MEASURING THE EFFECTIVENESS OF IT UTILIZATION IN CONSTRUCTION: A DIFFERENT POINT OF VIEW

Bahriye Ilhan[1] and Hakan Yaman

Faculty of Architecture, Istanbul Technical University, 34437, Istanbul, TURKEY

The objective of this paper is to develop a framework for measuring the effectiveness of Information Technology (IT) utilization and its application within the Turkish construction organizations. IT has been a vital part of today's business world and is applied among many sectors in the economy to increase competitiveness and reduce costs. IT also has an important role in construction projects since it enables improved information exchange, increased speed of information transfer, deals with security issues, real-time updating and virtual meetings. It has a great impact on construction via data transfer, data capture and data manipulation. Although its contributions are well known, the construction sector is confronted with ineffective use of IT systems. Therefore, there is a clear need for an evaluation framework to assess IT investments in construction organizations. It is important to examine the current situation in order to help increase the effective use of IT. In this context; first, previous studies are examined. Then the methodology of the study and the proposed framework are represented. The framework is based on the construction process and the outcomes of IT utilization. In order to test its validation, it is applied within design offices and contractors. The results of the application show that IT has a great impact on the whole construction process and the effective use of IT provides considerable outcomes. Finally, the limitations and opportunities for future study are pointed out in the conclusion.

Keywords: Turkish construction sector, effectiveness, information technology, measurement framework.

INTRODUCTION

The most important measures for an organization in order to be successful are processing data and using information effectively. Information is the one of the key resources in the operation of an organization due to its use in planning, controlling, organizing and decision making in other words main functions of managing. Hence the information and technology should be managed in an effective way and should not be an overhead for an organization. With the development of technology, the methods of processing and managing information have started to change from manual to digital. The new system, Information Technology (IT) is a combination of computing, management and communication. In the scope of this study, IT is considered as hardware whereas IT applications are software part of the information system.

IT is concerned not only with the development of new technologies but also with questions such as: how they can best be applied, how they should be managed and

[1] ilhanba@itu.edu.tr

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what their wider implications are. If the contribution from IT is to be maximized, it is necessary not only for IT people to understand business issues, but also for business people to have an awareness of the potential offered by technology. Once this two-way awareness and cooperation is achieved, then IT can take place as a significant contributor to creating and supporting business strategy (Ward *et al.*, 1990). The increasing development of technology has shown its effects on almost every sector. Although the penetration of IT in the construction sector has a rising tendency in recent years, the process of technological development in a construction enterprise is different from that in other sectors due to the project-based nature of construction as Tatum (1988) highlights. Besides this, the construction sector is highly fragmented and the construction projects are complex because of involving different phases and several stakeholders such as designers, engineers and suppliers. These characteristics of the construction sector are the main barriers to implementing IT efficiently.

Therefore, there is a clear need for a framework which helps to evaluate IT investments in construction. This study is focused on measuring the effectiveness of IT utilization. In order to achieve this; first, the background of the study is examined. Next, the methodology of the study and the proposed framework are represented. Then, the validation of the framework is tested via application within Turkish construction organizations.

BACKGROUND

Evaluating IT in construction has been examined by researchers several times (for further details see, Marsh and Flanagan, 2000; Andresen *et al.*, 2000 and Construct IT, 1998). It is necessary to mention how the benefits of IT were measured in these studies. Marsh and Flanagan (2000) argued that significant barriers preventing construction organizations from investing in IT include uncertainty concerning the identification and measurement of benefits associated with applications. Difficulties in quantifying benefits associated with improved information availability and decision making prevent effective IT cost/benefit analysis. In this study, a framework is presented which identifies metrics by which IT impacts both management and operational processes within construction in order to deliver value. On the other hand, Andresen *et al.* (2000) developed a new framework for measuring the benefits of IT in construction. In this framework efficiency, effectiveness and performance benefits are identified. It is stated that the key barrier to the more effective exploitation and application of IT in the construction sector has been the lack of investment on a scale comparable with other sectors. A primary reason cited for the low level of investment is the low level of perceived benefits from IT investments amongst construction business managers. The framework has been applied to testing within UK construction organizations. Many studies indicate that there is a need to evaluate IT systems in order to manage the projects more effectively, provide an opportunity to compare different projects, organizations and countries.

