporation	Participant
Ted Henson	Oshkosh Truck Corporation	Participant
Steve Dembicky	Michigan DOT	Participant
Lawerence Sweeting	Navistar	Participant
Mark Lester	Michigan DOT	Participant
Tom Donahey	Iowa DOT	Participant
James Dunleavy	Oakland County Road Commission	Participant
William McGowan	Kent County Road Commission	Participant

Public Private Partnerships

·Ted Hanson, Oshkosh, worked with airports and FAA developing crash rescue trucks and snow removal equipment. Oshkosh has worked closely with Minneapolis and Chicago O'Hare airports with their snowplow and fire truck configurations. Oshkosh also worked with Johnson County, Iowa on a four wheel drive 52,000 lb GVW snow removal trucks.

Addressed Focus Group Ideas

Maneuverable vehicle with low center of gravity

·Oshkosh has patented a rear axle steering system (four wheel steer) that is electronically controlled. This device reduces steering radius by 30%.

Low center of gravity

·There is the possibility of building a dump body or a chassis mount hopper that are set lower in the truck frame rails or between them to lower the center of gravity.

Provide adequate horsepower, all wheel drive, and anti-lock braking

·Specifications should reflect desired horsepower requirements.
·Navistar offers electronic turbocharged waste-gate "by-pass" system which improves low end torque while still meeting Federal emission control requirements. This system is used for short bursts of power, when needed.
·Oshkosh offers all wheel drive on their standard vehicle.
·Anti-lock braking will be required be Federal mandate starting 1/1/97.

Increased driver visibility, preferably 360 degrees.

·Heated windshields are available for some applications.
·Oshkosh offers side window wiper system which can be adapted to the taillight system.
·Oshkosh offers "deluge system" on cement mixers which floods the mirrors, windshield and side windows with water. The system uses an on board water tank.
·Oshkosh has reverse slope windshields which prevent windshield and wiper freeze ups due to melted snow and ice runoff.
·Oshkosh offers top mounted windshield wipers and tubular side window defrosters with fans.

Corrosive resistant vehicle

·An automatic washing system is available.

·Avoiding dissimilar metals can be avoided by specifications. For example, by specifying that air brake valves be manufactured from plastic.
·More effort could be made by truck manufacturers to eliminate corrosion. Some truck frames are already in pre-rusted conditions when they are primed.
·A better electro-plating process could be developed to limit corrosion.

Ability to carry larger payloads
·The range of the vehicle could be expanded by such specifications as larger fuel tanks or tag axles.
·A trailer could be attached to allow the ability to haul more material

Increased service range
·Automatic shutdown or partial shutdown system upon loss of oil pressure or coolant is a technology available from all engine manufacturers.
·Automatic greasing systems are also available. The greasing can be triggered by several methods. In the construction industry, some loaders and cranes are equipped with this system.
·Automatic tire inflation systems can be purchased. Tire pressure can be adjusted from the cab. This is common specification on military vehicles.
·Air suspension can be specified to reduce spring problems. In addition, self leveling air bag suspension systems will maintain underbody mounting height.

Additional questions addressed

Operator Ergonomics
·Noise is required by Federal standard to be less than 85 decibels at full engine rpm. Electronic mufflers and other anti-noise devices are available to reduce noise. Air suspended cabs are available and would also help to suppress noise in the cab.
·Adjustable interiors and control panels could be accomplished by copying existing road semis. Surround types of control panel are designed to fit the operator are available.
·Air conditioning is available. Oakland County has AC in all equipment.
·Air bags are not currently offered by any of the manufacturers. It may be required by Federal mandate in the future.

Fuel
·Fuel heaters are available that would eliminate jelling problems.

Icing of vehicle
·Chemicals are available that could eliminate the icing on mirrors and windows.
·There might be paint that would limit the ability for ice to adhere to the vehicle.

Hydraulic Systems
·The notion of unbreakable hoses is best addressed by the set-up vendors. Hydraulic hoses are available with protective nylon covering that can be bent in a tighter radius.

Cost Issues
·The government can borrow money less expensive than private industry so leasing would not be cost effective.
·Replacement schedule should be analyzed to determine the resale of equipment.

Durability

·The vehicle should be built to tolerate major impacts. Better lighting may eliminate collisions.

