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DEVELOPMENT OF AUTOMATED RESOURCE MANAGEMENT SYSTEM (ARMS)

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Abstract- The efficiency of construction industry is measured by on time project completion. Unfortunately, most of the construction projects suffer time and cost overruns owing to complex nature of construction industry. To overcome this challenge, construction industry needs to incorporate automation and information technology (IT) application in various construction processes. Projects subsume enormous unmanned resources to undertake project tasks on time and conforming to the quality standards. Unscrupulous resource management leads to schedule slippage, poor budgeting and disputes among project stakeholders. The application of modern automated tools can make efficient information management and project data sharing alongside augmenting productivity. This research focuses to integrate automated communication system with resource management processes to improve overall project efficiency. Factors contributing automated resource management have been identified through extensive literature review. Further, the scrutiny of factors has been carried out by gathering responses from industry experts using a questionnaire. A framework for automated management of non-labor resources is developed based upon communication links and relative information flow of construction activities. This framework supports in developing a mobile application that allows construction personnel to request for resources, check request status and resource monitoring. This research signifies that automated resource management system entails efficient communication among participants and leads to auspicious project delivery.

Keywords- Communication System, Construction Database, Construction Automation, Resource management

1 INTRODUCTION

Efficiency of construction industry is considered as on-time delivery of construction projects with minimal cost over-runs [1]. Unfortunately, many projects suffer delays and require plethora amount of resources to complete. With augmenting the complexity of construction projects, there likelihood of cost and time over-runs are increased. The complex nature of projects can be controlled efficiently with application of modern technology. From manual drafting to Building Information Modelling (BIM) and from manual labor work to use of heavy machinery, construction industry has made fortuitous progress in technological applications. There exists a broad gap to integrate technology in various domains of construction industry like risk improvement, communication and project controlling [2].

Proper communication and automated monitoring systems can help in increasing efficiency of construction practices [3]. Lack of adequate communication mechanisms, ineffective reporting system and facile data channels are the aftermath in terms of lower productivity and poor project performance. Additionally, emotional interference and physical barriers have proved to be problem in communication. On construction sites, people from different linguistics backgrounds communicate with each other. There is a need to address and overcome these barriers so to avoid miss-communication and to harmonize human resource interaction [4].

Construction industry is mainly relying on manual work for technical purposes and paperwork for documentation. Information through conventional channels gets dissipated easily thus causing delay in material delivery, extra cost

and lower productivity. In recent years, incorporation of information technology in different industries is an indication for construction professionals to adopt modern informatics tools to bolster communication database. Construction industry has incorporated information technology in different domains. Although, resource management system requires enough improvement on construction projects to ensure transparent communication among project participants. Therefore, automated, user friendly and sustainable resource management is a viable option to improve the current system [5]. The main objective of this research is to identify resource management factors causing time and cost overrun via consulting experienced professionals and development of a framework that encompasses communication, resource management and inventory management for construction sites. This framework engenders the development of mobile based application for automated management of unmanned resources on construction projects.

The findings of this study will redound to the benefit of construction industry considering that technology plays an important role in every industry today. Different factors causing time and cost overrun in construction industry were analyzed and identified after extensive literature review and consulting experienced professionals. Those factors help in developing a Framework covering communication, resource management and inventory management for construction sites. This framework can be used as basis for development of mobile application that will manage communication and resource management on construction sites.

2 LITERATURE REVIEW

Resource management and planning is considered one of the most important factors to ensure profitability and competitiveness in the current construction industry. Building materials and equipment entail almost up to 50-60% of the overall project cost [4]. In the broader aspect, the construction industry has made advancements in processes like design, planning and management. Despite these advancements, the construction industry is typically slow to adopt changes and there is a need to dig deep on substantial issues like on-site tracking and monitoring of unmanned resources.

The average time over-run on any project is between 10-30% of the original duration assigned. This statement was agreed upon by 76% of the contractors and 56% of consultants [6]. Lack of effective communications on site, material shortages and improper planning causes delays in construction projects [7]. Poor resource management is responsible for schedule slippage and cost overrun [8]. US National research council (NRC, 2009) also stated that to improve the overall competitive nature of construction industry the project schedules, labor and construction materials should be managed much more effectively.

