Automation in Construction 20 (2011) 729–739

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

A spatiotemporal database approach to the management of utility work schedules in transportation projects

Ssu-Min Tseng, Chien-Cheng Chou *, Ting-Wu Ho, Chia-Ying Lin, Te-Che Chen

Department of Civil Engineering, National Central University, 300 Jhongda Rd., Jhongli, Taoyuan 32001, Taiwan

ARTICLE INFO

Article history:
Accepted 16 January 2011
Available online 11 February 2011

Keywords:
Pavement
Utility cut
Utility permit
Databases
Scheduling
Infrastructure

ABSTRACT

As more and more utility installation and/or maintenance activities are located in highly congested urban roadways, frequent pavement utility cuts in such areas may cause more traffic disruptions and reduce pavement lifespan and quality. One way to lessen such inconvenience to the traveling public is to combine utility activities together in the hope of reducing unnecessary pavement utility cuts, which requires extensive coordination of the utility owners involved and deliberate management of utility work schedules. In this research, an information model and a system based on spatiotemporal database techniques were proposed to help public road authorities manage utility work schedules better. Issues such as constraints of utility permits, pavement moratorium, and utility clearance restrictions were addressed, and examples showing real utility activities and constraints were elaborated to test the functionality of the proposed model. The model can serve as a new managerial tool to facilitate the utility coordination process between public road authorities and utility owners.

1. Introduction

As more and more people dwell in urban areas, an increasing number of utility installation and/or maintenance activities are located in such areas that make a great impact on paved roads. The steady escalation of the internet penetration rate demonstrates the need for more communication equipment such as fiber broadband lines or wireless access points to be deployed along urban roadways in the near future. In order to provide new services or maintain deteriorating utility networks, utility owners have to cut pavements open, install new utility facilities or fix identified problems, backfill proper materials, and restore road surfaces. Reports showed that in the District of Columbia, USA, there were over 5000 utility cuts in 1996 and over 6000 cuts in 2000 [1]; in New York City, more than 250,000 cuts a year were made in 1999, and the number increased by 8% each year [2]. Another study indicated that utility activities in the UK rank as the second major cause of traffic disruptions, with estimated delay costs of $13 billion dollars, and uneven pavement surfaces due to frequent utility cuts may further result in driver annoyance and other safety issues [2]. Researchers have pointed out that pavement utility cuts are a major problem in the transportation infrastructure of the USA, not only reducing the pavement life by 7–12 years [3] but creating serious financial stress on public road authorities [1,4]. In sum, pavement utility cuts are increasing, and a systematical approach to helping public road authorities alleviate the inconvenience caused to the traveling public is needed.

Since utility owners need to obtain permits from public road authorities before commencing their work [4,5], the authorities should be able to collect the schedules and maps of all planned utility activities. If an information model and a system considering both temporal and spatial properties of utility activities are utilized, the authorities may be able to detect any potential conflicts between these planned activities. Further, because encouraging utility owners to work together is generally recognized by public road authorities as a potential strategy to reduce unnecessary pavement utility cuts [6,7], it could be realized by examining these schedules from utility permits submitted in order to identify the utility activities that can be performed together. Additionally, using an information system capable of handling spatiotemporal data might help the authorities check more factors when issuing utility permits. For instance, newly constructed or overlaid roads require a certain period of pavement cut moratorium [3]. A comprehensive protection strategy for these roads against any utility work could be implemented if the pavement moratorium information can be completely entered into the system, and if the authorities can examine the space and time conflicts between the pavement moratorium and utility permit data. Currently, no such information systems or research studies exist. Hence, a managerial tool that can keep track of the schedule and geometric boundary of every planned utility activity is highly desired. Any

* Corresponding author. Tel.: +886 3 4227151x34132; fax: +886 3 4252960.
E-mail address: ccchou@ncu.edu.tw (C.-C. Chou).

0926-5805/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.autcon.2011.01.004

potential cooperation between utility owners that might reduce unnecessary pavement utility cuts would be detected by such a tool, and public road authorities can use the suggestions generated to persuade the utility owners to work jointly.

To this end, this research aims at investigating an information model that can help public road authorities better manage utility activities to reduce unnecessary pavement utility cuts. A literature review regarding problems associated with utility activities and their overall impact is described first. The proposed information model that is designed to best describe spatial and temporal properties of planned utility activities is presented next, followed by model exploitation and evaluation of the prototype's software architecture. The example required to validate the model is described, and finally research conclusions are made.

