Interaction between Theory and Practice in Civil Engineering and Construction
Edited by Komurlu, R., Gurgun, A. P., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-2-4

THE TECHNICAL AND ECONOMIC FEASIBILITY STUDY OF USING SMART PHONES IN CONSTRUCTION SITE MANAGEMENT

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Construction project management is the application of knowledge, skills, tools and techniques related to project activities achieving the project requirements. Accurate and timely acquisition of the site data and information could improve the project management decision processes. However, obtaining the data and information in minimum possible time is the complex process due to nature of the construction site condition. There are several limitations with regards to the site data acquisition including, monitoring construction site, and sharing a daily status report. This study investigates the potential of using smartphone as a new technology in construction sites: (1) to improve monitoring and controlling the site activities; (2) to accelerate decisions making process by improving the speed and accuracy of information exchange process. This study provides an overview of the feasibility of using smartphones in three areas of project management knowledge, discussed in a Guide to the Project Management Body of Knowledge (PMBOK), including time management, quality management and human resources management. Validation was conducted through the real case study based on the proposed scenarios. Return of investment and sensitivity analysis of the two scenarios were also compared to find the efficient scenario. The results of this study can be applied to improve the monitoring and understanding of the site status and can potentially facilitate the decision making process.

Keywords: Construction projects, Project management, Quality management, Time management.

1 INTRODUCTION AND RESEARCH REVIEW

On-site construction management is an important component for the execution of successful construction megaprojects. Accurate and timely acquisition of on-site data and information about construction activities and resources facilitate decision making process, which entails productivity improvement. It is always challenging for site engineers/managers to collect and analyze the site information such as locations of materials, labor, and equipment along with the conventional status of progress. These challenges necessitate the development of methodology and using new technologies, with suitable sensing and communication capabilities to acquire and exchange construction information.

In recent years, several research studies have been conducted to investigate the feasibility of using mobile computing. For example, Son *et al.* (2002) extended the concept of technology acceptance model to investigate the factors that influence successful application of mobile computing devices in the construction industry. Another study by Chen and Kamara (2011) introduced a framework for the implementation of mobile computing on construction sites, comprising an application of a technical model.

Other studies investigated the process improvement in construction site. For instance, Pena-Mora and Dwivedi (2002) presented a collaborative management platform that enables project participants in different locations to share project information using Smartphones. Bowden *et al.* (2006) developed a vision to illustrate to industry professionals how the use of mobile information technology can improve construction processes. Wang (2008) proposed an RFID-based quality management system for monitoring and sharing quality data.

There are several related studies in other industries that can be applied in construction management such as location tracking, sharing data, and facilitating disaster response. For example, Pena-Mora *et al.* (2010) presented an information-technology-based collaboration framework to facilitate disaster response operations. The framework incorporated a web collaboration service, RFID tags, a building black box system, a geo-database, and a Geographic Information System (GIS). Behzadan *et al.* (2008) argued that a mobile worker's spatial context must be continuously tracked in both outdoor and indoor environments for a location tracking system to effectively support construction projects. Song *et al.* (2005) use of RFID and GPS to determine the location of RFID tags to track materials at the construction site. Ko (2005) also used an algorithm to develop a concept of trilateration with 4 readers and tags for three-dimension positions.

The previous studies showed that Smartphone-technology have great potential to considerably improve construction activities, including labor and material tracking, defect management, and progress monitoring.

This study attempted to improve the on-site management system by using smartphone-technology. Through the integration of location and construction site information, the proposed system would enable site engineers and managers to efficiently understand and find the location of work tasks and resources. The proposed methodology has a potential to improve the work efficiency and reduce cost and time of information transfer. Major features of the system are discussed in this paper. A real case study is also presented in order to validate the applicability.

2 METHODOLOGY DEVELOPMENT

Smartphones are the backbones of the proposed model. Several challenges should be considered in developing this model including, transferring, sharing, and collecting data. Hence, three scenarios have been defined; first scenario includes the conventional practice. The advantage of using smartphone and the potential of the technology has been investigated in the second scenario. The use of smartphones technology and other technologies that accompanying with the smartphones technology is investigated in the third scenario. Figure 1 illustrates the information flow in construction site. In the following sections, three scenarios will be discussed.