Different researchers have identified factors causing problems like time and cost overruns in relation to on-site resource management. These problems arise due to mismanagement of responsibilities by each stakeholder like client, contractor and consultant[2, 9]. The factors identified are categorized accordingly stating stakeholder responsible for the said problem. The major factors causing problems, identified by these researchers are listed below: -

Table 1-Resource management Factors effecting Time & Cost overruns

Responsibilities	Factors
CLIENT	Change in the scope of the project
	Delay in progress payment by owner
	Financial difficulties of owner
	Delays in decisions making
	Owner interference
	Unrealistic contract duration and requirements imposed
CONSULTANT	Delay in inspection and approval of completed works
	Unrealistic contract duration and requirements imposed
	Frequent design changes
	Mistakes and Errors in design
	Delay in Preparation and approval of drawings
	Incomplete design at the time of tender
CONTRACTOR	Inadequate planning and scheduling
	Lack of experience
	Poor site management and supervision
	Incompetent subcontractors
	Cash flow and financial difficulties faced by contractors
	Mistakes during construction
RESOURCE RELATED FACTORS	Fluctuation of prices of materials
	Shortages of materials
	Late delivery of materials and equipment
	Insufficient Numbers of equipment
	Labor Productivity
	Shortage of site workers

2.1 Use of Information Technology on Construction Sites

Information and Communication Technology (ICT) is increasingly being considered for versatile use in planning, design and project monitoring. Its use in data collection, life cycle assessment, and monitoring and controlling is a significant contribution to the advance knowledge and practice of ingenious decision making. Continuous access to information, communication and finances control, project data accessibility and reduced number of errors in documentation are the major benefits of using ICT [10]. Some of the technologies that can potentially help in designing framework were studied in detail and are as follows: -

2.1.1 Automated Data Collection Devices (ADCs)

These devices are being used commonly in the logistics and manufacturing industry and can make project operations easier on construction site [10]. According to [11], increased efficiency, reduction in the number of data entry errors and a reduced labor cost can be achieved with the use of ADC technologies. This has been augmented a lot using affordable cellphones which are accessible to almost everyone now and are being used holistically in industrial and commercial sectors. This will pave the way forward to implement automated construction techniques and aid job-site practitioners to get connected by using ADCs or personal cellphones. This method can help in reducing time and cost incurred by construction sites. [12].

2.1.2 Radio Frequency Identification (RFID) Tags

Radio-frequency identification (RFID) tags use radio waves to access information stored on a readable object. A tag can be accessed from several feet away. RFID tags are being used commonly in many industries and can also be used to increase efficiency on construction sites [13].

2.1.3 Quick Response (QR) Codes and Scanner

QR codes are a form of two-dimensional barcodes that can be read easily by an optical reader. Information stored in a QR code usually points towards a website or an application. This system is very easy to use and has a relatively larger storage capacity which leads to its comparison with the Universal Product Code (UPC).

2.2 Prospects

FIATECH is a non-profit consortium that has developed a technology roadmap for construction industry where they have focused on the concept of "Intelligent and automated construction site" which consists of the following ideas [14]:

- Tracking of material and non-material resources on site.
- Increase in the efficiency and productivity of the construction workers.
- Continuous flow of materials will be augmented using on-site tracking systems.
- Enabling construction workers to instantly locate required resources.

3 RESEARCH METHODOLOGY

3.1 Overview

The research methodology encompasses the development of an automated resource management system based on effective communication planning and mobile application. The main purpose of this mobile phone application will be to reduce the time consumed in manual record keeping, requesting material on-site, requesting the required machinery and to monitor the stockpile of resources available for use.

3.2 Identification of Factors

Effect of construction resource monitoring on project costs and time were studied. For this purpose, a detailed literature review is conducted to identify factors related to project cost and time with resource monitoring and controlling.