Electrical systems

·The use of loomed wiring systems and grease filled connectors may serve to provide environment resistant electrical systems.
·Extra ports for wiring connectors can be specified.

Repair parts

·Computerized diagnostic techniques should be written into the specifications. This technology is available from the major engine manufacturers.
·Numbered parts list could be facilitated by having parts books on software.
·Parts could be bar coded to allow easier identification.
·All wiring should be color coded.

Traction

·Technology is available to monitor engine speed and gear ratio to control traction.

Partnership Interest Form

Advanced Technology Applications for Highway Maintenance Vehicles

Company Name: ________________________________

Address: ________________________________

____

____

Phone/fax: ________________________________

Representative Name: ________________________________

Phone/fax: ________________________________

e-mail: ________________________________

Area of Interest:

- Communications/Technology Providers ❑
- Equipment ❑
- Vehicle Manufacturing ❑

Partnership Support:

- Committee Membership ❑ Yes ❑ No
- Technology Applications ❑ Yes ❑ No

Please describe________________________________

____

Overhead Administrative Support:

❑ $1,000 or more ❑ $5,000 or more

❑ $10,000 or more ❑ $20,000 or more

Return by May 3, 1996, along with supporting documentation about your organization, to:

Duane Smith
Center for Transportation Research and Education
Iowa State University Research Park
2625 N. Loop Drive, Suite 2100
Ames, IA 50010-8103

Appendix E

Develop Description of Systems

CONCEPT HIGHWAY MAINTENANCE VEHICLE WORKSHOP
ST. PAUL, MINNESOTA, JULY 23-24, 1996
AGENDA

JULY 23, 1996

9:00am WELCOME
Special guests
Proposed teams in handout
Workshop goals

9:30am PARTICIPANT INTRODUCTIONS AND TECHNOLOGY OVERVIEW
Company reports 10 minutes each (or less)
What is being proposed for the research project?

11:30am HOUSE OF QUALITY DIAGRAM
Explain the diagram
Technology must match up with the requirements

12:00 LUNCH BREAK

1:00pm DEVELOP THE VEHICLE CONFIGURATION
What are the basic features
How well matched are the state teams?

PROTOTYPE SCHEDULE
Winter of 1996-97
What has to happen and when?

DATA COLLECTION
The prototype vehicle
Maintenance management systems now and in the future

5:00pm REVIEW
The accomplishments of the day
Set the objectives for tomorrow
Think about the integrator's role
Adjourn for the day

JULY 24, 1996

8:00am
DISCUSSION OF THE INTEGRATOR'S ROLE How will the integrator function?
Should there be one, or one for each state?
Will this come from the private sector participation?

BUDGET ESTIMATION
Will be required for the "Pooled Fund Study" request.
Needs to be detailed for each of the participating companies.
What is the value of the technology being provided?
What is the estimate of effort to attend the coordinating meetings?
What are the other costs we should identify?
Need to be detailed for each of the state DOTs.
Value of equipment provided.
Estimate of effort to manage the research project.

STATE TEAM MEMBERS
Are we balanced?
Do the teams make sense for everyone?
Do we need to make adjustments?
Restate the involvement for each state team.

SCHEDULE THE NEXT MEETING
Date?
Location?
What do we need to accomplish?

2:00pm
ADJOURN

Attendees of the St. Paul Workshop

Name	Company
Jack Doherty	Bristol Company
Bill Hyman	Cambridge Systematics Inc.
David Pomplun	Crysteel Distributing
Tom Maze	CTRE
Chris Monsere	CTRE
Tim Simodynes	CTRE
Duane Smith	CTRE
Jeff Skorupski	Eaton Corp.
Roger Port	FHWA
Bill Lohr	FHWA
Dwayne Fosseen	Fosseen Manufacturing
Dick Relick	Fosseen Manufacturing
Dennis McCormick	Gressen Hydraulics, Dana Corp.
Mike Sherfy	Iowa DOT
Lee Smithson	Iowa DOT
Andre Clover	Michigan DOT
Tom Van Epps	Michigan DOT
Gene Valley	Michigan DOT
Ed Fleege	Minnesota DOT
Dave Johnson	Minnesota DOT
Paul Keranen	Minnesota DOT
John Scharffbillig	Minnesota DOT
Greg Krahenbuhl	Monroe Truck Equipment
Tom Ask	Odin Systems International
Ted Henson	Oshkosh Truck
Gil Boettcher	Roadware
Don Swanson	SXI Technologies
Alan Marder	SXI Technologies
Kevin Wald	Tyler Ice
Max Donath	University of Minnesota

ST. PAUL WORKSHOP — MEETING MINUTES
July 23-24, 1996

Attendance List

A complete list of attendees is attached. If any information is incorrect or missing (especially e-mail addresses) please contact Tim Simodynes at CTRE, by phone: 515-296-6686; fax: 515-294-0467; or e-mail: tim@ctre.iastate.edu.

