EVALUATION OF A REAL-TIME CONSTRUCTION PROJECT PROGRESS TRACKING

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ABSTRACT

Effective project management requires controlling all aspects of a construction project: quality and quantity of work, costs, and schedules to guarantee the success of the project. Performance monitoring of the entire construction project is crucial. One way of measuring overall performance is by using an aggregate performance measure known as Earned Value. All work is planned, budgeted, and scheduled in time phased planned value increments constituting a cost and a schedule measurement baseline. Earned Value is mainly used to monitor the progress of work and compare accomplished work with planned work. A proposed new model based on wireless communications technologies, to track the progress of percentage completed in a construction project is being presented in this paper. The model is based on the application of smart chips with wireless communication. It will greatly increase productivity and efficiency, reduce labor hours and time required for tracking, and give more accurate results in estimation. This new technology includes an automated system of reading RFID tags placed on items that send out either a tracking number, or other information for that item, directly to the reader. Keeping track of the material used on site, based on the estimated quantity will permit making a better estimate of the amount of work done on a construction site. A life cycle cost of the system will be presented. The model is evaluated using a utility function method.

Keywords: IT, Life Cycle Analysis, RFID, Wireless technologies,

1. INTRODUCTION

The evolution of Information Technology (IT) has changed the way that nearly all industries do business. Since desktop computers became affordable, management of information within organizations has transitioned from paper-based to electronic formats. The development of the Internet has also changed the way the world accesses and shares information. The construction industry has seen a similar penetration of IT and has in part changed due to IT (Tucker et al., 1994).

A construction project is considered as a process that involves many activities that are related to each other. During the construction phase of a project it is essential that good and timely flow of information prevail throughout the process. The desire for greater collaboration among construction participants must be aided by improved communication throughout the construction process. Unless current communication technologies and practices are improved dramatically, greater integration of design and construction could actually increase waste as it increases the corresponding need for communication (Elvin, 2003). Wireless technologies have the potential to solve this communication problem, increase collaboration, and provide new capabilities through evolving technologies. The basic premise of Wireless Construction is to network previously stand alone islands of communication on a construction site to allow for the network to be seamlessly interfaced with the ever growing world-wide-web. Still construction industry has been slower than other industries in adopting new technologies into its business processes due to the high cost associated with its implementation and lack of good evaluation methods to help as a decision tool.

Firms have to continuously improve their productivity and efficiency in order to maintain a competitive advantage. Monitoring the performance of the entire project is crucial. One way of measuring overall performance is by using an aggregate performance measure called Earned Value. Conventional methods relied on feedback given by superintendents on the construction site. Based on their experience and amount of work done per day, superintendents submit a report at the end of the workday so that progress of work based on a schedule developed earlier can be updated manually. This method is not efficient because it lacks accuracy in tracking progress, has delays in acquisition of information, and the schedule is updated manually. Once some problems on the construction site are identified, a new model based on wireless communications technologies, to track the progress of percentage completed in a construction project is presented. The model, based on a combination of Radio Frequency Identification tags (RFID), PDAs, and wireless technologies, in tracking the progress of percentage complete in a project; is being investigated in this research. An evaluation approach is also presented to prove its efficiency and benefits to the construction industry.

2. TECHNOLOGY OVERVIEW

The use of technology to improve the efficiency of construction site is a novel concept. Construction firms began to examine the use of barcodes for tool management by the beginning of 1990's (Goodrum et al. 2005). Later in the mid nineties, RFID was introduced to the construction industry. RFID can be viewed as a sister technology to bar code labels which use radio waves instead of light waves to read a tag (Jaselskis and El-Misalami, 2003). Data may be stored on the tag or transponder for the purpose of providing identification and other information relevant to the object carrying the tag. The RFID system is composed of tags that carry the data in transponders, and RFID readers that retrieve the data from the tags (CII, 2002).