METHOD

In this study, the research method comprises two parts. First, a new framework for effectiveness of IT utilization in construction is developed. Then, the proposed framework was applied for design offices and contractor firms for data collection. The various studies including efficiency, effectiveness and performance measurement models related to construction sector are reviewed and relevant issues were selected. The elements that are needed to be considered when developing an effectiveness measurement framework are identified. Since this study is a pilot study and aims to

make out if the industry is ready or not for such measurement, only the quantifiable part, effectiveness, is examined. The impacts of IT is considered on the construction processes both operational and management. It is, therefore, important to define the construction process. Construct IT (1998) defines ten distinct business processes which are considered from both function and process point of view. These processes are business planning, marketing, information management, procurement, finance, client management, design, construction, occupation and maintenance and human resources. According to Construction Specifications Institute (CSI) there are three main stages which are design, build and use. In this study, the framework is modelled by process oriented approach. The next step is to define the outcomes that arise from IT utilization in construction processes. The benefits that can be obtained from IT investment in construction are summarized and used in the framework. The outcomes are synthesized from the previous studies.

Developing the framework

The components of construction process, their involvements in the construction process and the outcomes of IT utilization are identified. The inputs of the framework which need to be determined are.

- Construction process.
- Weight indexes of each construction process phase.
- List of the outcomes that arise from IT utilization.

The phases that comprise the construction process are classified as feasibility analysis, design and planning including programming, schematic design, design development and construction documents, procurement (tender), construction, commissioning and operation and maintenance. The construction process is handled in terms of traditional project delivery system as it is the most common system used in both public and private sector in Turkey. Although all of the phases in the construction process have a great importance, their involvements in the construction process vary from each other. Weight indexes of each phase are shown in Figure 1. The distribution of weight indexes for the other phases is based on the following considerations including CSI weight indexes for especially design and planning phase and The Chamber of Architects of Turkey weight indexes for the other phases.

Feasibility analysis

The weight index is 15%. To invest or not, the decision makers need a guide in which the advantages/disadvantages of investment is assessed. In addition to these pros/cons, the weight of return of investment will have a great impact on decision.

Design and planning

The weight index is 30%. Having a proper design and planning phase enables an easy process of procurement. Design and planning process consists of four sub-phases which are programming, schematic design, design development and preparation of construction documents. The weight index of programming is 3% while schematic design is 8%, design development is 10% and construction documents is 9%. Consequently, a proper procurement phase will allow a successful construction process.

Procurement (tender)

The weight index is 15%. The investors select a capable contractor in order to complete the project within the targeted budget and time limits. With this regard, the procurement process should be carried out in diligence.

Construction
During the construction process the outcomes of the project items are executed. The quality of the work is in a direct relationship with the construction process. Therefore, 30% weight index is assigned for construction process.

Commissioning
The weight index is 5%. Field quality tests and start-up of the building are important for the quality assurance process during and following construction.

Operation and maintenance
The weight index is 5%. With the aim of providing an operable plant/project, the considerations/procedures for operation and maintenance phase cannot be ignored.