2. Literature review

Several approaches to reducing unnecessary pavement utility cuts have been proposed and investigated. All were designed to cause minimum disturbance to traffic and to have a low impact on the environment. Briefly, these approaches can be categorized into two types: technology-based and policy-based approaches [1]. The technology-based approaches such as the trenchless technique focus on construction methods, practices, tools, use of special pavement materials and so on that can be employed to ensure pavement integrity while performing the utility work [1,8]. The policy-based approaches focus on how to allocate construction resources, how to manage organizations and teams, and how to communicate and coordinate with project stakeholders in order to control frequent pavement utility cuts. The technology-based approaches usually accompany high initial cost and short history of proven success, whereas the policy-based approaches often involve incentives, disincentives, and changes of permit procedures that utility owners must follow to complete their works [1]. In fact, more researchers investigate the technology-based approaches. The policy-based approaches receive less attention in the literature; however, the trend is for the number of pavement utility cuts to escalate, public road authorities might need a managerial tool that can assist project managers in condensing or rescheduling the work schedules of planned pavement utility cuts performed by different utility owners in order to minimize the impact on the traveling public [5,7]. For example, assume that utility company *A* will install new facilities in a street during certain days, and utility company *B* will perform maintenance activities in the same area but one month later after completion of *A*'s work. If both *A*'s and *B*'s work schedules are flexible, the public road authority might be able to persuade *A* or *B* to reschedule its work so that the works can be performed consecutively or jointly. Identifying the project circumstances where two or more different utility activities can be combined together is very important to public road authorities because the influential area of pavements due to utility cuts can be carefully calculated so that both the number of utility cuts and the affected area can be minimized [6].

In addition to reducing unnecessary pavement utility cuts, public road authorities also face a challenge regarding the increasing number of interferences between the existing and the planned but not-yet-deployed utility facilities [9]. Public road authorities or other public agencies may prescribe the clearance distances between certain types of utility lines [9]. For instance, the government regulations in Taipei City state that any gas pipeline must have at least 5–6 m of horizontal separation. Calculating the influential area of a pavement utility cut requires consideration of these planned utility facilities. Research has shown that utility permit procedures may take significant time because public road authorities need to consider a myriad of factors when determining whether to issue the permit and coordinate with other organizations to address concerns such as environmental and archaeological issues [10,11]. Let us assume that a utility company has obtained its permit for placing new pipelines, and another utility company is in the process of acquiring its permit application to install new facilities. Without proper coordination and communication with the two utility owners, the public road authority might not be able to detect any possible clearance violation of the new utility facilities and still issue the permits. Hence, additional pavement utility cuts may be needed when one of the utility owners performs adjustments to fix the problem. The clearance violation might be resolved if the road segment involving the two utility owners will be rehabilitated jointly because there will be a coordination meeting hosted by the public road authority to address each party's concerns [4,5]. This is due to the fact that sometimes utility owners are willing to hold discussions with each other if the public road authority is involved [6,7]. Intermediate utility facilities to maintain the service during utility work are another possible source of utility interferences [4,9]. For instance, if water main lines are underneath temporal power distribution poles, serious problems such as voltage shortage or overloading may happen. Therefore, managing interferences of planned utility activities is becoming a nightmare from the perspective of public road authorities [4,9]. To reduce unnecessary pavement utility cuts, public road authorities require a systematical approach to effectively and efficiently manage any future utility installation and/or maintenance activities.

In fact, several geographic information systems (GISs) have been proposed to automate the utility permit process. These systems can keep track of the locations, ownerships, service types, sizes, materials and other relevant characteristics of utility facilities. For instance, Collier and Kranc [9] proposed a computer program to help grant or deny utility permits by checking physical constraints to installation, safety, and total cost. The program can examine a large set of possible installation configurations. Quiroga and Pina [10,11] developed a prototype to automate the utility permit data entry process and to design a mechanism to help maintain the data inventory of utility facilities. This prototype implemented adequate positional accuracy and utility installation documentation procedures. However, current GIS technologies do not support temporal data processing [12]. Therefore, the proposed utility permit information system might need to extend GIS's internal database components so that spatiotemporal data can be properly processed.

Another factor that might undermine the streamlined process of utility permits is the accuracy of existing utility facilities' locations on the map, especially when their as-built drawings and related documents are incomplete. Nowadays, utility owners and public road authorities have applied global positioning system (GPS) and GIS-based tools in collection of field utility data for ground-level and above-ground utility installations. These tools, such as the ones provided by Trimble, can help converse GPS spatial and attribute data collected into a GIS-based database [10,13]. Data dictionaries regarding the possible values of each utility attribute should be defined in handheld GPS devices in order to speed up the data entry process in the field. Utility location data can be differentially corrected either in the real time or post-processed mode and reach a horizontal positional accuracy of about 0.6 m (95% confidence level) [10]. On the other hand, the location information of underground utility installations can be obtained by applying ground penetrating radar (GPR) or subsurface utility engineering (SUE) techniques [14]. Hence, if integration work of all utility data is properly conducted, the end result will be an updated enterprise GIS database with sufficiently accurate utility network information accessible to every engineer.

Overall, if public road authorities would like to better manage the utility activities, they might need to pay more attention to the utility work schedules and boundaries and use a computerized tool to precisely depict the spatiotemporal information of each planned utility activity. The following section elaborates more temporal and spatial requirements of each utility activity so that an information model to capture such requirements can be proposed.