Wireless communications have sustained a tremendous growth rate over the past decade. Significant strides have been made in the technology and by the communication community to provide reliable services (Padgett et al., 1995). There are numerous applications for all different wireless technologies. Application of wireless technologies can be categorized into voice messaging, handheld and internet enabled devices, and data networking. With the advancement of wireless network comes the application of handheld computers at a construction site. Various construction firms started implementing handheld computers on the jobsite for gathering data, scheduling, quality inspections, layout, and other type of information exchanges (Inglesby 2000).

3. MODEL FRAMEWORK

The objective of the model presented in this paper is to track the quantity of materials and equipment usage on the construction site on real-time, and be able to calculate the percentage complete of the activities based on the tracking information. The main components of this system are RFID tags and readers, handheld computers, and a wireless network. Figure 1 presents the problem statement and potential solutions for these problems.

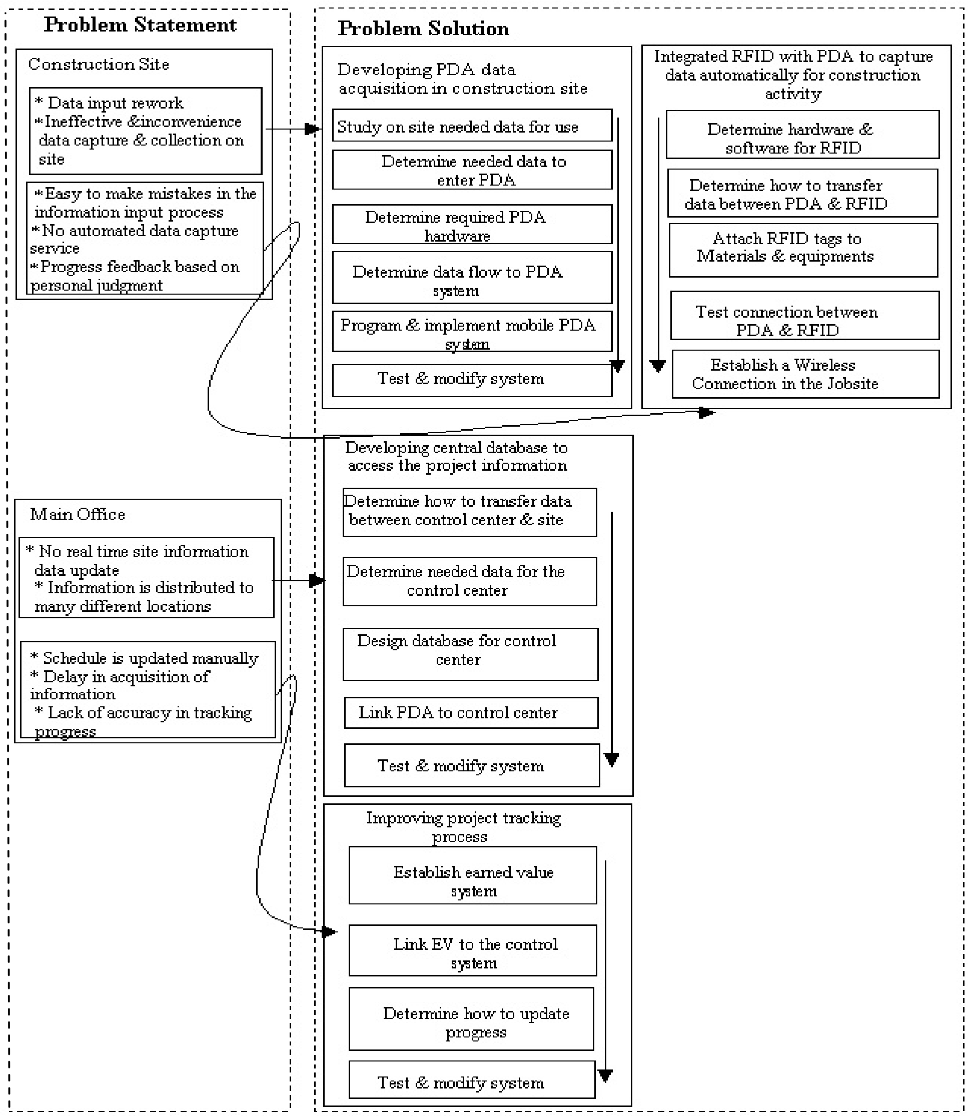

Figure 1: Problem Statement and problem solution

3.1 Model Description

Individual objects scheduled for arrival on the construction site are either tagged at the vendors or at the job site using radio frequency identification tags. The encoded information is scanned directly into a portable computer and wirelessly relayed to a remote project database. This database has dual functions. A