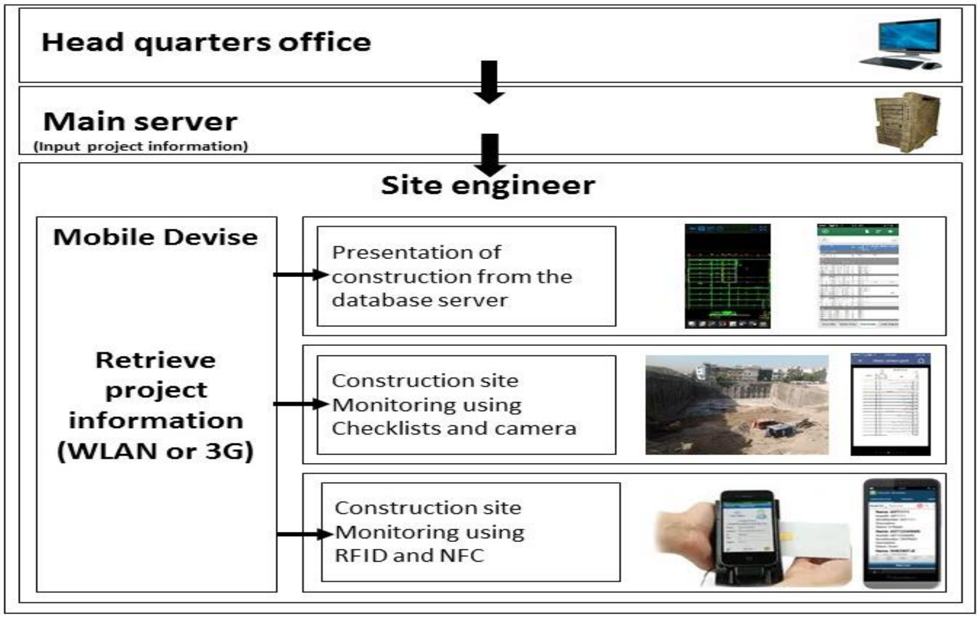

Figure 1. Data flow of the site monitoring.

2.1 Scenario 1: Conventional Practice

Understanding the current status of construction project is quite essential for construction engineers to accomplish successful on-site management. In this scenario all of information will be collected through visual surveying process and visual estimates. The information is recorded on paper, which is sometimes incorporate, time consuming, inaccurate, and difficult for data transferring.

2.2 Scenario 2: Using Smartphones Technology

In the second Scenario, Smart phones are the main part of the model; the sensors and applications of smartphones have been investigated in order to obtain, record, and transfer information in the site. In this scenario, maps, checklists, and timing plans are kept in smart phones. Therefore, it is not necessary to carry paper in order to gather, record, and control information. In addition, it is possible to control human forces, and also to do positioning through GPS. In this scenario, The speed of control process is higher than Scenario 1.

2.3 Scenario 3: Using Smartphone and the other Technologies that they operate With

In third scenario, smart phones are also the main part of the model. In this scenario other technologies, which can cooperate with smart phones are utilized, NFC and RFID are good examples. In Scenario 3, many processes can be done in a semi-automatic manner. These processes include: control of the project's physical progression, internal and external positioning of the site, and warning employees and engineers about risks.

3 CASE STUDY

The case study is an official-commercial project in the city of Tehran. Constructing of this project will take 5 years, the cost estimation is about 100,000,000 USD. We are in the third year of this project. Specifications of Smartphones that use are at a price of 399 dollars, which are capable of 3G and 4G communications, with 13-mega-pixel cameras, are used in this model. The other capabilities of these smart phones include the ability to support Microsoft Office files, and the ability to run PDF files. These phones are equipped with Wi-Fi, GPRS, GPS, and bluetooth.

In this section the cost of each scenario has been estimated. In the first scenario, the costs included the cost of human resource and the fund of the project. In the second scenario, the costs included the cost of smartphone, software, maintenance, and human resource. And lastly, costs of third scenario are all of the costs combined from the first two scenarios (Table 1). As mentioned, this study defined first scenario to clarify the cost of scenarios, therefore the second and third scenario can be compared to the first.

Table 1. Annual cost of scenarios.

	The initial cost $ US	**Year 1 $ US**	**Year 2 $ US**	**Year 3 $ US**	**Year 4 $ US**	**Year 5 $ US**
Scenario1	0	25235	33176	39882	46588	52941
Scenario2	4560	18940	25205	30235	35264	40294
Scenario3	10530	19530	25795	30823	35852	40882

After estimating costs, this study has initially determined the internal rate of return for state 1 (the comparison of scenarios 1 and 2 is observable in table 2) and state 2 (the comparison of scenarios 1 and 3 is observable in table 3) in order to assess the design economically. The reason for comparison scenarios 2 and 3 with scenario 1 is to figure out how much benefit, in proportion to the previous state (scenario 1), is gained for the project though the implementation of scenarios 2 and 3. This rate in state 1 is 150 percent, and in state 2, it is 62 percent. The initial Investments and annual Costs in state 1 is less that state 2. In addition, revenues from the implementation of Scenario 2 is more than Scenario 3. These factors cause of IRR differences in state 1 and state 2.

Table 2. State 1.

