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Email-based system for documenting construction as-built details

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ABSTRACT

Detailed as-built information is essential for progress tracking, corrective actions, and schedule analysis. As-built documentation, however, has mainly been a manual process that is time-consuming and error-prone. This paper proposes a low-cost framework that utilizes prevailing communication tools (email) to develop a project-wide system for progress tracking and bidirectional communication between project participants and head office. The framework integrates three main components: email forms for site data collection; customized scheduling application; and customized email application. In the schedule, the activities automatically initiate email requests for as-built information using an email form that has a checklist of possible site events and enables supervisors to attach notes and any requests for information. On a daily basis, the system automatically reads the supervisors' response emails and updates the schedule with all recorded as-built details. The paper discusses the development of a prototype system and demonstrates its usefulness on a small bridge-pier foundation example.

1. Introduction

As-built information plays an important role in performance analysis, corrective action planning, and later operation and maintenance of projects [1,2]. The sheer volume of as-built information, however, comes from different sources and in different forms [3] such as schedules, construction methods, cost data, resources, quality control data, written and verbal communications, daily progress and site events, and change orders. Such information is often unclear and not properly documented, thus contributing to misunderstandings, incorrect assessment of project performance, and lack of early warnings.

Until recently, on-site progress data collection has been mainly paper-based, which has been reported as one of the major problems that cause project delays and cost overruns [4]. Manual methods are slow, inaccurate, incomplete, time consuming, and labor intensive [5,6]. These limitations deviate the managers and their teams from solving actual problems and force them to spend most of their time dealing with secondary issues [7,8]. The study of McCulloutch [7], for example, reported that 30–50% of field supervisors' time is spent on recording and analyzing field data.

In view of the challenges related to site information tracking, researchers have examined various site data collection technologies (for progress tracking or field inspection) that range from low-end (paper-based) to high-end (e.g., sensing technologies, etc., as discussed later). Efforts that improve the traditional paper-based processes [9,10] aim at easing the manual work involved (Table 1). In between the low-end and high-end tools is a group of affordable and high-potential tools that include multimedia [11], information and communication technologies such as voice and wireless [12–15], hand-held tools [16,17], and web-based tools [18,19]. Many of these efforts served to mainly demonstrate the potential benefits of the tools, however, most efforts did not offer a project-wide automated solution for project control. The use of multimedia, for example, has been proposed since 1990 to improve data collection for delay analysis purposes [11] by recording video files as attachments to the activities in the schedule. While this is useful, it is still up to site personnel to find the time and effort to collect this information and link it to the schedule. Also, utilizing this information (e.g., understanding the percentage complete from a video) is still a manual process.

In addition to multimedia, various low-cost and high-potential IT tools have become commonplace, including Interactive Voice Response (IVR) systems, email service, and Short Message Service (SMS). These technologies have great potential for collecting and sharing site information in a timely manner. IVR is an efficient tool that can be used in a voice-based system to enable interaction with the user to automatically input information into the system by voice. Also, it can be used to access information from computer systems efficiently [13,14]. Email, on the other hand, has also become a popular form of data collection, exchange, and sharing [20]. In general, email is the most economical mean to send and receive mail in a fast way. Using email for collecting and tracking construction site information, therefore, is not only efficient but also cost-effective and has no geographical barriers. Because of its availability, affordability, and great potential, email has been utilized in this research and will be extended in the future to include IVR.

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Table 1
Comparison of available site data collection technologies.

Function	Technology		
	Low-end	High-potential	High-end
	Manual/paper-based	Multimedia, voice, phone, email, etc.	Sesing technology, 3D laser scanning, etc.
Communication with site Tracking daily progress Schedule updates Progress analysis Attach site events to activities Attach documents to schedule Respond to RFIs	All manual functions	All automated in the proposed system	Under development by many researchers Currently very expensive Not addressed in this research
Applies to	Small projects	Small/medium projects	All projects

Recently, several researchers in the literature have examined emerging high-end technologies (e.g., barcoding, RFID sensors, 3D Laser scanning, photogrammetry, GPS) for on-site real-time progress monitoring; tracking labor productivity; and tracking materials and equipment. Barcoding and radio frequency identification (RFID), for example, have been used to track the locations of resources [21–24]. Image recognition and 3D laser scanning have been used to track the quantities of work performed on site [6,25,26]. Photogrammetry has also been integrated with other tools such as 3D laser scanning [27] to extract 3D data from 2D progress images. With their high automation potential, continued research on these high-end tools is expected to reduce their future cost of implementation in projects.