database query returns graphical representations (e.g. computer aided design CAD) like where to install the materials and the method used for installation. The second function of the database is to relate the materials to the corresponding activities in the project schedule. Based on the percentage of usage of the materials installed on the construction site and the related activity, Budgeted Cost of Work Performed (BCWP) is updated and in turn the schedule will implement the changes automatically every time information is recorded in the Personal Digital Assistant (PDA) and sent through the wireless connection to the database.

The same thing is applied to the equipment on the construction site. The activities that involve only equipment work, like excavation, hauling are tracked through the number of hours these equipments are used. Based on the productivity of the crew and machines, the quantity of work to be done, and the total number of hours BCWP can be updated. Figure 2 represents the basic components of the system.

By the time this paper is written, only application of IT is evaluated. The model is not yet fully integrated in the construction site.

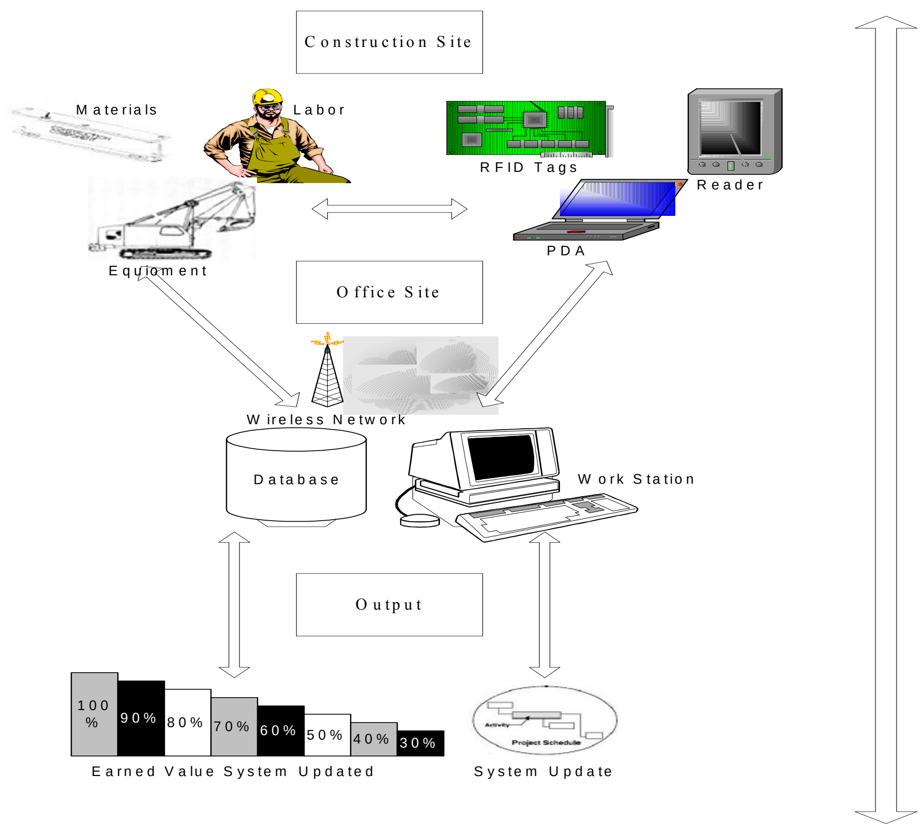

Figure 2: System Configuration

3.2 Model Applied on a Pre-Engineered Construction Site

The following example is a simplified case study to illustrate the earned value calculation using data obtained from our model in a Pre-engineered building construction. Figure 3 represents different parts of a Pre-Engineered building. At the manufacturer level, the company is responsible to attach RFID tags to the steel parts.

