Cost analysis of information technology-assisted quality inspection using activity-based costing

YONG-WOO KIM[1] and SANG-CHUL KIM[2]*

[1]*Department of Construction Management, 120 University of Washington, H Arch Hall, Box 351610, Seattle, 98195 USA*

[2]*Department of Architectural Engineering, Hanbat National University, San 16-1 Dukmyung-dong, Yuseong-gu, Daejeon, 305-719 Republic of Korea*

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One of the critical factors in quality control is the efficient management of quality field inspections. A method was developed to assess the cost impact of process improvements in construction jobsite management. Through the development of a prototype quality inspection system together with project database and mobile technology, the efficiency of a quality inspection system as a pilot study is examined. A time-driven activity-based costing (ABC) is used in evaluating the quantifying process costs attributable to the implementation of a new field inspection system. Inspection costs were reduced when the current inspection process is replaced by a new inspection prototype process using a project database and mobile technology. The cost analysis results also show that a new approach (1) identifies the inspection activities before and after the re-engineering process; (2) computes the cost driver rate before and after the re-engineering process; and (3) enables the performance of the scenario analysis by manipulating the volume of cost drivers under different scenarios.

Keywords: Activity-based costing, cost analysis, personal digital assistant, quality inspection.

Introduction

The contractor deals with several formidable tasks in managing a construction project. One of the important challenges is project control. Effective project control involves a multitude of tasks including the meticulous management of procurement, cost, schedule, quality, workforce and safety. Of these tasks, the three major measures for project performance assessment are cost, schedule and quality (Jung and Woo, 2004). Cost and schedule are objective and quantitative, whereas quality is subjective and qualitative (Construction Industry Institute, 1997).

Crosby (1979) defined quality as conformance to requirements. In the past, quality was typically defined as producing as few defective parts as possible. However, the concept of quality has extended to encompass a holistic business concept that spans customer satisfaction and even productivity. The International Organization for Standardization (2005) defined quality as the degree to which a set of inherent characteristics fulfils requirements. Also, quality is defined, according to the ANSI/ASQC A3-1978, Quality Systems Terminology. American Society for Quality Control, Milkwaukee, WI, as 'the characteristics of a product or service that bear on its ability to satisfy stated or implied needs'. In other words, quality represents how well the product serves the customer's needs. Quality is considered as a critical factor in determining project acceptance and contractual payment levels (Battikha, 2002). It has short-term implications affecting a project's material and labour costs, as well as long-term implications affecting the construction company's overall reputation (Schaufelberger and Holm, 2002). In this paper, quality needs to be confined to the conformance to requirements as the focus of the research is placed on the quality inspection process. Quality inspection, one of the critical processes in quality control, is the process of ensuring that final products fulfil the defined

*Author for correspondence. E-mail: harvard9@naver.com

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requirements assigned by the customer (Kim *et al.*, 2008). However, quality inspection requires enormous amounts of time and effort from inspectors and contractors.

The development of information technology has brought about many benefits to the construction industry, helping it meet increasingly complex challenges (Paulson, 1995). Information technology affects the way construction projects are managed.

The objective of this research is to develop a method of economically assessing the process improvements in construction jobsite management. As part of the research efforts, this study presents a method of using activity-based costing (ABC) in performing an economic assessment on quality field inspection improvements where quality inspection is carried out by an independent (or third party) inspector. First, we describe a prototype quality inspection system using a project database and mobile device. A method is developed that uses ABC for quantifying process costs attributable to the implementation of a new field inspection system. Data provided by four different heavy civil (sewage pipe) construction projects were used in developing ABC models. ABC models on two different types of inspection systems using a historical data-based project scenario were used for the cost analysis.

Related works

The US Department of Transportation (DOT) at the Federal Highway Administration offered a quality assurance software package, which is about quality assurance procedures (Battikha, 2002). The quality assurance package of the US DOT enables users to choose or define a proper inspection standard template for inspection (Battikha, 2002). Chin *et al.* (2004) presented a process-based quality management information framework to improve quality using a project database system. Love and Irani (2003) suggested a project management quality cost information system (PROMQACS) that was used to determine the cost and causes of rework that occurred in the projects. The project participants can use the information in PROMQACS to identify shortcomings in their project-related activities (Love and Irani, 2003). Recently, Wang (2008) proposed a quality management system based on radio frequency identification (RFID), which is used in complement with mobile devices and online portals enhancing material test management's effectiveness and flexibility. Kim *et al.* (2008) presented a computerized quality inspection and defect management system (QIDMS) that can collect defect data at a site in real time using a personal digital assistant (PDA) and wireless internet. Wang (2008) and Kim *et al.* (2008) showed the advantage of adopting online portals and mobile devices in the quality inspection process.

