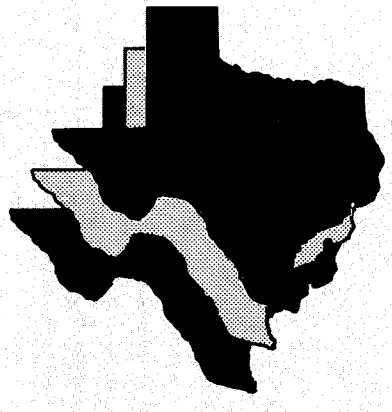
Summary Report 1440-1S
April 1994



DEPARTMENTAL
INFORMATION
EXCHANGE

AUTOMATION AND ROBOTICS FOR THE CONSTRUCTION, MAINTENANCE, AND INSPECTION OF THE TEXAS HIGHWAY SYSTEM

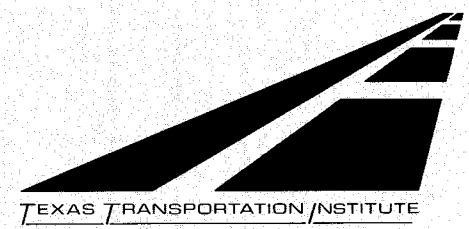
PROBLEM STATEMENT

Texas Department of Transportation (TxDOT) personnel working on the construction, maintenance, and inspection (CMI) of our infrastructure are performing some of the most labor-intensive and dangerous work in the state. Automation has the potential to remove workers from danger areas, increase safety for the motoring public, improve productivity, and reduce labor costs. What does the future hold for actual development and testing of CMI robotics hardware?

Automation, or Advanced Robotics Technology, involves the *use* of electromechanical devices that are designed to assist humans in performing their assigned tasks. For the CMI of highway facilities, this presents fundamentally different requirements. A CMI robot could not be preprogrammed with an exact response because the results of any automatic action will vary with time as the conditions surrounding it change. Because the need for mobility and easy adaptation to an uncontrolled environment, use of robotic technology in CMI tasks will most likely involve close interaction between man and machine. This means that before hardware development and implementation, to ensure operational efficiency, the viewpoints of all those who will be effected by automation of the task must be incorporated into an accurate definition of the problem. Only then can available or potential robotic solutions be screened for economic feasibility and prototype development.

OBJECTIVES

The Texas Transportation Institute (TTI) conducted study 1440, *Applications of Robotics and Other Automated Techniques to the Construction, Maintenance, and Inspection of Highway Systems* in cooperation with TxDOT and the Federal Highway Administration (FHWA). TTI researchers in the Construction and Automation and Robotics Laboratory (CARL) at Texas A&M University worked closely with TxDOT district and division engineers and field experts to identify CMI tasks which could possibly be improved through automation. They then consulted with Sandia National Laboratories' Robotic Vehicle Range to assess whether automated solutions or robotics technology



In cooperation with
Texas Department of Transportation
and the FHWA

Summary Report

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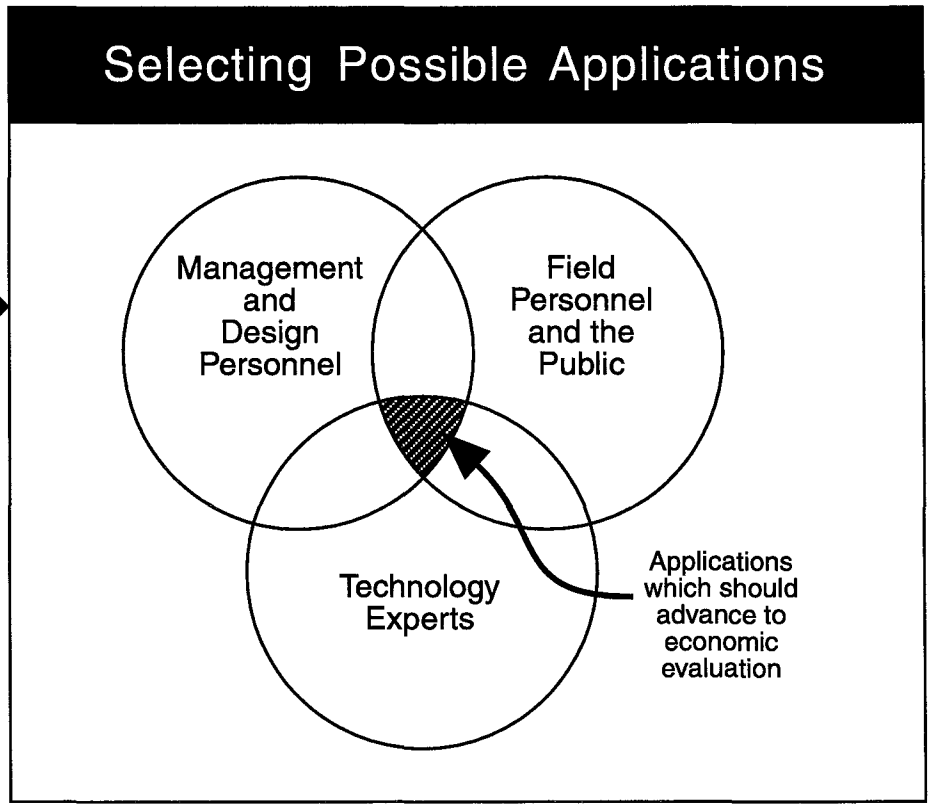
The Implementation Process Model

1. Identify potential application areas and alternative approaches.
2. Screen out operationally or technically infeasible applications (subjective filters).
3. Screen out uneconomic applications (objective filters).
4. Develop and lab test pathfinder designs.
5. Develop and field test prototype designs.
6. Manufacture, train, and implement the final product in the field.



could feasibly provide that improvement. Essentially, they asked the following questions in the identification process:

1. What CMI tasks present high risks or high costs?
2. Does that task present a possible robotics application?
3. How "robotfriendly" is that task?

