SHRP2
STRATEGIC HIGHWAY RESEARCH PROGRAM

PROJECT BRIEF R01 **MARCH 2009**

Renewal Project R01: Encouraging Innovation in Locating and Characterizing Underground Utilities

This document summarizes the findings of SHRP 2 Renewal Project R01 and identifies three follow-on projects for which requests for proposals were advertised in March 2009. The final report from this project will include a plan of research for the development of innovative tools and methods for locating and identifying underground utilities. The project will also produce a web-based database of utility locating and characterizing equipment. The Responsible Staff Officer for this project is Monica A. Starnes, who can be contacted at: mstarnes@nas.edu.

Accurately locating and characterizing underground utilities to protect or relocate them is a major cause of delay in highway renewal projects, drawing out project development and delaying construction starts. In addition, damage to underground utilities can raise environmental, health, and safety concerns. For these reasons, improved technologies are needed to locate and characterize underground utilities.

SHRP 2 Renewal Project R01 examines ways to encourage innovation in the location and characterization of underground utilities. Phase I of the project identifies the areas of highest potential for innovation and improvement; Phase II develops a research and development plan to advance promising technologies.

Methodology

Areas of specific need and promising innovations were identified through the following methods:

- Questionnaire responses from state and local transportation agency personnel, transportation design engineers, and firms that locate and characterize utilities;
- Searches of the relevant literature and of patents and patent applications;
- A Statement of Needs technology search distributed to the Federal Laboratory Consortium;
- Input from national and international organizations; and
- Case history analysis.

Utility Issues in Transportation Projects

Many factors contribute to problems that can arise when underground utilities are present in transportation projects. For example, records of utility presence, depth, and type are often incomplete, inconsistent, or inadequate for the needs of highway renewal projects. The fact that there may be multiple utility owners at any project location can cause further complications. Once utilities are located, additional problems may be encountered, including damage to the utility during construction. When project details are poorly planned, it may be necessary to move the utility more than once, or to disturb new pavement to accommodate the final correct utility installation. These problems are the basis for the widely recognized need for reliable utility location data and have given rise to the practice of subsurface utility engineering (SUE), which includes utility mapping, characterization, coordination, and design. SUE is most effective when systematically incorporated into organizational processes and introduced early in the design phase of transportation projects.

Utility Locating Technologies

Underground utilities can rarely be located visually; either remote means of location or excavation is required. Utility properties usually contrast those of the surrounding ground in terms of electrical conductivity, magnetism, heat, mass, electrical capacity, rigidity, etc. Geophysical location methods detect, image, and trace utilities by using these property contrasts. Many geophysical techniques for detection exist, but substantial improvements are required to achieve useful results. Two technical challenges associated with advancing the state of the art include, first, identifying new, more cost-effective techniques to locate and characterize utilities and manage the resulting data, and second, improving the detection abilities for difficult circumstances. The R01 project report addresses the range of both passive and active geophysical methods and summarizes the state of the art and of the practice for each method.

Developing and maintaining accurate and complete records of existing utilities provides the best means for locating them for future transportation projects.

Improved methods of permanently marking utilities with visible markers, tracer wires or tape, buried magnets, or other detectable devices hold promise for better results. Though many of these methods are not new, technological advances have led to more sophisticated marking devices and these are detailed in the final report. One such emerging permanent marking method is radio-frequency identification (RFID) tags or balls. Details related to an underground utility are programmed into the RFID tag, which later can be quickly discovered using a surface scan. Although RFID has been used in the field for years, these methods are still in a developmental stage and show strong potential for locating and characterizing utilities as technology advances are implemented.

Excavation is a more reliable means of locating utilities than the geophysical methods, although it obviously poses a greater risk of utility damage. Two popular methods of loosening the soil—air/vacuum and water/vacuum excavation—limit this risk. The water/vacuum method is a less expensive option, but it poses a greater risk of damaging utility wrapping and coatings than air excavation methods and the excavated soil is not suitable for backfill. A backfill material that is increasing in popularity is control density fill (CDF). When mixed and applied correctly, it is easily fragmented and removed; yet when mixed improperly, it can become as hard as concrete.

Developing and maintaining accurate and complete records of existing utilities provides the best means for locating them for future transportation projects. Aside from few owners, such as interstate pipeline companies, there is no mandate for who should prepare utility records or develop standards for their accuracy or completeness. Exposing utilities for construction purposes provides an opportune time to update existing records, but this activity is rarely included in a project schedule or scope.

Utility Characterization Technologies

The term 'utility characterization' refers to utility type, owner, size, material type, age, usage status, pressures, voltages, capacity, and condition. The report discusses various technologies for acquiring these basic characteristics through both external and internal inspection methods to identify metal loss, cracks, geometry, position, pressure carrying capacity, corrosion, bedding conditions, and pipe wall measurements.

Because only localized excavations are practical for external inspection, nondestructive tools are used to inspect buried pipes and these are detailed in the report. Internal inspection techniques have been a focus of development in recent years. Approaches to internal inspection include a range of technologies to provide visual or acoustic information. Lasers and sonar methods, nonlinear harmonics, magnetic inductance, and X-ray inspection can detect internal pipe geometry. Dye, tracers, focused electrode leak, and other technologies can test pipe leakage and integrity. It is expected that combinations of inspection systems will become more common as sensor integration improves and costs decline for multiple measurements.

There have also been advances in managing the data that result from utility mapping, record-keeping, condition assessment, and life-cycle costs that have important implications for the interaction between utility companies and transportation project owners. Current data management tools allow for planning proactive maintenance, rehabilitation, and replacement and can lower life-cycle utility costs. There are, however, no industry-wide standards for collecting characterization data.