The major factors identified are as follows:

- Miscommunication
- Misinformation
- Extensive paper use
- Difficult record keeping
- Misplaced materials
- Shortage of materials

- Delayed delivery of materials to site
- Non availability of materials and equipment
- Delay in material procurement
- Lack of communication

3.3 Design of Questionnaire & Site Surveys

In next step, a detailed questionnaire was developed, and responses were gathered from relevant industry professionals. This questionnaire was used to draw input from the field experts on how technology can be materialized to eradicate problems relevant to resource management. This questionnaire aided in the identification of experts' needs and their willingness to adopt an automated resource management system. The Survey questionnaire used open ended questions to get true picture of prevailing situation at our construction sites. Further, these factors were shortlisted based upon their relative frequency that effect resource monitoring on construction sites. The outcome of this research assists in identification of proper communication channels and standard operating procedures in construction projects. Following parameters were assessed in different parts of the questionnaire:

- How on-site material requests were being handled?
- How on-site machinery requests were being handled?
- How procurement was being managed?
- How on-site communication was being done?
- How automation can be integrated in our current practices?

A detailed and comprehensive survey was conducted at various construction sites within cities of Rawalpindi and Islamabad. Detailed survey has been conducted from construction professionals working on different infrastructure and mega projects including residential societies, metro bus, roads and building projects. The sample size appropriate for such a study was calculated using the sample size calculator developed by creative research systems [9]. A total of 72 responses were gathered with 95% confidence interval. The survey was distributed to construction experts who have experience in adopting latest technologies in their projects.

3.4 Framework Design

In the first step of framework design, the critical factors were defined as input which extracted from site surveys. The communication framework included planning of the information flow channels, requests for the required machinery, information flow about availability of the construction machinery, requesting construction materials and record keeping of available materials in the construction yard. For this purpose, different modules were designed and each module was specified to a user having different functionality according to their needs. The basic outline of the design is as follows:

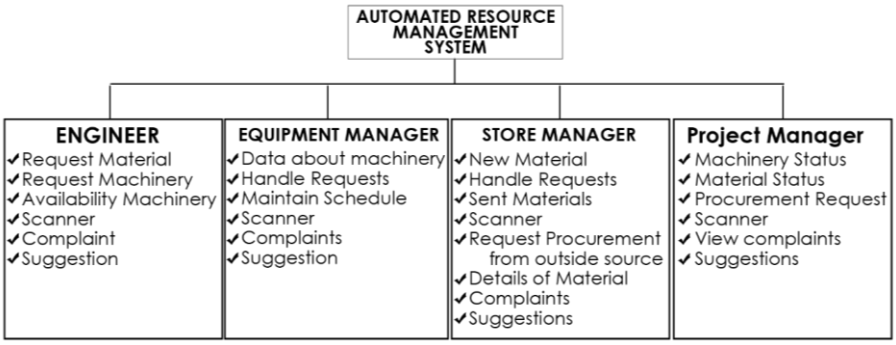

Figure 1: Activities available to each professional in the ARMS app

Figure 1 shows details about activities and options available to each professional working on construction site. As mentioned earlier every professional was assigned a specific module according to his need, role and responsibility making it a user-friendly application for every construction professional. For example, requesting material and machinery, checking availability of material and machinery and complaint/ suggestions are options which are essential

for proper working of engineer on construction site. But Engineer does not need to know details about procurement of materials which is included under store manager module.

4 RESULTS

A survey was conducted to analyze the identified factors. Total number of 72 responses was received. Survey questions were focused to get the insight depth and identify root cause of the problem. Professionals working with different stakeholders like client, contractor and consultant were approached. The respondents were equipped with average experience of 10 to 20 years in construction industry. 96% of the professionals agreed that time and cost overruns are serious problems for construction industry. It was found that at least 62% of the times projects suffer time and cost overrun. According to survey conducted, improper management of material and machinery are one of the leading factors causing time and cost overrun.

A person generates or handles more than 20 requests per day working on site. In consequence, surplus paper is used in making these requests. Site engineer is not notified about status of their requests for material and machinery which causes confusion and delays in their relevant tasks. On average 60% of the time a required material is not available or delayed in construction yards. This indicates that proper inventory management techniques are not being used. It clearly demonstrates that manually driven tasks subsumes plethora of resources. The outcome of this study shows that Automated Inventory management systems will alert the store/ procurement manager to procure required material prior its shortage.