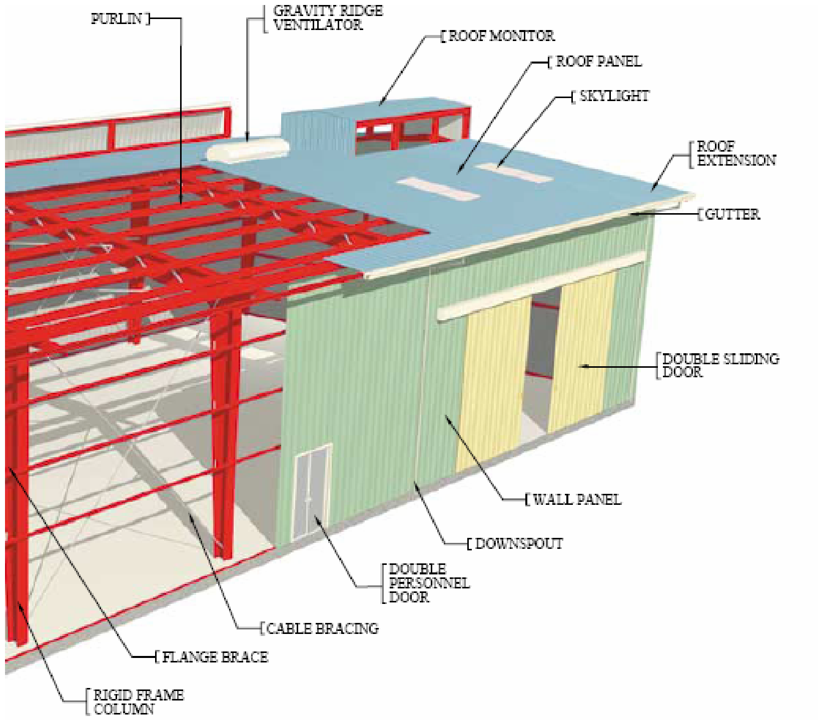

Figure 3: Pre-engineered Building Model (Zamil Steel 1999)

The steel building consists of 8 bays (16 columns) spaced at 19.5 feet, with width of the building equal to 39.5 feet, and an eave height equals to 13 feet. In this example, only installation of steel columns is taken into consideration Based on a normal crew size, it takes one hour to install one column. The cost of one column is $150 and the cost of its installation is $300 per hour.

As soon as the materials arrive to the construction site, the tags on the steel parts are scanned. The scanned information is sent wirelessly to the data base system.

BCWS = (150*16) + (300*16) = $7,200

When the installation of columns starts, materials being used are scanned and information is sent to the database system: Start of installation (activity A: column installation). Monitoring of activity A is so simple, every time a column is installed; tags are scanned prior and after installation. Start and end time of installation is sent to the database. Using software, earned value of activity A is calculated.

At the end of day 1, based on information sent to the database system, only six columns were installed instead of eight columns (only 37.5% of the scheduled work was done instead of 50%). So BCWP = ($150*6) + (300*8) = $3,300, ACWP = $4,800

Once BCWP and ACWP are calculated, variances and indices can be calculated and the status of the construction project is reported.

4. EVALUATION METHODS OVERVIEW

There are at least 30 currently available IT benefits evaluation methodologies (Andresen, 1999a). Two main categories arises from these methodologies; those seeking to quantify inputs and outputs in order to attach values to them-objective methods, and those relying on the attitudes and opinions of users and system builders-subjective methods.

