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Evaluation of subsurface utility engineering for highway projects: Benefit–cost analysis

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ABSTRACT

Accurate location of buried utility infrastructures is a vital issue for utility owners, utility managers and engineers, designers, and contractors that perform new installations, repairs, and maintenance on highway projects. Unreliable information on underground utilities can result in undesirable consequences such as property damage, claims, and other social and environmental problems. Subsurface utility engineering (SUE) is becoming a significant method for reducing the potential for underground utility conflicts at the project planning phase. SUE accurately identifies, characterizes, and maps underground utilities through four quality levels. This study presents a SUE benefit–cost analysis (BCA) to encourage a better understanding of SUE and the use of SUE. Eleven main benefit factors and two cost factors are identified and estimated on twenty-two SUE projects and eight non-SUE projects from Pennsylvania Department of Transportation (PennDOT) districts. In addition, this study reveals the relationship between benefit–cost ratio and complexity levels of buried utilities.

1. Introduction

As human society has flourished in modern times, more and more infrastructure systems have been constructed to meet an ever-increasing demand. However, the expansion of infrastructure has resulted in many problems in the construction industry. Underground utility damage at construction sites has been one of the major problems (Lew and Anspach, 2000). In general, the utility damage has been caused by inaccurate underground information. Existing records and visible feature surveys by site visit are typically 15–30% off the mark, and sometimes considerably worse (Stevens and Anspach, 1993). A one-call system was developed to solve the problem of inaccurate existing records. However, the information provided by one-call systems has not effectively met the need to accurately locate underground utilities. This one-call system only provides the information on buried utilities of members. In other words, information on existing utilities of non-members is not available in the one-call system. In addition, utility owners/operators who are notified by the one-call center incorrectly mark or even fail to mark their utility locations sometimes. Old utilities also may not be discovered under this system. Two or three days, timing of utility locations before actual construction, also may not be enough for utility companies to accurately locate and mark their underground utilities. Failure to use the one-call system at all is a further problem in utility damage during construction (Sterling, 2000).

Subsurface utility engineering (SUE) is an engineering process that utilizes new and existing technologies to accurately identify, characterize, and map underground utilities early in the development of a project (ASCE, 2002). As shown in Fig. 1, SUE is divided into four quality levels which are represented by different combinations of traditional record, site survey, geophysical technology, and vacuum excavation system. The accuracy and reliability of underground information increase from quality level D to quality level A, but the costs increase from quality level D to quality level A (Jung, 2009). SUE can be the most suitable and reliable method for reducing risks associated with uncertain underground information through geophysical technologies and non-destructive methods. This study takes an in-depth analysis of highway projects executed by districts of the Pennsylvania Department of Transportation (PennDOT). The key objective of this study is to perform a detailed benefit–cost analysis (BCA) to provide a better understanding of SUE and encourage the use of SUE. Eleven main benefit factors and two cost factors are identified and estimated on 22 SUE projects and 8 non-SUE projects. In addition, this study reveals the relationship between benefit–cost analysis and the varying complexity levels of buried utilities. The BCA can help owners and designers to select SUE for their underground projects.

2. Background on benefit–cost analysis of SUE

Designers and engineers who had an interview with this study expected numerous benefits on their own projects. The benefits are very crucial to all the parties concerned including the DOTs, utility

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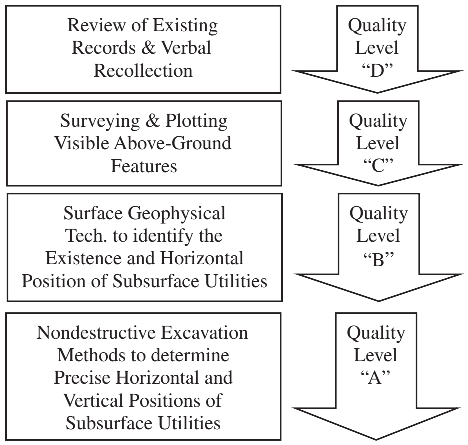

Fig. 1. Quality levels of SUE.

owners, designers, contractors and engineers. SUE improves design by using accurate underground information and construction by reducing unnecessary utility relocations, utility damages, and social and environmental damages. Ultimately, these benefits frequently result in reductions in time and cost for whole projects (Jung, 2009).