Quality inspection

Quality field inspection requires a number of activities that involve more than one stakeholder. This research focuses on quality field inspection that requires an independent (or third party) inspector.

Generally, quality inspection consists of three stages: inspection preparation, inspection, and follow-up documentation. In the inspection preparation stage, a quality engineer or manager of a contractor retrieves drawings and specifications from the site office and prepares a quality inspection request. The inspection ensures compliance in completed tasks from standards specified in drawings and specifications. Any detected non-conformance or deviation is reported along with a quality plan for corrective action. Approval is given to allow a contractor to proceed with succeeding activities only if the proper corrective action is taken and confirmed.

However, the following problems in quality inspection practices have been identified in several case studies (Kim *et al.*, 2008):

- time-consuming process: duplication of data in site and office;
- data losses and damages due to non-unified or non-formatted data recording system;
- difficulty in monitoring whether the defects have been properly corrected;
- lack of a number of onsite staff;
- poor communication;
- no standard repository of data and feedback systems.

Quality inspection system using project management database and mobile device

Many researchers presented the advantages of using mobile devices in the construction industry (Baldwin *et al.*, 1994; Fayek *et al.*, 1998). Moreover, mobile devices have been applied in numerous construction industries to (1) develop field inspection support systems related to mobile computing hardware, technologies for collecting inspection data, and application software (Sunkpho and Garrett, 2003); (2) support information-sharing platform in a collaborative environment (Pena-Mora and Dwivedi, 2002); and (3) use in supply chain management systems (Tserng, 2005). Those research results suggest that mobile technology could help field engineers or inspectors with inspection and follow-up documentation process due to real-time information transmission.

Kim *et al.* (2008) presented a daily schedule management system that integrates labour, equipment, material and mobile technology. Work by Kim *et al.* (2008) provided the foundation for the suggested quality inspection system as their work had shown that mobile technology (i.e. PDA equipped with wireless network) allows information on a daily schedule management system to be interfaced with the necessary labour, equipment and material information on the project management system based on the needs of onsite personnel.

As shown in Figure 1, a quality engineer or project engineer of a contractor can retrieve the daily inspection task through their PDA. The system provides a list of tasks that require inspection the following day.

Once a task is selected, checklist and drawings are retrieved from the project database (Figure 2). The inspection request on a selected task is generated and transmitted to a third party inspector.

A quality manager and an inspector can easily detect any deviation from the standards. After the task has passed inspection, an inspector approves and signs with their PDA. All relevant information included in the approval is automatically transmitted to the project database. Inspection data are stored in the database and can be retrieved and printed when needed as shown in Figure 3.