	The initial cost $ US	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Investment	4560	0	0	0	0	0
Cost	0	411	500	588	676	764
Benefit	0	6300	7970	9650	11320	12650

Table 3. State 2.

	The initial cost $ US	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Investment	10530	0	0	0	0	0
Cost	0	1000	1088	1176	1265	1352
Benefit	0	5700	7382	9060	10735	12060

Then the sensitivity of the internal rate of return of the three items of "Invest, Cost, and Benefit" is examined within changes from 20 percent to – 20 percent, in order to figure out what changes in percentages will be seen in each item of the internal rate of return. The analysis of the sensitivity of the internal rate of return in states 1 and 2 is observable in Fig 2.

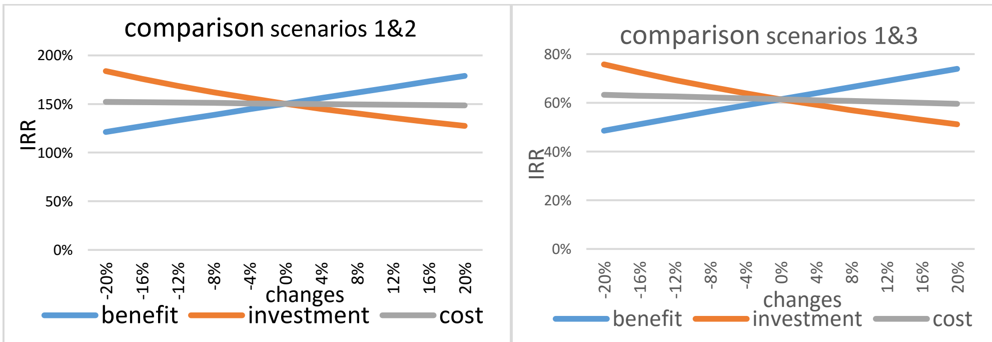

Figure 2. Sensitivity analysis regarding investment, cost, and benefit.

Delays in civil projects are common happenings. Therefore, the internal rate of return has been examined considering the construction period. The internal rates of return have been presented in Figure 3 according to different construction period between 5 to 10 years. Another item which is important in this project is Smartphone costs. Considering the characteristics of different projects, different mobile phones with different prices might be needed. Thus, the internal rates of return have been presented in Figure 4 according to different smart phone costs.

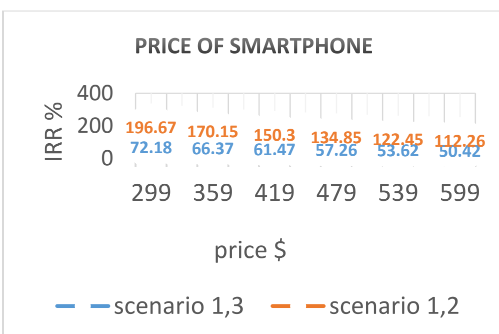

Figure 3. Sensitivity analysis regarding years of operation.

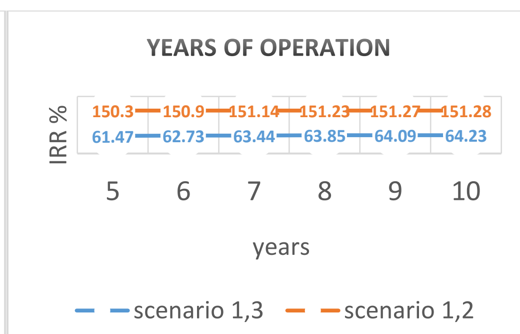

Figure 4. Sensitivity analysis regarding price of smartphone.

Considering the percentage of the internal rate of return, the plan is applicable. But the plan that must be selected is the one which is effective both economically and technically. Second scenario is more economic comparison with the third one; however, there is more capability in the third scenario. Also more money should be spent in scenario 3. Regarding Above tables the changes of IRR sharply increase or decrease because of the role of smartphones, in the event that the costs of the other technologies effect on the third scenario.

4 CONCLUSIONS AND DISCUSSION

Using smartphone-technology has provided a flexible and powerful environment for project managers and experts by facilitating on-site construction management processes. This study investigate feasibility of using smartphones in three areas of project management knowledge, discussed in PMBOK, (1) time management; (2) quality management, and (3) human resources management. The first developed scenario includes the current practice to on-site construction management. The potential of using smartphone has been discussed in second scenario. The third scenario investigated the use of smartphones and some related technologies that can be employed with this technology.

A case study, a commercial construction building, was investigated to validate the proposed model. The results of this study shows that the reduction in travel time in visiting a field office, for acquiring project information, is one of the benefits of this model. The results illustrates that the quality of a construction project can be improved using the proposed system. This study also investigated sensitivity analysis regarding investment, cost, benefit, sensitivity analysis regarding years of operation, and sensitivity analysis regarding prices of smartphones.

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