The final product of the research is an automation implementation model which provides a systematic process of evaluation and elimination for CMI problem areas and, applying the first two phases of the model, a list of seven work areas that display a potential for robotics solutions.

FINDINGS

The Implementation Process Model

The recommended six-phase research and development process model works as an analysis framework going from concept initiation to field implementation:

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With the ultimate goal as the cost-effective development and implementation of robotic hardware for use with CMI work tasks, the researchers incorporated two nontraditional, "preprototype" research phases into the model—phases two and four, subjective filters and pathfinders.

Subjective filtering is a process of elimination in which three important groups—management and design engineers, field personnel and end-users, and technology experts—brainstorm to build a consensus about what robotic technology could be implemented at a reduced risk and cost. Specifically, TxDOT per-

sonnel answer such questions as: "What problems most concern TxDOT? What will be the equipment needs and set-up times, the effects of the potential robotic application on other tasks or operations, and the possible logistic problems in overall operations?" The answers to these questions guide the technology experts as they address the key question—"What exactly is out there that could be adopted, modified, and applied to the specific CMI task?" If an application passes through all three groups and a relatively feasible automation solution is identified, it then qualifies for the objective filtering phase, which examines the economic feasibility of conceptual designs.

After passing the objective filters, and before actual prototype development, the model advocates an interim phase, pathfinder development and testing. This involves the construction of laboratory test platforms where researchers compare candidate technologies, investigate different technological options for incorporation into the prototype, and adjust performance estimates from the economic analysis to the experimental results. If researchers can detect and correct major design or operational problems in a pathfinder, the prototype has a greater chance for a relatively low-cost, error-free field test, and then successful implementation.

Potential CMI Robotic Applications Identified

Working through the first two phases of the implementation model, several potential robotic applications and available technologies were identified in the first part of this study.

- Flagging for Traffic Control
- Culvert Clean-out and Inspection
- Drilled Shaft Inspection and Measurement
- Placement and Retrieval of Traffic Cones
- Nondestructive Testing of Roadway Density During Construction
- Underwater Structure Inspection for Scour and Corrosion
- Luminaire and Traffic Signal Bulb Replacement

All of the discussions on inspection revealed one central topic — What type of emissions will best probe the environment under inspection?

The study's final report details each application assessment and the reasons for recommending the application for further feasibility research or not.

"Flagging for Traffic Control" was dropped from further consideration at the end of the study. Interviews lead to the conclusion that it is more a human behavioral problem of the motoring public than a technological need for automation. While various technologies are available (portable traffic signals, remote control paddle and flag devices, message and arrow boards), there was a general reluctance among maintenance personnel to fully trust anything other than a fellow worker. "Traffic Signal and Luminaire Replacement" was also eliminated due to obvious economic unfeasibility and the increasing availability of fiber optic technology which would allow a more convenient location for the light source. If maintenance personnel can possibly repair the light from the side of the road, a robotic arm would be rendered unnecessary.

Four of the tasks were recommended for phase three research (economic feasibility studies). Since two existing machines were identified as already available, automatic placement and retrieval of traffic cones was classified as worthy of further research. Use of these automated devices can benefit high density traffic areas where cone placement and retrieval represents a major portion of the work day.

The three other potential robotic application areas all involve inspection: "Culvert Clean-Out and Inspection," "Drilled Shaft Inspection," and "Underwater Inspection for Scour and Corrosion." In fact, taken as a whole, all of the discussions revealed one central topic—what type of emissions will best probe the environment under inspection? Possibilities include atomic particles (neu-

trons), electromagnetic radiation, electric currents and fields, magnetics, and vibration/sound (shakers, sound, ultrasonics). Future research is needed to determine the economic feasibility of adopting and/or modifying the various existing devices that employ these measurement techniques and to see how effective they would actually be for the specific tasks.

IMPLEMENTATION

If robotic techniques are to be successfully implemented for the CMI of our infrastructure, then actual hardware must be built and tested under actual field conditions. This study has completed the first steps toward this goal by producing the necessary information about some CMI tasks that are appropriate for automation. Districts and divisions can use the developed implementation process model to continue identification of their own specific CMI problem areas in need of robotic automation.

Since ground penetrating radar (GPR) is already used in TxDOT's pavement management system and another study is currently investigating its effectiveness in measuring pavement layer thickness, researchers recommend an implementation study specifically targeted toward GPR for nondestructive testing of roadway density during construction. Also, the study advisory committee recommends that "Drilled Shaft Inspection" take the number one priority for further automation research.

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The information in this summary is reported in detail in TTI Research Report 1440-1F, "Applications of Robotics and Other Automated Techniques to the Construction, Maintenance, and Inspection of Highway Systems," by Walter W. Boles, Don A. Maxwell, Philip D. Heermann, Wesley D. Scott, Robert W. Adams, Connie J. Flickinger, Richard M. Gallegos, John A Mannering. November 1993. The contents of the summary do not necessarily reflect the official views or policies of TxDOT or the FHWA.