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Using Interactive Voice Response to Enhance Site Information Tracking

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Abstract: This paper presents a practical framework that utilizes Interactive-Voice-Response (IVR) and Email technologies to facilitate full documentation of construction as-built details. First, activity-specific flow diagrams have been developed to guide IVR sessions and a cloud-based IVR service has been used to develop a prototype system with both Email and IVR capabilities. For practicality, the system has been designed for bidirectional voice/Email communication. It allows activity supervisors to initiate calls/Emails for progress updates, and also allows eligible activities on the office server to automatically initiate progress requests. In case of information requests, the system automatically contacts the responsible person and sends the responses back to the supervisors. In addition, the system introduces a new legible representation of the schedule, following the Critical Path Segments (CPS) technique, in which all as-built information are shown on annotated daily segments. So that accurate critical path analysis is performed at the segment level not the activity level. The paper discusses the design and implementation of the proposed framework and demonstrates the benefits of its improved bidirectional communication and visual as-built representation in greatly enhancing project control.

1. Introduction

One of the greatest challenges facing construction managers in controlling projects is to keep track of all actions that take place on site in order to facilitate progress analysis, detect potential problems, and select appropriate corrective actions (Wang et al. 2007). Moreover, documenting work progress with supported documents provides clear information to update all project participants with up to date project progress (Ahsan et al. 2009). Current as-built documentation, however, has mainly been a manual process that is time-consuming and errors-prone (Trupp 2004; Navon 2007), thus contributing to misunderstandings, incorrect assessment of project performance, and lack of early warnings. To facilitate decisions on appropriate corrective actions and forensic schedule analysis, enough details are required on how the progress events of all parties have evolved, including work stops, slow progress, acceleration, rework, etc.

Existing commercial scheduling software represented activities as continuous blocks of time for certain durations (Figure 1-a).This representation, however, does not show the mid-activity events made by the various parties, and thus, does not facilitate schedule analysis. As opposed to this representation, Hegazy and Menesi (2010, 2012) presented a critical path segments (CPS) approach that has a much richer representation of mid-activity details (Figure 1-b), coupled with a refined critical path analysis done at the daily segment level to avoid calculation errors. As shown in the figure, activity durations are divided into daily segments and each time segment can hold progress amount or other events made by any party, in addition to notes, hyperlinks to related documents, and explanations. Recording (or averaging) the progress percentage on the daily segments clearly conveys information related to speed of construction (actual vs planned). The daily segments also can represent the events that occurred on specific dates and caused by the

owner “O”, the contractor “C”, and/or neither “N” (e.g., weather). Rework amount is also represented as a negative percentage complete recorded on the relevant time segment(s) (Hegazy et. al. 2011). Such a generic activity representation clearly shows the evolution of all as-built events and allows a more granular level of detail at the segment level, which is general enough to facilitate corrective actions and schedule analysis. Due to its rich visualization and its usefulness for project control, the CPS representation has been used in this paper. The additional details of this representation, however, will require a large effort to collect data from site using manual methods. This paper, therefore, aims at automating the data collection process using affordable IT technologies such as email and interactive voice response (IVR) systems. Early effort by the authors (Hegazy and Abdel-Monem 2012) surveyed variety of IT tools for site data collection, ranging from low-end to high-end, then developed a basic email-based progress tracking system, which is expanded in this research to include interactive voice features.