With the potential of low-cost IT tools (email and electronic messaging) clearly demonstrated in the literature, this research aims at integrating such technology into a project-wide communication and documentation system that automates the manual functions in Table 1. This includes full documentation of the as-built evolution as well as facilitating corrective action decisions and schedule analysis.

2. Level of detail in as-built information

The project manager's ability to decide on appropriate corrective actions or to do forensic schedule analysis requires enough details on how progress events of all parties have evolved, including work stops, acceleration, rework, etc. In order to introduce realistic and practical support for project control, it is important to examine the level of as-built detail at which project control decisions can be efficiently done. Basically, an additional level of detail will only be necessary if such detail will directly impact project control decisions. Examining different level of project as-built details can be demonstrated by the example in Fig. 1. The figure shows the as-planned schedule for a simple 4-activity case, against two cases of as-built details. The as-planned duration is six days (the top path has two days of total float), while the as-built duration is nine days (the top path became critical), with project delay being three days. Brief explanation of the two cases and the analysis of their as-built schedules are as follows:

Case 1. This case shows a typical representation of progress as provided by existing commercial software. This as-built schedule can be determined using least amount of information which is the actual start and actual finish times of each activity (percentage complete is 100%). Such level of information does not describe the party responsible or the reason behind any daily interruption. Accordingly, due to the lack of details, the responsibility for the three-day project delay is allocated as sole contractor responsibility.

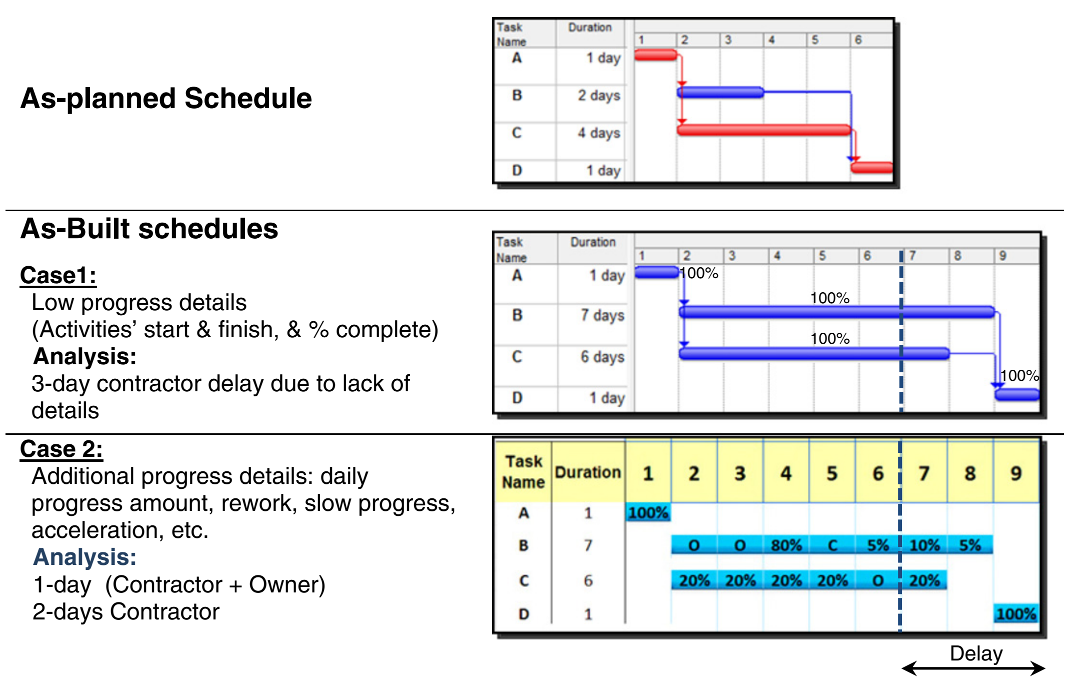

Fig. 1. Different levels of as-built details have different implications.