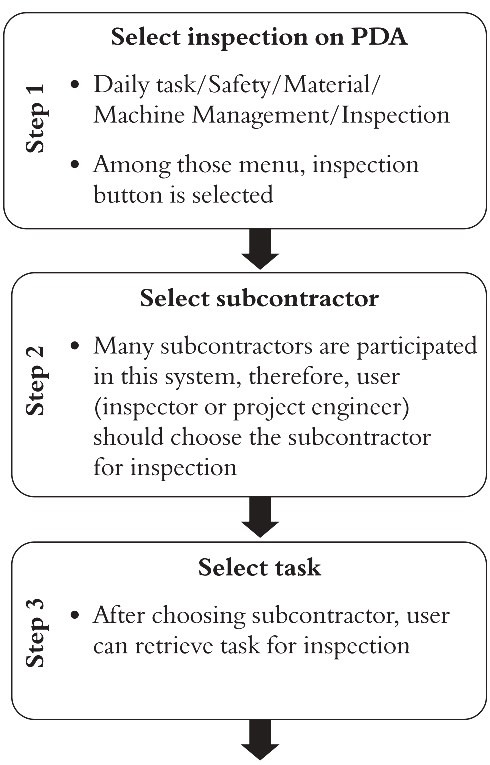

Figure 1 Selecting task for inspection

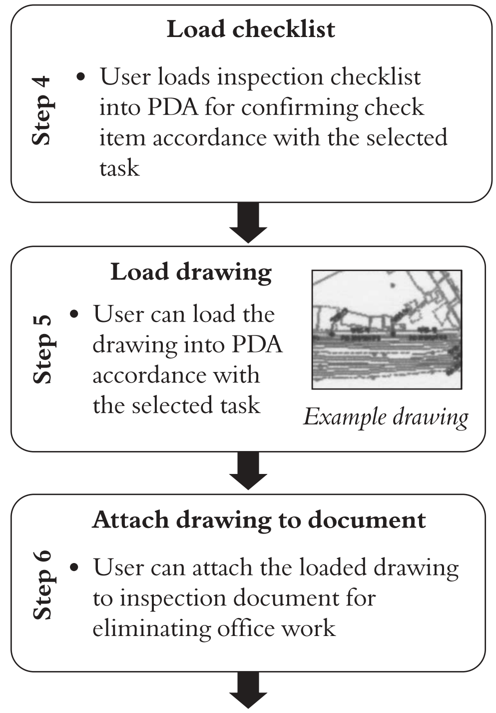

Figure 2 Load drawing for attached inspection documents

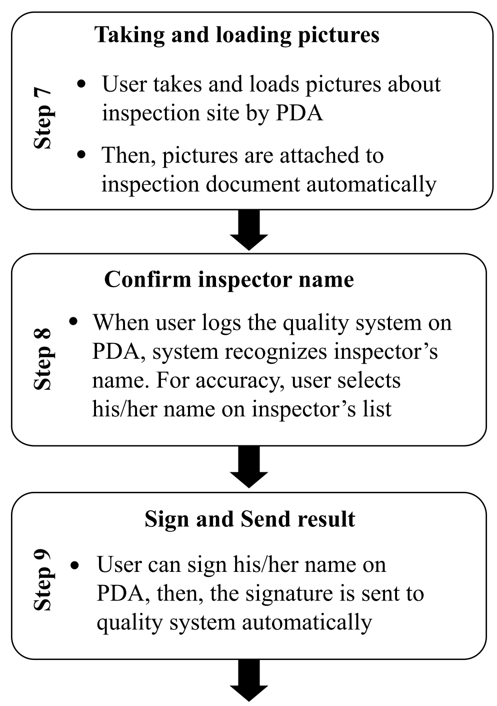

Figure 3 Load pictures and inspector's signature

If an inspector finds any work that does not conform to the specifications and/or drawings, a picture is taken and a non-conformance report is generated using the inspector's PDA. The non-conformance report is then transmitted to the contractors. Periodically, quality managers can easily retrieve inspection results trends, including the frequency of and reasons for failed works.

Research method

The economic evaluation of process re-engineering involves the use of explicit monetary values of processes associated with field quality inspection. However, the difficulties with tracking overhead resources (such as indirect labour) associated with the inspection process pose a challenge to cost analysis. ABC is applied to the analysis of a cost impact to demonstrate how ABC, applied as an evaluation tool, affects the process re-engineering of quality inspection.

Activity-based costing

Activity-based costing (ABC) is a costing model that identifies activities in an organization and assigns the cost of each activity resource to all products and services according to the actual consumption by resource and activity (Cokins, 1996). ABC is found to provide management with a more detailed cost analysis of activities and processes (Kim, 2002). ABC differs from conventional costing in its treatment of indirect costs (Cokins, 1996). Instead of combining costs into all-embracing departmental cost pools, ABC identifies key activities throughout the business and allocates activity costs to cost objects (i.e. products or projects) based on the volume of individual drivers for each activity (e.g. number of inspection requests).

However, traditional ABC appeared to cause two significant problems. First, setting up an ABC system can be very costly, especially if the current accounting system does not support the collection of ABC information. Second, the system must be regularly updated, which further increases its cost (Kim, 2002; Kaplan and Anderson, 2004). Such limitations motivated Kaplan and Anderson (2004) to develop time-driven ABC. The most important characteristic of this technique is its simplicity, as time-driven ABC estimates only two kinds of parameters: (1) the unit cost of resources; and (2) the time required to perform a transaction or an activity (Kaplan and Anderson, 2004). The research uses a time-driven ABC in that the resource consumption by activity varies over time and updating the system takes up additional resources.

ABC as an evaluation tool for process re-engineering

Traditionally, a time-tracking method has been used to measure how labour-involved process re-engineering is effective (Rojas and Songer, 1999; Moreau and Back, 2000; Wang, 2008; Jang and Skibniewski, 2009). A time-tracking method traces how much time is spent on each resource in the process. From a cost allocation perspective, a time-tracking method uses a one-stage allocating (Figure 4), which assigns resources to the cost object. As seen in Figure 4, a one-stage costing only uses a resource cost driver, which measures the demand intensity on resources by process or cost object. The time-tracking method uses time as a resource cost driver to allocate resources to the cost objects. In the one-stage time allocation method, time should be tracked throughout the period. The need for tracking all the time makes it difficult for an organization to continuously perform a long-term tracking of the costs.