Private Sector Presentations

After a brief welcome, each private sector company was invited to make a short, 10 minute presentation about what their company could offer for the Prototype Maintenance Vehicle. A short summary of each company's highlights follows.

<u>Odin Systems (unassigned)</u>
·Automatic sytems including bridge anti-icing
·Expert system to optimize chemical rates, blade configurations, or routes
·RWIS interface
·Video Imaging

<u>Roadware (unassigned)</u>
·Function as system integrator
·Serve as contact for Norsemeter friction device

<u>Gressen Hydraulics/Dana Corp. (unassigned)</u>
·Micro processor granular liquid display
·Ground speed based
·Closed loop system to monitor output
·Rate, time, and events data download capabilities

<u>Fosseen Mfg. and Development (unassigned)</u>
·Provide alternate fuel systems
·Increased power for short applications
·Fuel savings and emission reductions

<u>Norsemeter (unassigned)</u>
·Continuous friction measuring device
·Road Analyzer and Recorder (ROAR)

<u>Crysteel Truck Equipment (Iowa Team)</u>
·Supply equipment for snow and ice control
·Prewetting systems
·Ground speed control
·Underbody scrapers
·V-Box with sander
·Front and rear or standard mount wing plows

<u>Tyler Ice (Minnesota Team)</u>
·Tailgate V-Box, front end spreaders

<u>Cambridge Systematics (data coordinators)</u>
·Next generation management systems
·ITS applications
·GPS applications
·Public Private Partnerships

<u>Univ. of Minnesota (CAMDAC) (unassigned)</u>
·Road departure analysis
·Driver fatigue studies using human factor analysis
·Steering control sensors/collision avoidance
·Differential GPS
·Use in poor visibility conditions
·Monitor in-lane position
·Monitor vehicle conditions
·Magnetic Smart tape

<u>Monroe Truck Equipment (Michigan Team)</u>
·Integrator of various types of equipment
·Manufacturer of various types of snow control devices
·Underbody scrapers
·Salt/Sand spreaders with ground speed controls
·Pre wetting systems and specialty spreaders
·Rear and standard mount wings
·Digital spreader controls for functions

<u>Eaton Corporation (Michigan Team)</u>
·Fleet Advisor
·GPS with two way communications
·Read sensors and vehicle data links
·Customer configures activities
·Can function with all maint. activities

<u>Oshkosh Truck (unassigned)</u>
·Heavy duty truck

·Pre wetting systems
·GPS (Real time)
·Two way communications
·Customer configured device
·Digital spreader control
·Closed loop system/monitor output

SXI Technologies (Minnesota Team)
·Universal Data Logger
·Monitoring system
·Communications
·System integrator
·Surface temperature
·Vehicle weigh in motion

·Heads up display
·All steer
·GPS
·Rear vision system
·Forward looking infrared radar (FLIR)
·Windshield deluge system

Bristol Company (Iowa Team)
·Digital spreader controls for pre-wet and/or anti-ice
·Liquid tanks
·Ground speed synchronization

Technology Match-up

Tuesday after lunch, the technology available on each state's team was compared. Any deficiencies in technology were corrected by allowing other vendors to provide the technology. Unique technologies, supplied by only one vendor, were considered for use on all three state trucks. On Wednesday morning, budget numbers for the technology were determined. Two numbers were requested, the value of the hardware or time the vendor was willing to contribute and the amount that the project would fund. Following the budget discussion, a preliminary schedule for installation of the components was discussed. The results of these discussions are summarized in the following table.