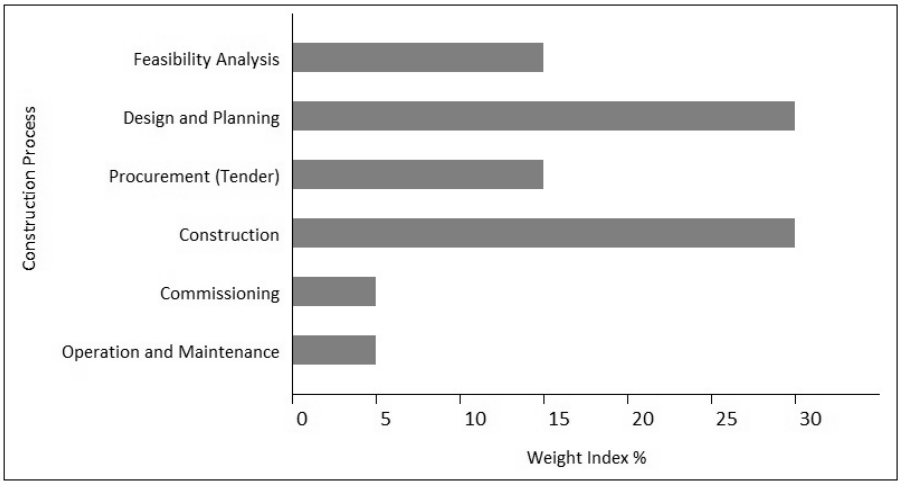

Figure 1: Weight Index of each Construction Process

The last input that needs to be determined for the effectiveness measurement framework is the outcomes that arise from IT utilization. Table 1 presents the IT utilization outcomes. The outcomes are revised from the point of Andresen *et al.* (2000) considering the construction process. The IT benefits relating to the functions are spread to the process as much as possible.

Table 1: IT Utilization Outcomes for each Construction Process

Construction Process	**IT Utilization Outcome**
Feasibility Analysis	Detailed Requirement Analysis
	Minimizing Risk
	Competitive Advantage
	Flexible Business Alternatives
	Balancing Workload
	Decision Quality
	Reliability
Design and Planning	Improved Quality of Design Outputs
	Minimizing Construction Technology Risks
	Project Data Exchange
	Effective Communication
	Project Stakeholder Satisfaction

Construction Process	IT Utilization Outcome
Design and Planning	Improved Resource Usage
	Creativity
	Better Organization and Management of Project Team
	Detailed Design Scope Definition
	Reliable Design Appraisal
	Better Control of Time
	Better Control of Cost
	Better Control of Scope
Procurement (Tender)	Faster and Consistent Responsiveness
	Appropriate Evaluation
	Effective Communication
	Minimizing Risk
Construction	Improved Quality of Construction Outputs
	Minimizing Construction Technology Risks
	Project Data Exchange
	Better Organization and Management of Project Team
	Better Control of Time
	Better Control of Cost
	Better Control of Scope
	Faster Performance Reporting
	Better Substantial Completion
	Improved Resource Usage
Commissioning	Minimizing Punch List Items
	Owner Satisfaction
Operation and Maintenance	Ability to Utilize Feedback
	Increased Market Share
	Better Customer Relationships

Once the elements are identified which are necessary for developing an effectiveness measurement framework, a matrix is organized as shown in Table 2. Table 2 presents the framework for evaluating the effectiveness of IT utilization in construction. The outcomes of IT utilization are represented in the horizontal rows and the phases of construction process are placed in the vertical columns with their weight indexes. Within the context of the framework, the user specifies the percent of the outcome of IT utilization in each construction process. The sum of each column can be a maximum of 100%. The multiplication of each column and the weight index (total weighted score) shows how much each process is affected by IT. On the other hand, the multiplication of each row and the weight index (total weighted score) gives the total impact of the process on the entire construction process (as a percent of all impact). This matrix is a useful tool for providing a benchmark of the processes and the outcomes in their own right and for examining the relationship between them. It is possible to see which process is more affected by which outcome of IT utilization and to measure the effectiveness. The model is not specific to any one type of organization in the industry but designed to cover the full range of types of organizations in the industry.