Stevens (1993) presented that administrative cost savings were found to be 2% of overall project costs, engineering cost savings yielded 0.5%, construction costs realized savings of 2.25%, overrun costs realized savings of 5%, and utility relocation cost savings yielded 5%. The results of his research showed that the total cost savings of SUE projects may range from 10% to 15% of overall project costs on a typical project. Lew (2000) developed 21 categories to quantify the savings in terms of time, cost, and risk management aspects after conducting interviews and surveys of DOTs, utility owners, SUE consultants, and contractors, and analyzed 71 SUE projects by studying the projects in detail. He resulted in an average of \$4.62 in savings for every \$1 spent on SUE, ranging from \$0.34 to \$206.67. Brown and Mckim (2002) presented various benefit–cost ratios on SUE. In their research, a study by Virginia DOT stated \$7 in savings for every \$1 spent on SUE, the Society of American Value Engineers (SAVE) showed a 10:1 return rate, and Maryland DOT showed an 18:1 savings. Jeong et al. (2004) modified the results of the Purdue Study (Lew, 2000) after reanalyzing the same data. In their research, the average ratio of the cost of SUE to the total construction was 1.39%, ranging from 0.02% to 10.76%, and a cost savings of \$12.23 for every \$1 spent on SUE was quantified in 71 SUE projects. They indicated that a reduced number of utility relocations was the most outstanding cost savings, with 37.1% in SUE cost savings. Reduced claims and change orders were ranked as second contributors to cost saving, at 19.3%. Reduced accidents and injuries and reduce project delays represented 11.6% and 9.6% in SUE cost savings, respectively. Other cost savings that account for 22.3% included reduced right-of-way acquisition costs (3.5%), induced savings in risk management and insurance (3.3%), and other categories (15.5%). Osman and El-Diraby (2005) analyzed nine SUE projects in Ontario, conducting interviews and project case studies. They identified 11 cost saving items from the 21 cost savings items used by Purdue Study. The results of Ontario Study showed that the average return-on-investment (ROI) for SUE is approximately \$3.41 for each \$1 spent, ranging from 1.98 to 6.59. In addition to previous studies, FHWA reported that the use of SUE nationwide could result in cost savings exceeding \$100 million per year for highway work alone and a state utility engineer of the Virginia DOT indicated that \$700,000 worth of utility conflicts was eliminated, with less than \$100,000 used for SUE in a project in Richmond (Anspach, 1994).

3. SUE benefit–cost analysis

The studies outlined above have shown that using SUE can save money on projects involving underground utilities. This study describes a benefit–cost analysis that further quantifies the cost savings of SUE. The BCA identifies how much money can be saved per dollar spent on SUE. This study uses both SUE projects and non-SUE projects to quantify the cost savings of SUE, while previous studies used only SUE projects. This approach can increase the reliability of benefit–cost values.

4. Benefit–cost analysis

Benefit–cost analysis is an approach that is preferred to prove the effectiveness of new systems or techniques. BCA estimates the equivalent monetary value of the benefits and costs of projects to determine whether or not the systems or techniques are worthwhile. The BCA of SUE is conducted with SUE projects and non-SUE projects that have problems related to underground utilities. B/C (Benefit/Cost) is the fundamental relationship in BCA. When $B/C > 1$, utilizing SUE provides more beneficial results than not using SUE. If $B/C \leqslant 1$, there is no reason to utilize SUE. All projects in this study were collected from district offices of PennDOT. Estimated benefits and costs were investigated by conducting interviews with PennDOT utility engineers who were involved in the projects, analysis of historical data, review of individual project studies, and actual benefits and costs derived from direct costs of projects.

4.1. Benefit–cost analysis of SUE projects

In SUE projects, benefits are estimated costs that are derived from utility engineers' feedback, historical data, and individual project studies. The benefits are determined from the differences in underground utility information before and after using SUE. SUE costs were obtained from direct costs of using SUE in the projects. Equation 1 shows the equation for the benefit–cost ratio (BCR) of SUE projects.

$$BCR_{SUE} = \frac{B_{SUE}}{C_{SUE}} \tag{1}$$

where BCR_{SUE} is benefit–cost ratio of SUE projects; B_{SUE} is estimated benefits of SUE projects; and C_{SUE} is actual SUE costs of SUE projects.

4.2. Benefit–cost analysis of non-SUE projects

Previous studies utilized only SUE projects to quantify cost savings of SUE. Those studies inferred estimated costs as SUE benefits from utility conflicts that were revealed by SUE. However, as Osman and El-Diraby (2005) mentioned, the mere identification of utility conflicts does not necessarily result in a cost being incured. In this study, non-SUE projects with problems are also used to determine the cost savings of SUE, because they can provide direct costs as SUE benefits incurred from problems related to utilities. SUE costs of non-SUE projects must be inferred, since SUE was not used. The SUE costs used are estimated costs, which are determined with input from PennDOT utility engineers, historical data, and individual project studies. Eq. (2) shows the equation for the benefit–cost ratio of non-SUE projects.

$$BCR_{\text{non-SUE}} = \frac{B_{\text{non-SUE}}}{C_{\text{non-SUE}}} \tag{2}$$

where $BCR_{\text{non-SUE}}$ is benefit–cost ratio of non-SUE projects; $B_{\text{non-SUE}}$ is actual benefits of non-SUE projects; and $C_{\text{non-SUE}}$ is estimated SUE costs of non-SUE projects.