IOWA TEAM, (Ames)

Item	Technology Provider	Provider Contribution	Project Contribution	Schedule
50,000 GVW, plow, spreader	IDOT			10/01/96
Trip Master	Rockwell			?
AVL System	Rockwell			?
Two Communication	Rockwell			?
Material Application	Bristol	$12,500.00	$12,500.00	09/01/96
Incremental Power	Fosseen	$1,500.00	Fuel	09/15/96
Continuous Friction Device	Norsemeter	$45,000.00	$20,000.00	01/01/97
Surface Temp	SXI	$500.00		10/01/96
Vehicle Weight Sensor	SXI	$1,500.00		10/01/96
	Sub Total:	*$61,000.00*	*$32,500.00*	

MICHIGAN TEAM, (Cadillac)

Item	Technology Provider	Provider Contribution	Project Contribution	Schedule
Plow, Box, Truck	MDOT			?
Fleet Advisor	Eaton	$25,000.00		09/01/96
AVL System	Eaton			09/01/96
Two Communication	Eaton			09/01/96
Material Application	Monroe	$8,000.00		09/01/96
Incremental Power	Fosseen	$1,500.00	Fuel	09/15/96
Continuous Friction Device	Norsemeter	$45,000.00	$20,000.00	01/01/97
Surface Temp	SXI	$500.00		10/01/96
Vehicle Weight Sensor	SXI	$1,500.00		10/01/96
	Sub Total:	*$81,500.00*	*$20,000.00*	

MINNESOTA TEAM, (St. Cloud)

Item	Technology Provider	Provider Contribution	Project Contribution	Schedule
1996 Ford, V-Box, Wing mount, underbody plow, spreader	MNDOT			08/15/96
Data Logger	SXI	$25,000.00		10/01/96
AVL System	Tyler Ice	$42,000.00		09/15/96
Two Communication	SXI			10/01/96
Material Application	Tyler Ice			09/15/96
Incremental Power	Fosseen	$1,500.00	Fuel	09/15/96
Continuous Friction Device	Norsemeter	$65,000.00		01/01/97
Surface Temp	SXI			10/01/96
Vehicle Weight Sensor	SXI			10/01/96
Air Foil	Monroe			09/01/96
	Sub Total:	*$133,500.00*	*$0.00*	

Evaluation Plan Team Committee

It was agreed that an evaluation team would be needed to assess the prototype vehicle. It was decided that the team would consist of:

- ·Lee Smithson , Iowa DOT
- ·John Scharffbillig, Minnesota DOT
- ·Andre Clover, Michigan DOT
- ·One equipment operator from each of the three states
- ·CTRE
- ·Don Swanson, SXI
- ·A representative from Rockwell
- ·A representative from Monroe Trucking Equipment

Appendix F

Foreign Technology Applications Report

APPENDIX NOT INCLUDED

from

Foreign Technology Applications for the Winter Maintenance Concept Vehicle

Complete report available from

Duane Smith
Center for Transportation Research and Education
Iowa State University
2625 N. Loop Drive, Suite 2100
Ames, IA 50010
515-294-8103

Appendix G

Phase II Work Plan

PHASE TWO
CONCEPT HIGHWAY MAINTENANCE VEHICLE
WORK PLAN

Prepared for the
Iowa Department of Transportation
Michigan Department of Transportation
and
Minnesota Department of Transportation

Prepared by the
Center for Transportation Research and Education
ISU Research Park
2625 N. Loop, Suite 2100
Ames, IA 50010-8615

October 1996

PHASE TWO

HIGHWAY MAINTENANCE CONCEPT VEHICLE WORK PLAN

RESEARCH PROJECT STATEMENT

This research project focuses on the development of a vision and a specification for an advanced highway maintenance concept vehicle and will focus on winter storm maintenance operations. Snow and ice control during winter storms are one of the most complex tasks for an operator, the vehicle, and the highway maintenance supervisor. Therefore, winter storm maintenance provides an environment that is likely to benefit the most from vehicle navigation systems, on-board computers and data recorders, sensors and automated attachment controls, automatic vehicle location systems, and advanced communication systems. Other maintenance tasks are taken into account during the advanced vehicle conceptualization and specification development.

This work plan is for phase two of a three-phase plan. Phase one has been completed, and during that phase, a literature search has been completed, the prioritized list of functions developed, funding for continuation of phase two and phase three was researched, private sector partners were selected, the description of the vehicle systems was completed, and a cost effectiveness analysis was conducted.