Real risks are associated with not knowing if, where, and what types of utilities are located within highway right-of-way.

Possible Advancements

Improvements in detection capabilities, cost effectiveness, database integration, and real-time data retrieval are being advanced by a range of participants in both the transportation and utility communities. A sampling of promising technological developments includes an acoustic plastic pipe locator with a depth-to-diameter ratio capability of approximately 36:1 at a depth of 4 feet; plastic pipe that incorporates magnetized particles; merging a computer-assisted radar tomography array with an inductive array to produce digital mapping with a dual-array system; a multi-sensor time domain electromagnetic system that supports acquisition, processing, visualization, and interpretation of multiple sensor and supporting data in a 3D workspace; and underground sensing technologies developed for landmine and unexploded ordinance detection. These and other developing applications are described in the report.

Implications from Case Histories

The project final report includes case histories that highlight the benefits and results associated with locating and characterizing utilities. For instance, SUE mapping surveys are related to cost benefits in several studies: A 1999 Purdue University study reported that surveys performed when a project is 30% complete and using 0.125%–2% of the total construction costs, produce an average benefit-cost ratio of 4.6 to 1. A Virginia Department of Transportation (DOT) study found the ratio to be 7 to 1; a Society of American Value Engineers study documented a 10 to 1 positive ratio; and a Penn State University study for Pennsylvania DOT showed a 22 to 1 ratio. These ratios considered only savings in construction costs and schedule delays; costs associated with utility strikes and other qualitative measures were not considered.

Multi-channel Ground Penetrating Radar

Conclusion

Real risks are associated with not knowing if, where, and what types of utilities are located within highway right-of-way. Identifying and assigning costs to those risks will support rational decisions on appropriate tools and budgets for specific projects.

SHRP 2 Renewal research Project R01 identified and ranked potential solutions to the problems posed by underground utilities. Technologies that organize utility data and provide better methods of utility detection ranked higher than developments that would characterize utilities. Other highly ranked needs are guidelines that will maximize the benefit-cost ratio and further development of smart tagging technologies.

Three new research projects were drawn from the prioritized list of most-needed advancements and requests for proposals were released by SHRP 2 in

March 2009. These RFPs address the following topics:

R01-A: Innovation in Technologies to Support Storage, Retrieval, and Utilization of 3-D Utility Location Data in Highway Renewal

The goal of this project is to support the development of software and hardware to take advantage of recent advances in global positioning system and geographical information system technologies to increase the quality and efficiency of storing, retrieving, and utilizing utility records with three-dimensional positional information. It is also intended to demonstrate the collection and use of such information in a multi-utility environment. This would make it possible to reduce the time spent in repeatedly 'refinding' utilities so that resources can instead be focused on finding utilities that are unknown or incorrectly recorded. A comprehensive record of utility information beneath public right-of-ways would be a product of this practice.

R01-B: Utility Locating Technology Development Utilizing Multi-Sensor Platforms

The goal of this project is to support the technological development of multisensor approaches to improving the detection and accurate determination of position for buried utilities. Methods that leverage the presence of known utilities to improve detection performance are encouraged.

R01-C: Innovation to Expand the Locatable Zone for Underground Utilities

The primary objective of this project is to improve the detection and accurate determination of the positions of buried utilities within an expanded locatable zone up to Quality Level B as defined by the Construction Institute of the American Society of Civil Engineers' (CI/ASCE) standard 38-02, the Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data, using any appropriate methods without duplicating the scope of project R01-B. This objective may be accomplished by combining existing methods or developing new technologies. This project will also develop guidance that transportation agencies may use to include the developed innovative methods into their "Utility Accommodation Manual" and also can assist utility owners by expanding the locatable zone and improving detectability of future utility installations.

The research was conducted and a report was prepared by R. L. Sterling, J. Anspach, E. Allouche, J. Simicevic, C. D. F. Rogers, K. Weston, and K. Hayes. The lead institution is the Trenchless Technology Center, Louisiana Tech University. The cooperating organizations are So Deep Inc.; University of Birmingham, U.K.; and Civil Design & Construction Inc.

The Technical Coordinating Committee for Renewal Research in SHRP 2 oversaw the conduct of the research that is the basis for this report and reviewed its findings. The committee membership includes **Randell H. Iwasaki**, California Department of Transportation; **Daniel D'Angelo**, Office of Design, New York State Department of Transportation; **Thomas E. Baker,** Washington State Department of Transportation; **Thomas Callow,** City of Phoenix; **Steven D. DeWitt,** North Carolina Turnpike Authority; **Alan D. Fisher,** Cianbro Corporation; **Michael Hemmingsen,** Davison Transportation Service Center, Michigan Department of Transportation; **Dennis M. LaBelle,** M and T Consultants, Inc.; **William N. Nickas,** Corven Engineering, Inc.; **Mary Lou Ralls,** Ralls Newman, LLC; **John J. Robinson, Jr.,** Pennsylvania Department of Transportation; **Michael Ryan,** Michael Baker Jr., Inc.; **Cliff J. Schexnayder,** Chandler, Arizona; **Ronald A. Sines,** QC/QA Operations, P J Keating Company; **Doug Urbick,** A. Teichert & Son, Inc.; **Thomas R. Warne,** Tom Warne and Associates, LLC; **James T. McDonnell,** AASHTO; **Cheryl Richter,** Pavement R&D, Federal Highway Administration; **Steve Gaj,** FHWA; **Lance Vigfusson,** Manitoba Infrastructure and Transportation; **Frederick D. Hejl** and **Amir N. Hanna,** TRB Liaisons.

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