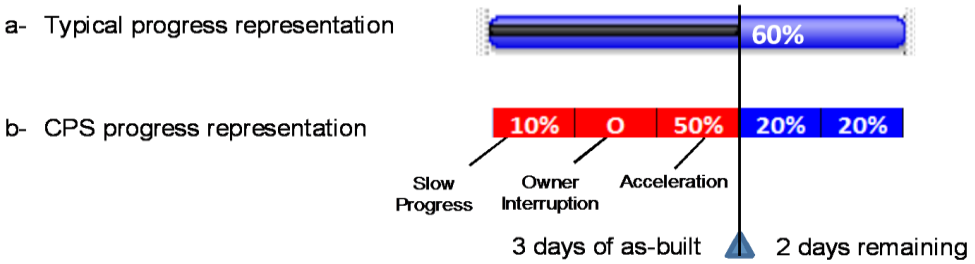

Figure 1: Higher level of as-built details in CPS representation

2. Voice-Based Applications In Construction

Research on using voice-based system has grown rapidly over the years as technology advances fast. Early efforts used voice recording as part of multimedia systems (including pictures and videos) that are statically attached to various activities (Abudayyeh 1997). Recently, the use of voice has matured and has incorporated advanced features such as voice recognition and voice commands (Sunkpho and Garrett 2000; Reinhardt and Scherer 2000). Sunkpho and Garrett (2000) for example, used voice commands to facilitate bridge inspection documentation using hand-held devices. Voice recognition was also utilized in construction by (Tsai 2009) to record and update site material logs. A recent survey by Ahsan et al. (2009) investigated the communication preferences in UK construction industry and concluded that communication by phone and cell phone were the first and second preferences, followed by email and SMS. Currently, phone systems are running over the Internet using Voice over Internet Protocol (VoIP) or internet telephony. Such powerful and low cost tool can bring tremendous savings in communications expenses (Liao andTseng 2010).

Among the powerful voice-based technologies for phone communication is IVR, which has been extensively used by various companies for technical support purposes, but has not yet been utilized in construction site communication. IVR is an efficient tool that has great potential to be used for automatic bidirectional communication between site and head-office in a cost-effective manner that has no geographical barriers. It can be concluded that using a combination of IVR and email tools will greatly benefit the construction firm to track site information efficiently. IVR is a telephony technology that allows interaction between callers and a phone system to acquire or enter information into a database. IVR enables the caller to select from pre-set options to enable a specific activity to occur such as paying a bill, scheduling an appointment, or calling for a field inspection of construction. IVR today also offers speech recognition, text-to-speech, fax or email required forms and information. In recent years, with greater development of phone and computer technology, IVR has expanded to include different features such as the ability to immediately post and review inspection results, fax or email inspection reports and other information, and fax or e-mail required forms and documents requested by users.

Different cities in Canada and United States (e.g. City of London, City of Toronto, Washington Country Government) have applied IVR technology since 1990 in their system to facilitate and automate the information and assistance required by their customers. This service is operational seven days a week (almost 24 hours a day) including schedule, reschedule or cancel inspections, check or review status of their requests, obtain inspection results, and leave messages for the inspectors or contractors. Therefore, IVR can be used to automatically connect site personnel (e.g. inspectors or contractors) with the head office, enter or retrieve information from database system, respond to urgent information requests, and convey a short notification for a number of people immediately.

3. Activity-Specific Site Events

Developing an automated system for as-built documentation requires a good understanding of the activities' tracking needs and possible site events. Previous research by the authors (Hegazy and Abdel-Monem 2012) has been done focused on highway projects, to analyze all daily site events related to highway construction activities. In this research sample daily as-built forms and as-built drawings were first analyzed and a comprehensive literature analysis (e.g., Ellis and Thomas 2002; Assaf and Al-Hejji 2006; Ministry of Transportation and Infrastructure 2012) that address highways' activities daily site events, common delays, site requirements, and construction precautions were deeply analyzed. Accordingly, common site events related to each activity are highlighted; Table 1 summarizes the common site events related to each activity. Based on this information, activity-specific IVR flow diagrams have been designed to simply collect complete as-built data by phone. The diagram has dynamic questions related to four categories of information: progress amount; events by different parties and their reasons; quality control/safety issues; and request for information (RFI). The flow diagram is dynamic in the sense that the sequence and content of questions are changed according to current status of the activity, the possible site events, and the user's answer (i.e., the call is directed to various branches depending on the previous answer). Such dynamic features can collect complete site information and save supervisors time.