THE CONSORTIUM

The conceptualization and design of the concept maintenance vehicle will be supported through a consortium of three snowbelt state departments of transportation. The state departments of transportation of Iowa, Michigan, and Minnesota all have reputations for embracing innovation in maintenance management and maintenance practices and therefore will form the core and founding membership of the consortium. Other private and public sector members will be invited to join the consortium as they are identified and when the appropriate time approaches. Once an appropriate selection process has been established, private sector groups will join the consortium.

The various consortium relationships are identified as:

<u>Initial Membership</u>

- Iowa Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Center for Transportation Research and Education (staff for consortium)

<u>Other Public Sector Participants</u>

- Federal Highway Administration
- Other state departments of transportation
- Representative local government agencies

<u>Private Sector Partners</u>

- Bristol Company
- Cambridge Systematics
- Fosseen Manufacturing

Global Sensor Systems
Monroe Trucking Equipment
NAVISTAR International
Norsemeter
Oshkosh Trucking Corporation
Roadware Corporation
Rockwell International
SXI Technologies
- Air Weight
- King Communications
- MPSI
- RoadWatch
- Unicom Signal
- Squarerigger

Tyler Ice Division

RESEARCH PROJECT TASKS

Task 1: Detailed work plan

This task will develop a detailed work plan. The Microsoft project software will be used and will include similar data as was presented in the phase one work plan. The tasks and sub-tasks will be described and completion dates will be established for each. There will be development of a plan for test and evaluation of the protocols and establishment of the frequency of data download/transfer from the prototype vehicles to specified data bases.

A two-day meeting is proposed that will bring a consensus as to the objectives to be accomplished with the first and second prototype vehicles. This meeting will determine details about data capture, reporting protocols and frequencies, and the intended use in the highway maintenance business.

Task 2: Document the technology that has been selected for the winter of 1996-1997

The process that was used to establish the three-state teams will be documented and will show the continuity of technologies from team to team. Each of the state team members will be discussed, and the features and strengths of each team will be highlighted.

The schedule for prototype development that was agreed upon in phase one will be presented and key dates will be emphasized.

Task 3: Document any adjustments and modifications required for incorporation of the technology onto/into the basic truck

There is a need to document the location, on or in the vehicle, of technology items being used in the prototype vehicle. There will be documentation of the space required, where that space was provided, and any tabs or connectors that were added for the purpose of attaching the devices. The location of power or hydraulic lines will be captured and recorded along with the location of any computer cables or electrical lines.

If there are any basic changes in the vehicle specifications (upgrading the hydraulics for example), they will be documented and reported to the appropriate DOT.

Task 4: Document the reliability of the technology during the winter of 1996-1997

It is reasonable to assume that some of the selected technologies have not been utilized in the environment of the snow and ice removal vehicle when considering vibrations, noise, corrosive chemicals, and cold temperatures. The study will document if there are any negative effects due to the environment and will record the data from the technologies and determine if the data output is consistent in the varying environment. Since these technologies have never before been assembled to work as an integrated unit, this study will determine the compatibility that exists between them and how the data outputs are related.

There is an interest in providing data that is captured by the concept vehicle to other systems. This potential will be researched, evaluated, and reported upon. As an example, a question such as "Can the pavement temperature recordings from the concept vehicle be incorporated into other weather systems and supplement the data used for weather predictions?" will be addressed and documented. This will begin the process of recording any data architecture changes that are desired to be included in the second prototype vehicle for the winter of 1997-1998.

Task 5: Document the validity and repeatability of measurements

If the data captured on the moving concept vehicle is to be of value, it must be consistent and be predictable under a given set of conditions. This task will want to determine if the data repeats itself on a reliable basis and if trends in the data can be identified.

Task 6: Conduct interviews with vehicle users during winter of 1996-1997

It is not the desire of the research team to burden the equipment operators driving this prototype vehicle with the task of lengthy, time consuming reporting procedures. Many times this will detract from the effectiveness of the observations requested and, thus, influence the success of the research. The researchers at the Center for Transportation Research and Education will replace this burden with telephone interviews with the equipment operators. These interviews will be conducted on a weekly basis and will include questions that have been agreed upon by the entire research team. A key question will be to ascertain if the technology has made the equipment operators work load any easier, or if it has added to the job.

