CONCEPTUALIZATION OF THE FUTURE HIGHWAY MAINTENANCE VEHICLE

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ABSTRACT

The universal challenges facing governmental agencies today are to increase productivity and quality, and to be more environmentally friendly. This comes at a time when road users are requiring more independence and an increased level of service for winter driving. The snow and ice control operations provide a situation that will benefit from utilization of advanced technology. In recognition of this potential, the state DOTs of Iowa, Michigan, and Minnesota have formed a consortium to support a project that will define vehicle and equipment requirements, develop and evaluate a prototype vehicle, and produce vehicles for fleet evaluation. The Center for Transportation Research and Education, a center of Iowa State University, is providing staff support to the project. A key element of this project is the inclusion of private sector partners in the consortium.

The approach that is being pursued is defined in three phases: 1) description of the functions and a financial evaluation; 2) prototype development and evaluation; and 3) a comprehensive fleet evaluation. The first phase will identify concepts, define the functional requirements, develop high level designs, and perform a cost effectiveness analysis. During the second phase of the project, manufacturers, systems integrators, and the consortium will develop one prototype concept vehicle (or possibly one for each consortium state) which will be evaluated against the performance criteria. In phase three, several vehicles will be built for fleet evaluation. It is likely that these vehicles will be standard design maintenance vehicles with advanced technology systems incorporated into them.

The project schedule is driven by the winter months and the need to have the prototype and fleet vehicles available for winter maintenance operations evaluations. The schedule is to have a prototype vehicle ready for testing during the winter of 1996-1997, and fleet vehicles available for the winter of 1997-1998.

INTRODUCTION

Some of the universal challenges facing governmental agencies today are to increase productivity and quality, and to be more environmentally friendly. These challenges are of major importance to three-quarters of the state's department of transportation (DOT) who must face the perils of winter as they strive to provide around the clock mobility to the road user. Snow and ice control during winter storms presents highly complex tasks and long, stress-filled hours for equipment operators and their supervisors. Continued cutbacks in DOT staffs dictate that (now) one equipment operator be able to drive a snow plow truck and manage all its ancillary equipment, whereas in the past there were two operators in the truck. These staff reductions come at a time when road users are requiring more independence, through greater mobility, and an increased level of service for winter driving. Reliable, just-in-time deliveries are the backbone of most states' economic well being, and are essential in the ability to attract new industry.

Therefore, snow and ice control operations provide an environment that will 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 can improve operator efficiencies: for example, the equipment operator could automatically set the most efficient underbody snowplow blade angle and down pressure by utilizing onboard computers and sensors. Computers can record and analyze roadway surface temperature and friction values to determine optimal timing and application rates of chemicals and abrasives. Automatic global positioning vehicle location systems can track and record work progress. Computers, video cameras, and sensors can monitor vital signs of the major vehicle components and the ancillary snowplow equipment. By warning operators of abnormal conditions they can help avoid costly and untimely breakdowns.

THE CONSORTIUM

In recognition of the potential that exists when utilizing advanced technologies for highway maintenance activities, this project has been initiated to define the vehicle and equipment requirements, to develop and evaluate a prototype vehicle, and to produce vehicles for fleet applications. To initially focus on the maintenance operations that are most under public observation, the winter snow and ice operations will receive the first consideration for technology applications. At the same time, the research team realizes that many of the technologies adopted will transcend the entire maintenance operations spectrum. The conceptualization and design of the advanced highway maintenance vehicle is being supported in phase one through a consortium of three snowbelt state DOTs. The state DOTs of Iowa, Michigan, and Minnesota all have reputations for embracing innovation in maintenance management, maintenance operations practices, and research. Therefore, they form the core and founding membership of the consortium. The Center for Transportation Research and Education (CTRE), a center of Iowa State University, is providing staff support to the consortium. The project definition and objectives are parallel to the interests and experience of the CTRE support staff. A key element of this project is the inclusion of private sector partners into the consortium. Private sector partners bring 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. Private sector partners and additional public sector members will be invited to join the consortium. The various consortium relationships are identified as:

- Initial Membership
  - Iowa Department of Transportation
  - Michigan Department of Transportation
  - Minnesota Department of Transportation
  - Center for Transportation Research and Education—staff to consortium
- Other Potential Public Sector Participants or Observers
  - Federal Highway Administration
  - Other state departments of transportation
  - Public works agencies
  - Representative local government agencies
- Potential Private Sector Participants
  - 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 and initialization stages. There are many developments that will occur when technology options are evaluated and properly categorized as to their value and feasibility for the project. The inclusion of private sector partners adds a dimension that can initially only be imagined. The approach that is being pursued is defined in three phases with the first phase having the most clarity of scope and the following phases being more broadly defined due to their reliance on phase one results. The three phases are: 1) description of the functions and a financial evaluation; 2) prototype development and evaluation and; 3) a comprehensive (fleet) evaluation. At the time of the Eleventh Equipment Management Workshop, the project is in phase one and the writing style will document the progress to date as well as describe tasks that have been identified but not yet accomplished.