Table 1: Possible site events for highway activities

Activity	Events related to		
	Owner	**Contractor**	**Third-party**
Mobilization	Delay in site handover or access	Delay in material/ equipment delivery Delay in obtaining permits	Bad weather
Clearing & Grupping	Late permits of right of the way Differing site conditions Work scope changes	Distant disposal area Shortage or equipment breakdowns	Bad weather
Survey & Staking	Approval delay Modifications in drawings/specifications	Error in benchmarking Difficulties in site conditions Unqualified workforce	Bad weather
Excavation	Delay in inspection or testing Differing site conditions	Damage to existing utilities Difficulties in site condition Unavailability/ delay of site utilities	Bad weather
Grading	Delay in inspection or testing Delay in material/equipment delivery	Traffic restrictions at job site Equipment shortage or breakdowns	Bad weather
Underground Utilities	Work scope changes Delay in inspection or testing	Relocation for utilities Utility is not protected as required	Bad weather
Asphalt Paving	Delay in inspection/testing Errors/discrepancies in design docs.	Bad surface preparation Traffic restrictions at job site Asphalt paver breakdowns	Bad weather
Concrete work	Delay in inspection or testing Errors or discrepancies in design docs.	Bad surface preparation Traffic restrictions at job site Delay in material/Equipment delivery	Bad weather
Electrical & Signage	Late approval Errors/Modifications in drawings/specs	Error in sign work Unforeseen site events Shortage or low productivity of labors	Bad weather

The IVR flow diagram of each activity has been implemented on an internet telephony server (ifbyphone, 2012) by creating a list of 18 linked questions (partially shown in Figure 2). Using such IVR application allows users to customize the questions (multiple choices, prompt question, play recorded message, record supervisor voice, etc.).

For example, question 2 asks the activity's supervisor if there was any progress on that date and gives two choices (press 1 for "yes" or press 2 for 'no"), as highlighted in Figure 2. The applications can be set so that the questions are read to the supervisors using Text To Speech technology (TTS) or through a recorded message. It also has other features such as call transfer to a certain number, send instant messages/notifications to supervisor's phone or Email, and record supervisors' answers. Using the activity-specific flow diagrams ultimately minimizes the time and cost wasted in site data collection and facilitates bidirectional communication between site personnel and project participants.

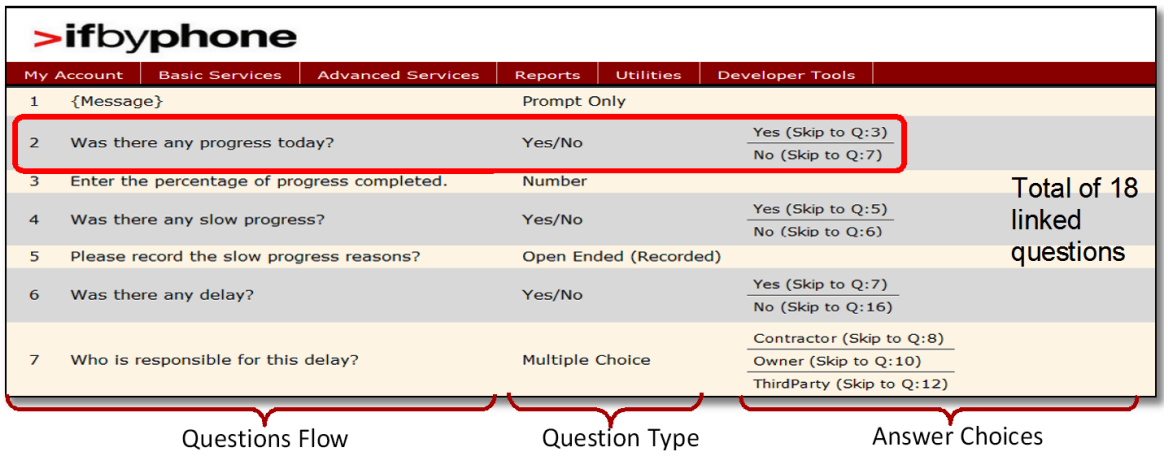

Figure 2: Implemented IVR survey on cloud-based service.

4. IVR-Based Framework For As-BuiltTracking

To facilitate automatic bidirectional communication between site and head office, the email-based system developed by Hegazy and Abdel-Monem (2012) has been expanded to include email and IVR technology, the framework components as shown in Figure 3. The supervisors are contacted by the automated system to provide complete actual as-built details about the progressing activities (e.g., progress amount, text/voice of site events, responsible party, and any RFIs) which facilitate good understanding of project progress, corrective action needs, and schedule analysis.