VALIDATION AND EVALUATION OF THE FRAMEWORK

The proposed framework was applied for both design offices and contractors so as to verify its validation. It has been sent to ten design offices and eight contractors. Although the framework is quantifiable and easy to understand, unfortunately only five of design offices and four of contractors sent their feedback. The possible reasons of limited number of contributions can be summarized as not comprehending the framework, finding it unfamiliar and not knowing how to fulfil the expectation. The

framework shown in Table 2 was submitted to the organizations with two additional information requests. Firstly, the weight index of each construction process was again enquired provided that the proportions do not meet the requirements of their projects. Secondly, it was inquired about the software used and required in order to achieve IT utilization.

The results show that the specified weight indexes were accepted in general with the exception of two organizations. One of the contractors stated that procurement (tender) process should have more weight index than 15% while feasibility analysis should have less than 15%. The new proposed weight indexes are 25% for procurement (tender) and 5% for feasibility analysis. On the other hand, another contractor emphasized the importance of commissioning and operation and maintenance processes. 10% was suggested for each process and 5% for procurement (tender) process. With the exception of one organization, the feasibility analysis column was not filled in. The reason of not getting an answer for feasibility analysis can be design group does not participate in this process and the owner assigns another group, in other words, outsourcing becomes a part of construction process. On the other hand, the values of that contractor show that balancing workload, better control of time, detailed requirement analysis, faster and consistent responsiveness and owner satisfaction are the most important IT utilization outcomes in the feasibility analysis. Improved quality of design outputs, effective communication, better organization and management of project team, detailed design scope definition, creativity, better control of time, improved resource usage, project data exchange and detailed requirement analysis are the most important and common outcomes that arise from IT utilization in design and planning process. Although these outcomes mostly overlap with the proposed ones for design and planning process, some outstanding points should be highlighted. The values given for detailed requirement analysis are quite high for each design office. It can be inferred that the studies to be done in the feasibility analysis are mostly handled in the design and planning process. Moreover, owner satisfaction and better customer relationship have an impact even though they are not considered as IT utilization outcomes for this process. Reliable design appraisal, project stakeholder satisfaction, better control of scope, better control of cost and minimizing construction technology risks were evaluated with lower values by some of the design offices.

For procurement (tender) process; the proposed outcomes shown in Table 1 were also pointed out by the organizations. However, project data exchange, ability to utilize feedback, reliability and decision quality were considered as the most important ones.

All IT utilization outcomes specified for construction process were touched on with the exception of minimizing construction technology risks, better control of scope and better substantial completion by the contractors. Project data exchange, better organization and management of project team, faster performance reporting, improved resource usage and better control of time have a great impact on construction process. Furthermore, balancing workload, effective communication and faster and consistent responsiveness were stated with different weights.

Finally, the contractors found that effective IT utilization helps to minimize punch list items and provides owner satisfaction, better customer relationships and effective communication in commissioning process. The results show that similar responses were given for maintenance and operation process with the exception of ability to utilize feedback. None of the firms mentioned about increased market share IT

Table 2: Framework for measuring the effectiveness of IT Utilization in Construction

IMPACT OF IT UTILIZATION IN CONSTRUCTION PROCESS

Weight Index %	15	30				15	30	5	5	100
		Design and Planning % (max. 100)								
Outcomes of IT Utilization	Feasibility Analysis % (max. 100)	Programming 3%	Schematic Design 8%	Design Development 10%	Construction Documents 9%	Tender % (max. 100)	Construction % (max. 100)	Commissioning % (max. 100)	Operation and Maintenance % (max. 100)	Total Weighted Score
Ability to Utilize Feedback										
Appropriate Evaluation										
Balancing Workload										
Better Control of Cost										
Better Control of Scope										
Better Control of Time										
Better Customer Relationships										
Better Organization and Management of Project Team										
Better Substantial Completion										
Competitive Advantage										
Creativity										
Decision Quality										
Detailed Design Scope Definition										
Detailed Requirement Analysis										
Effective Communication										
Faster Performance Reporting										

Table 2: Framework for measuring the effectiveness of IT Utilization in Construction (Cont.)