The difficulty in evaluation centers on the fact that both costs and benefits are difficult to quantify. In addition, there are often hidden costs and benefits. Overly notes that technology based programmes often result in benefits and costs which were not identified or acknowledged in the planning and resource allocation process (Overly 1973).

4.1 The Value of the technology in Construction

The potential for technological improvements to benefit the construction project are many and are highest during the construction phase (O'Connor and Tucker 1986). In construction, value is generally viewed as tangible and direct, and is often defined in terms of changes in the following three metrics: Cost (or budget); Time (or schedule); Quality. Other measures such as safety, rework, and productivity are also widely used, however, these are intrinsically related to the above three metrics. Thus, if rework is required on a project, the budget and/or the schedule may grow. Similarly, when productivity, safety, or other measures of project performance are affected, the budget, schedule, and quality are the ultimate measures of the effects. Construction companies usually expend considerable effort through their project control function to ensure that the project adheres to the planned budget and schedule, and that it meets the specified quality standards.

4.2 Technology Evaluation Methods

4.2.1 Life Cycle Cost

The term Life-Cycle Costing is quite broad and encompasses all those techniques that take into account both initial and future costs and benefits (savings) of an investment over some period of time. The following model can be used to estimate the life cycle cost of the model presented in this paper:

$$LCC = INC + HDC + CA + INSC + TC + DISC + CS$$

Where LCC is life cycle cost; INC is introduction cost; HDC is hardware cost which includes the cost of RFID system, the cost of handheld computers, and the cost of wireless network; CA is software acquisition cost, and the cost of internet database system; INSC is installation cost; DISC is disposal cost = [(unit cost of the disposal)*(-0.1)]*(inflation) / (discounting); CS is system support cost = [2.5*(direct labor cost per man-month)*∑MMSi]* (1 + F) + additional support costs.

With ∑MMSi as the required man-months for support in month i, and F is overhead factor.

The components of the life cycle cost can be categorized into two major groups: recurring costs and non recurring costs. The recurring costs are training cost and system support cost. The non recurring costs are introduction cost, hardware cost, installation cost, and disposal cost

4.2.2 Utility Function

Engineers like to discuss goal seeking in a mathematical terminology. A good way to identify potential benefits of applying a new technology in construction is by using Utility Functions.

Utility, as the word used here, is an abstract variable, indicating goal-attainment or want-satisfaction.

The performance of the model will be scaled based on five criteria:

1) Material management (control waste)
2) Tools Management (control losses)
3) Equipment management (increase productivity)
4) Labor productivity (increase productivity)
5) SPI and CPI indices (taking decision for critical activities)

So the utility functions will have the following shape:

U = f (material management, tools management, equipment management, labor productivity, SPI & CPI indices)

5. ASSESSING AN IT INVESTMENT IN THE CONSTRUCTION INDUSTRY

5.1 Identify the Need

The first step in analyzing the feasibility of any investment is to realize that there is a need to be fulfilled. This realization can come about by necessity or opportunity.

There may be inefficiencies in work processes recognized or simply an opportunity to exploit that will give the analyst's organization an edge over their competitors, or both.

Unlike the structured environment and highly repetitive processes in manufacturing, construction poses many barriers to the implementation of advanced technologies. Characteristic fragmentation, diversity, and fierce competition of the construction industry combine to make Research and Development (R&D) difficult (Tucker 1988). In a fiercely competitive environment with thin profit margins, individual firms, especially the smaller ones, simply can't afford to conduct R&D or pay added regulatory costs of introducing new technologies. For this reason, the construction industry has a high resistance to adopt new technologies and change traditional processes, and most instances to date have been part of either university funded research or pilot project through consortia such as FIATECH, CONSIAT Construction Integration & Automation Technology), and COMIT. This shows that at the present the need for adoption of new technologies in the construction industry should largely be for competitive advantage, not necessity. Many of the inefficiencies that exist in construction can potentially be eliminated with the implementation of IT investments.