The proposed framework enables the activities, on a daily basis, to automatically call or email their supervisors for as-built information update, analyzes the received responses, and accordingly updates the project schedule and generates as-built reports. To illustrate the site data collection procedures, a demonstration case study is discussed in the following section.

5. Case Study

The developed prototype system has been applied to simple case study of bridge-pier construction. The activities involved in the case study and their estimated durations were defined in Microsoft Project software as shown in Figure 3. The project is expected to take 16 working days (22 days including weekends), starting from June 6th, 2012. The main system options allow

the user to modify the communication list, start site data collection using email or IVR, read the received responses, check for any RFIs, update the schedule, and generate full as-built reports.

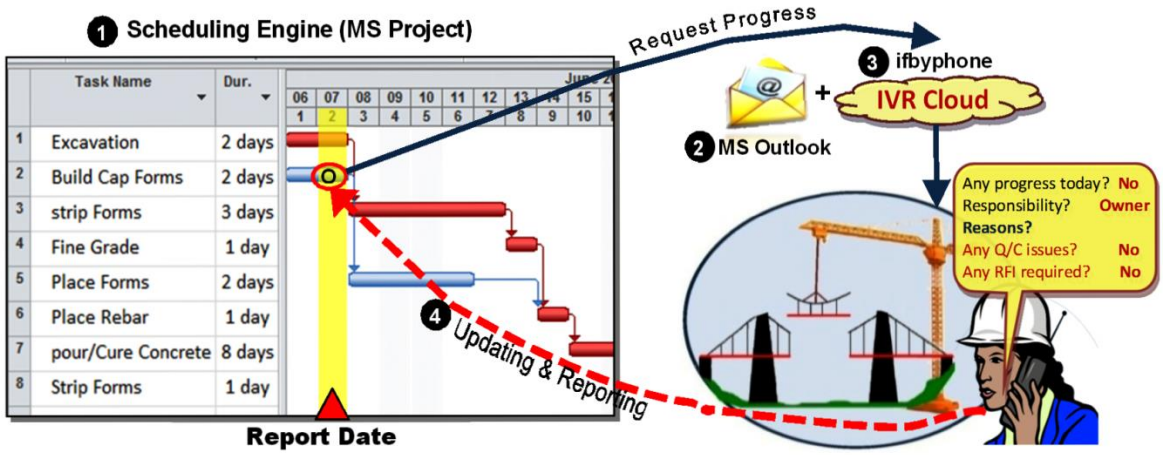

Figure 3: Components of the proposed as-built tracking framework.

The process of as-built information tracking, as it applies to the case study, can be summarized as shown in Figure 4. Detailed step-by step process is as follows:

- The process starts by automatically identifying the activities that are planned to start (their predecessors are completed), or continuing on the current progress date. In the case study, activities 1 and 2 are the ones to start on the first day of the project;

- For the eligible activities, the system retrieves the supervisor's contact information, the IVR flow in case of progress request by phone, or the email form name in case of progress request by email;

- The system sends requests to the supervisors. In case of progress request by phone (case of activity 2 “Build Cap Forms”) the system contacts the IVR cloud service to initiate a phone call following the set of questions in Figure 2. In case of progress request by email (e.g., activity 1 “Excavation”) the system sends an email form for supervisors to respond with the actual progress, site events, responsible party, quality issues, information requests, and attach any supporting documents (e.g. drawings, text, pictures, and videos);

- Once the supervisor(s) reply, their responses, and any attachments collected by the cloud service and send as email files to the project email account. The system then loads the latest received email responses and saves the information into the project database. In this step also, the system automatically forwards any received RFI requests to the responsible person’s phone or email. The answers to this RFI are then send back to the supervisor. This bidirectional communication between site and head office is one of the clear advantages of the system to quickly respond to urgent needs; and