Phase I: Description of Functions and Financial Analysis

The first phase will identify concepts, define the functional requirements, form public and private partnerships, develop high level designs, and perform a cost effectiveness analysis for a highway maintenance concept vehicle. As an over-arching activity, during Phase I, funding opportunities to carry the project into prototyping and fleet development will be investigated and promoted.

The process of identifying the requirements of this concept maintenance vehicle is very similar to the product development process used in the manufacturing community. This will be the first time that some of the technologies have been brought together to meet the needs of the maintenance equipment operator and to provide the functions required for roadway maintenance activities. Because the introduction of new technologies into highway maintenance vehicles is similar to new product development, the process that will be utilized is one used in the private sector called "Quality Function Deployment" or "QFD." The process requires customer input before the product is designed and manufactured. The key is to identify the customer requirements "in their own words" and not in the words of a marketer or an engineer. Once the customer requirements have been defined in QFD, and documented using the House of Quality process (discussed later in this paper) a prototype concept design is assembled, tested, evaluated, and modified. The changes required to meet the customers' needs will 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 basic technical requirements of the concept maintenance vehicle. The ideas that were generated by the focus groups were recorded in a format called an affinity diagram which is an organized output from a team brainstorming session or a focus group. The purpose of an affinity diagram is to generate, organize, and consolidate information concerning a product, process, or complex issue or problem. Ideas were generated and written on a "post-it" which was put on the wall. After all ideas were generated by the group, the ideas were organized into logical categories and each category was named by the focus group itself. The focus groups used a relations diagram to study the relationships among aspects of the concept vehicle requirements and to identify root causes and effects. By identifying these 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 roadway maintenance vehicle and equipment requirements 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 representatives are on the outer edges of the highway maintenance activities and, as a result, they provide some of the most innovative input to the process. It is a project objective to capture the vehicle requirements 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. The focus group sizes, to be most efficient, varied between 15 and 20 participants. Five focus groups were conducted at four different locations: Cedar Rapids, IA., Roseville, MN., St. Cloud, MN., and Troy, MI. The activities of the focus groups were documented to capture the entire list of ideas and functional descriptions for the concept vehicle. As a result of the employee focus group activities, each partner state's department of transportation has developed a prioritized list and a detailed description of the concept vehicle functions available for technology transfer applications.

More than 650 ideas were captured during the focus group sessions. The ideas were grouped into vehicle status categories (at rest, pre operations, roadway systems operations, and post operations along with administration and infrastructure) and then into technology categories. The following listing shows a sample of those ideas and how they are technologically grouped for further analysis.

- Communications:
  - Hands free communication
  - Real time link with garage for repair purposes
  - Communicate weather/road conditions to public
- Controls in the Cab
  - Voice activated controls
  - Heads up displays
  - Verbal read back of systems functions
- Durability
  - Vehicle/equipment that tolerates major impacts
  - Impact attenuator on rear of vehicle
  - Corrosion resistant components
- Environment Sensors
  - Roadway friction/surface temperature sensors
  - Chemical condition of roadway surface
  - Collision avoidance sensors when visibility is poor
- Maneuverability
  - Short turning radius
  - Low center of gravity
  - Articulated vehicle
- Operator Ergonomics
  - Reduced vibrations/noise in the vehicle cab
  - Air conditioning
  - Adjustable control panels to fit a wide size range of operators
- Payload
  - Larger payload
  - Carry multiple materials and change on the run
  - Measure on board payload
- Snow Plowing
  - Multilane clearing with one pass
  - Adjustable, automatic wing plow
  - Flexible plow to match roadway contours
  - Automated pressure on all plows
  - Vibrating plow
  - Teeth on scraper blade for grooving ice
  - Front plow and wing—eliminate the snow cloud
  - Plows capable of operating at normal traffic speeds
- Spreading Material
  - Eliminate lumps in material/detect spreader plugging
  - Application of material controlled by roadway condition
  - Precise placement of material
- Traction
  - All wheel drive
  - Anti lock braking system
  - Automatic inflate/deflate tires for improved traction
  - Hovercraft to eliminate the friction concerns
- Vehicle Avoidance and Sensing Systems
  - System to warn public when approaching vehicle from rear
  - Backing sensor/monitors
  - Vehicle/obstacle avoidance systems