5.2 Determine the Objective

Once the need for investment has been identified, the goals and objectives of the study should be determined. This step should layout what the outcome of a successful solution would provide, and who the stakeholders of the solution are.

5.3 Identify the Alternatives

The first alternative to consider is the "do-nothing" scenario and is the base by which all other alternatives will be analyzed. Some form of functional analysis should be performed to understand how the current business process functions. Process flowcharts can be developed to assist in this task.

Identifying the other alternatives involves researching what type of products on the market can provide the successful solution previously determined. When selecting specific product alternatives, an initial comparison should be made to ensure that an overpriced product is not being selected.

5.4 Perform an LCC analysis

The next step is to set the study period in which the financial analysis will cover.
It is typical for IT investments to be considered over a maximum of three years due to the rapid change in technology that is currently taking place. If the investment is being considered for a single project, then the study period should be the length of the project or three years, which ever is the minimum. It would be beneficial at this point to determine what time interval cash flows will be represented at, i.e. monthly, quarterly, annually. If a multiple year study period is being considered, then representing cash flows annually is the typical practice.

Once the study period is set the cost should be assessed over that period of time and assigned to the time interval in which they will occur. Any costs that result as a change in the "do-nothing" scenario should be considered. The obvious costs are the direct initial costs that go into purchasing the necessary products such as hardware, software, and wireless communications equipment. Other direct initial costs are planning and feasibility studies, initial wireless consultant fees, training of users, wireless provider activation fees, software development, IT systems integration, implementation costs, etc.

Direct ongoing cost to be considered include maintenance, upgrades, replacements, ongoing training, wireless subscription fees, salaries of in-house technical support or periodic wireless consultant fees, etc. Finally, any indirect costs should be identified, such as staff time spent in training, downtime due to device failure, and any initial drop in productivity.

The ultimate goal of an LCC analysis is to determine the present value of all costs incurred over the study period; however, if the analyst plans to account for the effects of income tax, then the cost should not be discounted at this point. This is due to the fact that income tax will be levied on current dollars, not constant discounted dollars.

5.5 Identify and Quantify the Benefits

This step involves documenting the changes that will occur in the current business processes as a result of the implementation of the investment. These changes are what will ultimately produce the benefits of the investment. Benefits can be classified as tangible and intangible. Tangible benefits will be any benefit that a dollar value can be assigned to. These include reduced travel time, reduced staff, work process elimination, worker productivity gains, reduced paper, reduced material wastage, reduced rework, etc. Intangible benefits are those in which a dollar value can't be directly assigned. Some intangible benefits can be broken down into sub-benefits, which are tangible. For instance, improved information quality is intangible; however, this benefit results in worker productivity gains, reduced rework, and reduced material wastage which can be assigned a dollar value.

6. EXPECTED OUTCOME

The authors believe that applying the following model at construction sites will bring some tangible benefit to the project. It will offer a lot of information at the construction site. It eliminates gaps in time and space and gets rid of duplicate work. It will integrate previously stand alone islands of work, depending on the job description of each individual. Moreover, it will greatly increase productivity and efficiency, reduce labor hours and time required for project tracking, and give more accurate results in estimation.

7. CONCLUSION AND RECOMMENDATIONS

There are many ways that the construction industry might benefit from incorporating this model. It will permit information to flow in a faster, more timely manner between all related parties. All the technologies presented in the model are already applied in construction industry, but combining these technologies together is the prominent feature of this model. Tracking project progress with less work done, fewer assumptions made, and a better method used is the dream of every project manager. Undeniably, new systems come with uncertainties, risks, costs, problems and application resistance. Companies interested in implementing this model within their organization must recognize the nature of the new technologies involved, their life cycle, and most importantly how to integrate their work processes with these technologies.

A detailed model should be presented, which includes the description of each component of the system proposed and how they interact with each other. A case study should be used to validate the hypothesis made: Implementing this model on the construction site will increase productivity and efficiency, decrease materials waste, and build a more reliable construction activities progress system.

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