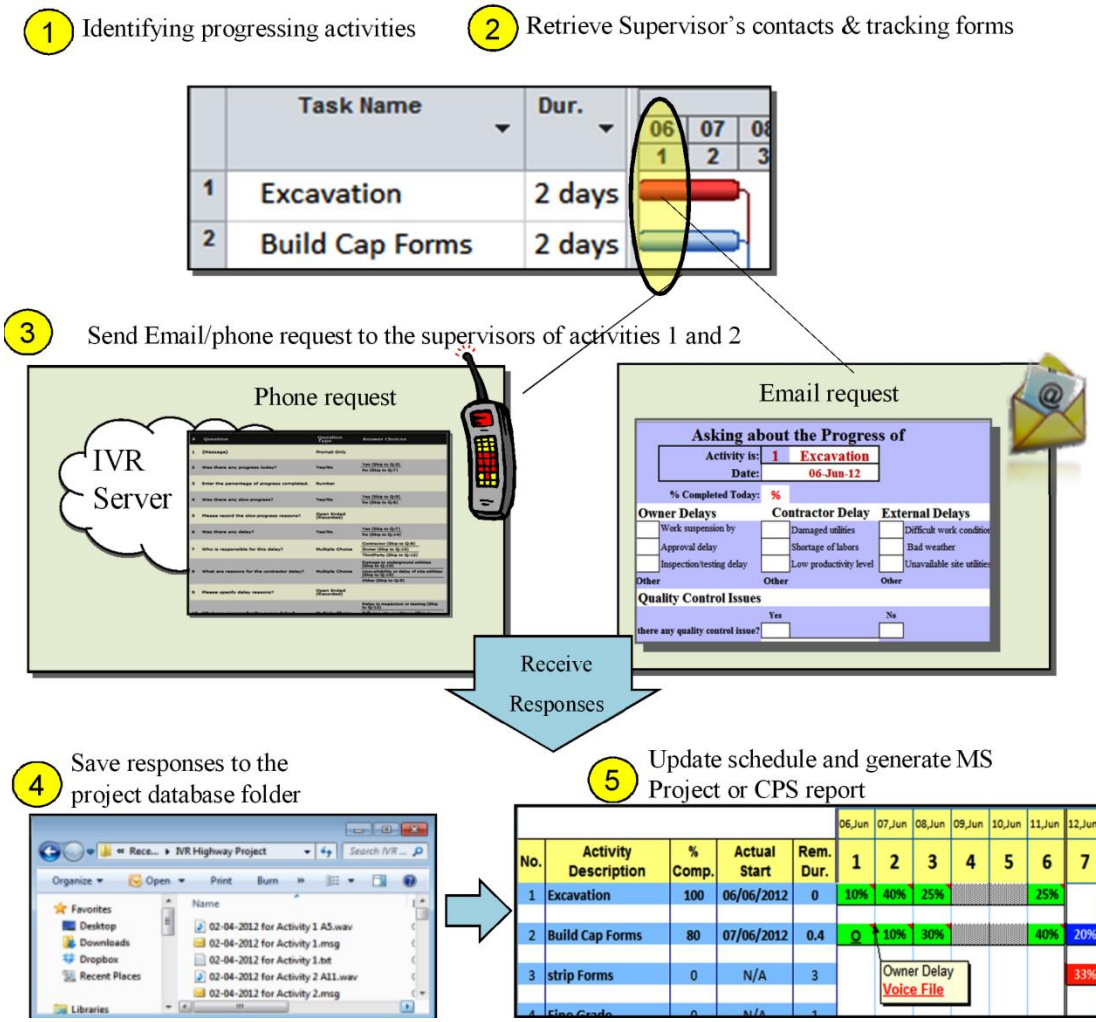

Figure 4: As-built information tracking process.

- After reading the new as-built information, the system automatically updates the project schedule and saves all site events related to each activity along with any attached files. Two important reports are generated by the system: (1) an automated update to the MS Project schedule with the cumulative percentage complete for each activity (Figure 5a); and (2) a detailed CPS report of the schedule with the evolution of all as-built events, with all details shown as comments on their associated activities days (Figure 5b). Both reports show that the project duration is extended to 24 days (2 days delay). The MS Project schedule report can only show the bars of completed and on-going tasks being extended, without any progress details. The CPS report, on the other hand, provides all the daily details, with additional information shown as comments on the relevant days. At the end of day 1 (June 6th), for example, the status of activities "Excavation" and "Build cap forms" has been updated to show that Excavation experienced slow progress (10% on day 1, as opposed to 50% per its two-day planned duration). On the same day also, the cap forms activity had zero percentage complete due to owner's delay. The CPS report, therefore, is more informative and can help decision makers to better follow the project progress and take suitable corrective action planning and schedule analysis.