- Driver Visibility
  - Rearward visibility of equipment
  - Visibility during white-out conditions
  - Windows that stay frost and ice free
  - Improve nighttime visibility
  - Scratch free windows
- Visibility of Vehicle to the Public
  - Highly visible, reflective color
  - Eliminate snow cloud
  - Plow lights higher than equipment operator's sight line
- Wheels and Rims
  - Non-cracking rims
  - On board jacks for wheel repair
  - Flat resistant tires

A workshop was held on April 23, 1996 in Detroit, Michigan. Attendees included representatives from state departments of transportation, system integrators, and manufacturers of vehicles, vehicle components, and on board vehicle communications. The workshop provided a basis for reviewing the project with potential private sector partners and soliciting their interest in joining the consortium.

Participants were divided into three breakout sessions: vehicle manufacturers, communications and technology providers, and equipment vendors. Each session evaluated the ideas generated by the focus groups and concluded nearly all the ideas could be met with current off-the-shelf technology.

Each session member was asked to discuss their experience or familiarity with public and private partnering. Only two private companies had partnering experience. A great deal of interest was expressed in pursuing public and private partnerships in the development of the concept vehicle. The research team will select firms most capable of prototyping a concept maintenance vehicle.

The results of the QFD activities, which are the functional requirements evaluation activities, will be documented using a "House of Quality" (HOQ) diagram or process. The HOQ diagram will record the technical requirements as defined by the focus groups. The technical requirements will be evaluated by the research team using a weighted factor analysis and will determine the relative importance of the requirements. The next recorded elements are the technologies available to meet the technical requirements and an evaluation to determine their feasibility. The HOQ process will determine if technologies are conflicting in their proposed applications. The last step will incorporate the feasibility of each technology requirement. This allows the research team the ability to make educated recommendations for the proposed technologies and their potential in this research project.

In cooperation with the private sector partners, the state partners will collaborate to predict the manufactureability and feasibility of systems and subsystems that have been defined by the focus groups. This activity will look at the development of a prototype vehicle (or possibly one for each participating state) and its evaluation. In addition, a fleet evaluation will be anticipated and 30 production vehicles are planned to be provided and distributed to the consortium states.

A cost effectiveness analysis from the DOT's viewpoint will be conducted. The objective of the cost effectiveness analysis is to determine the DOT's financial justification for purchasing the concept vehicle. The analysis will answer the question. "Will the concept vehicle pay for itself within a reasonable length of time?" Cost indicators will include considerations such as increased operator comfort, increased utility, increased safety to the driving public, reduced driver delay, improved communications, and increased productivity for both field and office personnel. It is the desire of the research team to utilize measurement indicators already in place in the consortium states maintenance management systems.

Phase II: Prototype Evaluation

During the second phase of this project, manufacturers, systems integrators, and the research team will develop one prototype concept vehicle (or possibly one for each consortium state). An evaluation plan will be developed. After the prototype vehicle(s) has been built, it will be tested and the necessary or desired modifications will be made to improve the vehicle's design. The vehicle's performance will be evaluated following the structured 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 this time. Task descriptions for Phase III, a budget, and a schedule will be prepared as part of Phase II recommendations.

Phase III: Comprehensive Vehicle Evaluation

In Phase III, several vehicles will be built 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 agencies. During Phase III, an evaluation plan will be developed and a thorough evaluation of the vehicles will be made.

CONCLUSION

The project is ongoing at this time and is gaining momentum. The next step in Phase I is formation of public and private partnerships. That will be followed with a June meeting in Minnesota when the partners identify the customers requirements using Quality Function Deployment as a guide. Once the customer requirements have been defined, a prototype vehicle will be built and evaluated.

The schedule for completion of the entire project is driven by the desire to have a prototype vehicle(s) available for testing in winter snow removal operations during the winter of 1996-1997. To meet that schedule, the research team, which will include the private sector partners, the original consortium states, and additional consortium states who participate, will have to evaluate the technical requirements and assemble the prototype vehicle(s). At this time it appears that this is a justifiable schedule. After the prototype vehicle(s) has been in operation under normal winter snow and ice operations it will be evaluated for performance and modified as needed. The fleet evaluation of 30 new vehicles will need to coincide with the purchasing schedule for the participating DOTs. At this time it appears feasible to provide these production vehicles for the winter of 1997-1998. 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.