Task 7: Identification and evaluation of new and developing technology

There is continuous evolution of technologies, many of which may have merit to be included in the second prototype vehicle for the winter of 1997-1998. The researchers at the Center for Transportation Research and Education will continuously solicit information from vendors and evaluate the appropriateness of the technologies. In addition, innovations within the technologies provided on the first prototype will be recorded and included on the second vehicle.

Task 8: Develop modified system requirements for the winter of 1997-1998

After the first prototype vehicles have completed their assignments during the winter of 1996-1997, the experiences will be reviewed and appropriate modifications and changes will be detailed for the second prototype vehicle. At this time, the results of task 7 will be incorporated into the vehicle requirements. A development schedule will be established for the modifications required and for incorporating new technologies.

Task 9: Identify and document other maintenance functions for prototype evaluation during the spring and summer of 1997

There has always been the understanding that this prototype vehicle, and other vehicles that will follow it, will be functional for all of the roadway maintenance activities and not just snow and ice removal. The time between the winters of 1996-1997 and 1997-1998 will provide the opportunity to test the prototype vehicle in other environments. This task will determine the tasks that are appropriate for review, and a schedule of activities will be observed and the data elements recorded.

Task 10: Develop a plan to correlate the prototype data with base data

Up to this point, the technologies which are being incorporated on the concept vehicle have not been correlated with base data elements. For example, the pavement temperature recordings will require validation with other pavement temperature recordings. Another example will be the validation of the friction readings that come from the attached friction meter and how close does it measure the friction as measured by more conventional methods. Comparison tests will be designed and implemented in this task.

Task 11: Conduct meetings for a "Top Down Management Plan"

The concept maintenance vehicle, so far, has included the input from equipment operators, mechanics, managers, and maintenance supervisors and has incorporated technologies that are available “off the shelf.” This approach is often referred to as a “bottom up” approach to technology advancement. But, there needs to be given equal consideration to a “top down” approach. This approach will consider how the data can be used in state DOT maintenance management systems, what the data architecture should be to ensure compatibility with other DOT systems, what the logical data transfer points from the vehicle to the rest of the business processes are, and will include the input from top management personnel in the overall process. The “top down” approach will be discussed in this task, and an approach to implementing it will be developed for consideration by the research team.

Task 12: Document the technology that has been modified or added for the winter of 1997-1998

This task will document the technologies that are to be included in the prototype vehicle number two. The individual technologies to be utilized will be recorded and an evaluation plan will be provided that will cover the test period.

Task 13: Document the adjustments and modifications required for attachments

There is a need to document the location, on or in the vehicle, of technology items being used in prototype vehicle number two. There will be documentation of the space required, where that space was provided, and any tabs or connectors that were added for the purpose of attaching the devices. If there are any basic changes required in the truck specifications, they will be documented in this task. The location of power or hydraulic lines will be captured and recorded along with the location of any computer cables or electrical lines.

If there are any basic changes in the vehicle specifications (upgrading the hydraulics for example), they will be documented and reported to the appropriate DOT.

Task 14: Document the reliability of the technology during the winter of 1997-1998

It is reasonable to assume that some of the selected technologies have not been utilized in the environment of the snow and ice removal vehicle when considering vibrations, noise, corrosive chemicals, and cold temperatures. The study will document if there are any negative effects due to the environment and will record the data from the technologies and determine if the data output is consistent in the varying environment.

Since these technologies have never before been assembled to work as an integrated unit, this study will determine the compatibility that exists between them and how the data outputs are related.

There is an interest in providing data that is captured by the concept vehicle to other systems. This potential will be researched, evaluated and reported upon. As an example, a question such as “Can the pavement temperature recordings from the concept vehicle be incorporated into other weather systems and supplement the data used for weather predictions?” will be addressed and documented. This will complete the process of documenting any data architecture changes that are desired to be included in this second prototype vehicle.

Task 15: Document the validity and repeatability of measurements

As stated in task 5, if the data captured on the moving concept vehicle is to be of value it must be consistent and be predictable under a given set of conditions. This task will want to determine if the data repeats itself on a reliable basis and if trends in the data can be identified. The process developed in task 5 will be the basis of this task, but will be modified as the research team desires, due to the experience gained in the first prototype vehicle.