IMPACT OF IT UTILIZATION IN CONSTRUCTION PROCESS

Weight Index %	15	30				15	30	5	5	100
		Design and Planning % (max. 100)								
Outcomes of IT Utilization	Feasibility Analysis % (max. 100)	Programming 3%	Schematic Design 8%	Design Development 10%	Construction Documents 9%	Tender % (max. 100)	Construction % (max. 100)	Commissioning % (max. 100)	Operation and Maintenance % (max. 100)	Total Weighted Score
Faster and Consistent Responsiveness										
Flexible Business Alternatives										
Improved Quality of Construction Outputs										
Improved Quality of Design Outputs										
Improved Resource Usage										
Increased Market Share										
Minimizing Construction Technology Risks										
Minimizing Risk										
Minimizing Punch List Items										
Owner Satisfaction										
Project Data Exchange										
Project Stakeholder Satisfaction										
Reliability										
Reliable Design Appraisal										
Total Score										
Total Weighted Score										

utilization outcome. The information gathered from design offices and contractors about software shows that there is a general tendency for using Microsoft Office for office automation and communication, Microsoft Project and Primavera for scheduling and CAAD (Computer-aided Architectural Design) software programmes for design development. There are also some other software specified by the organizations such as different e-mail clients, some in-house software, integrated software for structural analysis and design, enterprise resource planning and accounting software. On the other hand, BIM (Building Information Modelling) was suggested as required software in the whole construction process due to its ability for controlling and coordination in real time.

CONCLUSIONS

It has been argued that measuring the benefits of IT investment in organizations is difficult. It is more complicated for construction organizations because of the specific characteristics of the construction sector. In contrast with other sectors in the economy, construction is a project-based sector producing unique products. A long production process including project initiation, design and planning, procurement (tender), construction, operation and maintenance phases is repeated for each construction project. Moreover, the risk factor is much higher in construction when compared to the other sectors because of the unpredictable work environment. There are a large number of resources used in the construction activities and participants with different specialties involved in the construction project, and this means more interrelationships exist in construction. It can be said that the construction sector has a complex and fragmented construction process and IT may have an impact on each process. It is, therefore, more difficult to evaluate the IT effectiveness than other sectors. The outcomes that arise from IT utilization in the main phases of the construction process are the main metrics for the proposed framework to measure the effectiveness of IT utilization. This framework is aimed at understanding in which phase of the construction process which type of possible IT utilization outcomes arises. Therefore, it is possible to evaluate the IT usage in the construction sector. Moreover, it is important to comprehend what should be done to improve IT effectiveness; which construction process is critical in terms of IT utilization and what kind of outcome is significant for construction projects. In this sense, it can be briefly said that design, planning, construction and relatively procurement (tender) processes comprise the critical processes on which IT has impact. Although this is an estimated result, the low feedback for other processes shows that the required importance is not given to initiation, commissioning and operation and maintenance processes. Moreover, the leading IT utilization outcomes can be summarized as project data exchange, effective communication, better organization and management of project team, better control of time and cost, improved quality of output, improved resource usage, ability to utilize feedback and minimizing construction risks. As it can be easily seen IT utilization provides a great deal of benefits for all stakeholders of a construction project. Nevertheless, the feedback for the software utilized shows that IT utilization has still been performed by traditional methods even though more efficient alternatives are available. However, the specialized software developed for each function and those that allow integration of each process should be used for improved quality of construction projects. This can be the result of not paying enough attention for the training of the employees due to the high work load and the low consciousness of IT investment and also the cost of such software.

The level of hardware, IT spectrum and IT literature limit the scope of this study as they are not considered within the application. For future study, the framework for measuring IT utilization can be developed including efficiency and performance outcomes and its application within the construction organizations is evaluated. Moreover, the readiness of organizations to adopt IT can be examined.

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