Almost all of the respondents agreed to the envisaged approach that Record Keeping using automated application will take lesser time and will be easier to manage. Computerized cloud-based storage system stores data for longer period and finding a record is easier as compared to manually maintained records system. On the contrary, large number of tiers involved in making a request to procure material from outside source utilizes large amount of time.

4.1 Framework for Development of Mobile Application

Based on Survey results, a framework was developed. The developed framework for mobile application substantiates an integrated approach to abate extra time and cost considering resources with their integrated roles. Many industry professionals emphasize the need of adopting integrated technological application on construction projects. The proposed framework primarily focusses on augmenting communication among team members in a coordinated and systematic way. The framework also caters organization culture, human disposition and stakeholder expectation. This framework can be implemented in many industries and market segments. This Framework will be used for development of mobile application.

The mobile application developed will help in generating requests, checking status on requests, managing procurement, onsite communication and problem solving. The framework will solve following problems in the mentioned ways: -

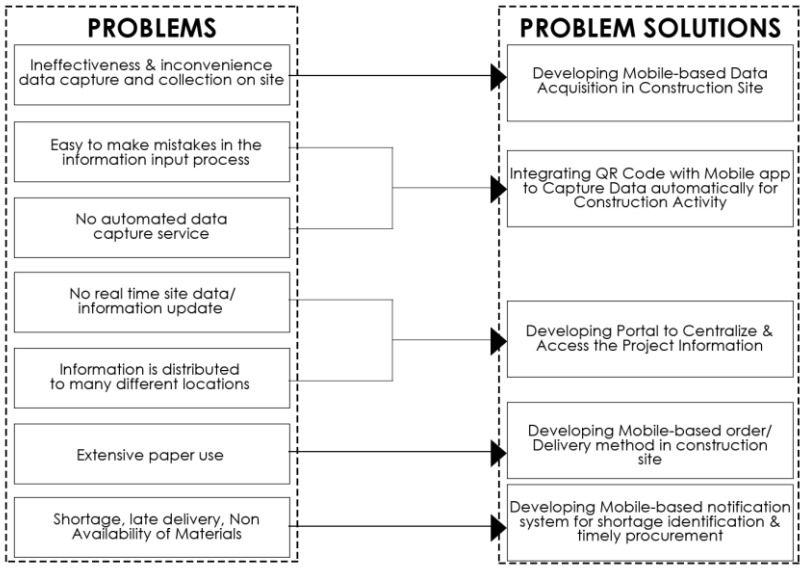

Figure 2: Planned Solution of Different Problems in Framework

Figure 2 includes planned solution for different problems that were identified in the survey. For example, ineffective and inconvenient data capturing on construction site can be catered by using mobile based data acquisition. Chances of making mistakes is reduced by providing automated data capturing service using QR code with proposed mobile application. Centralised portal for accessing project information helps in providing real-time site data and collection of information at one location.

4.2 Practical implementation

Implementation of proposed framework and mobile based application is much easier as almost every person uses android or iOS based mobile devices. Availability of QR scanner in mobile phones and easy to produce QR codes has made it possible to implement the suggested mobile application. Use of existing technologies for our help makes it easier and economical to implement this study.

5 CONCLUSION

A Framework was designed for development of mobile application after elaborated field survey to identify major resource administrative issues being faced on construction sites. A proper schematic framework is designed to automate the on-site management system. This framework used automation techniques like mobile applications, QR codes and RFID tags to deliver the progress information swiftly. On-site personnel are given access to the information providing ease of operation and data sharing. According to survey conducted, on average a single construction professional handles about 20 requests for material daily that amounts to around 6000 pieces of paper yearly per person. A great reduction in paper consumption can be achieved with automated on-site resource management system.

The developed automated system will accelerate the material approval process from hierarchy of members and help in overcoming communication barriers. Additionally, earlier material procurement can be ensured prior to its shortage that consequently save huge amount of time in resource acquisition. The framework developed in this research can be used to design a mobile application which will handle requests for material and machinery, check availability status, site staff can track requests and make complaints/ give suggestions about any problem being faced. Besides this, the framework should be linked to planning software like Primavera P6 and MS Project and notification system should be developed which sends notification to check material availability prior to start of any activity. Moreover, management of manned resources can be integrated in this mobile application.

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