The prototype system for as-built documentation has been used in a number of experiments studies to test its functionality and potential improvements. The initial experiments showed that the system has several benefits as a result of its structure and its implementation as an add-on to existing project management tools. Being an add-on to MS project enables the system to benefit from its wide array of built-in features for defining the activities and their relationships; leveling of project resources; and handling large-size projects. First impression about the use of the prototype is that it is easy-to-use, simple, and the sound quality is high. Because the system initiates calls after regular work hours (e.g., evening), the impact of site noise on sound quality is not expected to be an issue. After using the system for some time, however, it was felt that provides the users with more time to think about answers rather than having to respond immediately to a phone call.

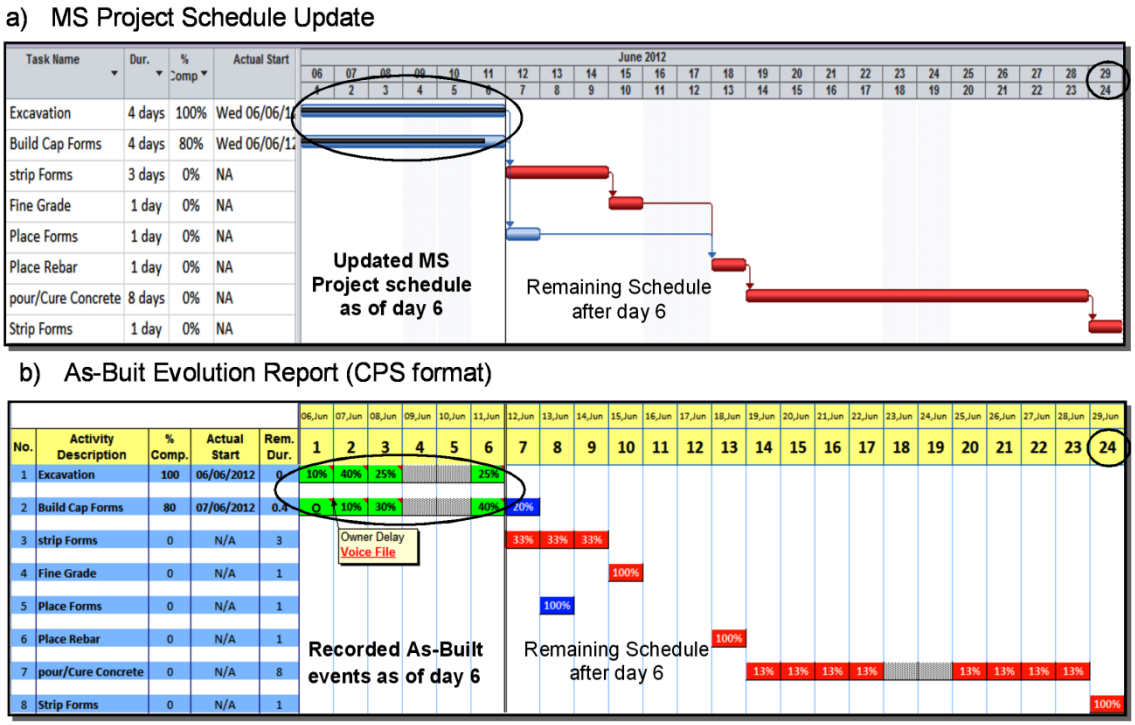

Figure 5: As-built Documentation Schedule Report.

6. Concluding Remarks

This paper presented low cost framework utilizing Email and Interactive-Voice-Response (IVR) technology to automate as-built documentation. The combination of Email and IVR proved to have great potential to minimize the time and cost associated with site data collection by asking relevant and dynamic questions related to each activity. Using structured Email also facilitates collecting of complete site data. The developed framework has been applied as add on program on existing commercial scheduling software (MS Project), so that the activities themselves calling for progress, receiving data, updating the schedule, and all data received will be linked directly to the daily segments of each activity. The developed framework is expected to help construction firms have better control over construction operations by providing timely information for decision making. It also contributes to automation efforts in the construction industry, which can lead to higher productivity and fewer disputes.

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