Task 16: Conduct interviews with vehicle users during winter of 1997-1998

As stated in task 6, it is not the desire of the research team to burden the equipment operators driving this prototype vehicle with the task of lengthy, time consuming reporting procedures. Many times this will detract from the effectiveness of the observations requested and thus influence the success of the research. The researchers at the Center for Transportation Research and Education will replace this burden with telephone interviews with the equipment operators. These interviews will be conducted on a weekly basis and will include questions that have been agreed upon by the entire research team. A key question will be to ascertain if the technology has made the equipment operators work load any easier, or if it has added to the job.

The process that is utilized with the first prototype vehicle will be the basis for the process in this task. It will be modified as directed by the research team.

Task 17: Develop a plan for phase three, fleet evaluation

The next phase of this research project is to conduct a fleet evaluation in each state. This is envisioned to include 10 vehicles in each of the participating states, a total of 30, that are equally designed with advanced technologies and applications. The technologies used will be the ones that have been utilized during the prototype development and evaluation tasks.

An implementation plan will be developed in this task that will provide for this fleet evaluation. Several vehicles that are working together give a better evaluation of the overall benefits gained from advanced technology applications than does a single prototype vehicle.

Task 18: Final report

A final report will document the implementation and evaluation of the two prototype maintenance vehicles. The first one will be evaluated during the winter of 1996-1997, and the second will be evaluated during the winter of 1997-1998. This report will be presented to each of the participating state DOTs and to each of the research team partners.

PROJECT CONTRIBUTIONS

Technology Provider	Technology	Contribution
IOWA TEAM (AMES)		
Iowa DOT	50,000 GVW, Plow, Spreader, Underbody Scraper, Wing Mount	$85,000
Rockwell International	Trip Master, AVL System, Two-Way Communications	70,000
Bristol Company	Material Distribution System	12,500
Fosseen Manufacturing	Incremental Power System	1,500
Roadware Corporation	Norsemeter Friction Meter	45,000
SXI Industries	Surface Temperature Sensor	500
SXI Industries	Vehicle Weight Sensor	1,500
	Sub Total	$216,000
MICHIGAN TEAM (CADILLAC)		
Michigan DOT	50,000 GVW, Plow, Spreader, Underbody Scarper, Wing Mount	$85,000
Rockwell International	Trip Master, AVL System, Two-Way Communications	70,000
Monroe Trucking Equipment	Material Distribution System	8,000
Fosseen Manufacturing	Incremental Power System	1,500
Roadware Corporation	Norsemeter Fiction Meter	45,000
SXI Industries	Surface Temperature Sensor	500
SXI Industries	Vehicle Weight Sensor	1,500
	Sub Total	$211,500
MINNESOTA TEAM (ST. CLOUD)		
Minnesota DOT	1996 Ford, V-Box, Wing Mount, Underbody Scraper	$85,000
Tyler Ice	AVL System, Material Distribution System	42,000
Fosseen Manufacturing	Incremental Power System	1,500
Roadware Corporation	Norsemeter Friction Meter	65,000
SXI Industies	Data Logger, Two-Way Communications,	25,000
SXI Industries	Surface Temperature Sensor	500
SXI Industries	Vehicle Weight Sensor	1,500
Monroe Trucking Equipment	Air Foil	500
	Sub Total	$221,000
	Grand Total	$648,500

DETAILED BUDGET
for Period
December 1, 1996 - June 30, 1998

(19 Months)

Salaries*			$115,083
	Tom Maze - 4 weeks	9128	
	Duane Smith - 19 months @40%	39728	
	Bill McCall - 4 weeks	6425	
	Marcia Brink - 2 weeks	1379	
	Account clerk @ 10%	6416	
	Secretarial support @ 15%	4640	
	Research assistant - 2 @ 1/2 time	47367	
Wages (graphics assistance)			$300
Benefits-Salaries			$23,820
Benefits-Wages			$36
Travel			$41,400
Supplies			$700
Other	(Printing, telephone, copies,equip rental)		$9,751
	Subtotal	$191,090	

Equipment	$52,500
Indirect Cost @ 44%	$84,080
Total Award	$327,670

*Salary estimates include a 5% increase on July 1.

Note: When additional states are added to the research team, the budget for travel may need to be adjusted.