ABC was adopted as an evaluation tool for construction process re-engineering. ABC uses a two-stage costing, traces resources to processes, and then assigns processes to products and services. As seen in Figure 4, ABC uses two cost drivers: the resource cost driver (time) and the activity cost driver. Practically, a cost driver is the factor of which the volume is in proportion to the costs of the activity (Horngren *et al.*, 2000). In many cases, the instance of activity is used as the cost driver.

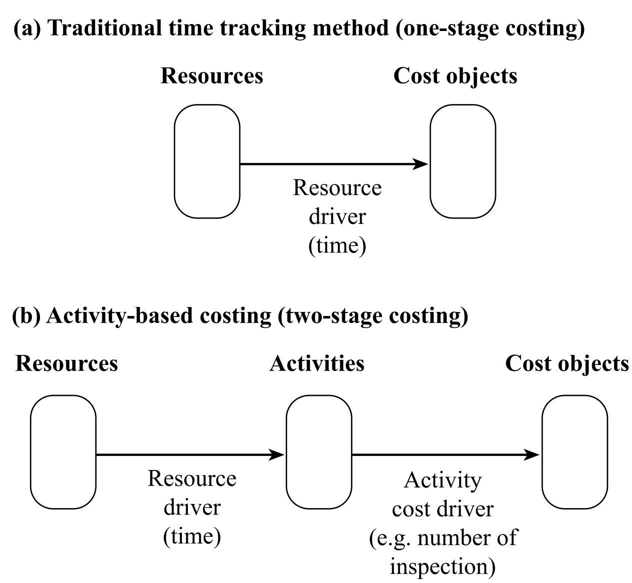

Figure 4 Time-tracking method vs. activity-based costing

In ABC, the volume of the activity cost driver is the only variable to be traced for the period after the resource consumption rate (resource consumption for one transactional activity) is fixed. ABC helps the organization to easily trace the costs of the re-engineered process, whereas the time-tracking method (one-stage allocation) makes it hard to continuously trace the costs except for the pilot study. For the same reason, the organization can use ABC as an accounting tool to keep track of supporting processes that involve overhead resources, which are hardly measured in a traditional accounting system.

ABC modelling

As previously stated, ABC uses two-stage costing. Figure 4 presents the relationship between products/services (cost objects) and the resources that are consumed by the product or service.

The activity cost driver rate is calculated by multiplying the volume of resources consumed by each activity (e.g. how many hours a draftsman needs to spend in generating shop drawings) by the unit cost of each resource, c_i (e.g. hourly wage of a project engineer) as shown by Equation 1. The activity cost driver rate (C_j) refers to the unit cost of performing the *j*th activity. For example, costs for generating one sheet of shop drawing come to an activity cost of 'generating shop drawings' with the number of sheets being understood as a cost driver. Equation 1 below shows how this can be represented:

$$C_j = \sum R_{ij} \times c_i \quad (1)$$

where C_j is the activity cost driver rate that refers to the unit cost of performing the *j*th activity, R_{ij} is the time required by *i*th resource to perform a transactional activity (j), c_i is the unit cost (i.e. hourly wage) of resources, m is the total number of resources needed to perform the *j*th activity.

The cost of performing the *j*th activity is calculated by multiplying the activity cost driver rate by the volume of the cost driver. When the total cost of making a product or service is calculated, the costs of all the activities must be added. Therefore, the cost of making the *k*th product or service can be given as

$$TC_k = \sum(C_j \times d_{jk}) = \sum(\sum R_{ij} \times c_i \times d_{jk}) \quad (2)$$

where TC_k is the cost required to make the *k*th product or service, C_j is the activity cost driver rate from Equation 1, d_{jk} is the cost driver volume (i.e. quantity of activity) and n the number of activities needed to produce the *k*th product or service.

In this case study, TC_k refers to pipe inspection costs, and activities are confined to activities related to field inspection. $\Sigma\Sigma\ R_{ij}$ can be represented as a $i \times j$ matrix ($R_{i \times j}$) representing times required by *i*th resource to perform a transactional activity (j). Examples of the resource consumption matrix are found in Tables 5 and 6.

The variables that need to be determined in the calculation of inspection costs, as seen from Equations 1 and 2, are the resource consumption matrix, the unit cost of resources, and the volume of activity cost driver. The unit cost of resources is determined by standard inspectors' wage rate published by the Korea Construction Consulting Engineers Association and a contractor's human resource department. The resource consumption matrix and the volume of cost driver are determined by interviews with quality managers and project engineers. Details on the source of data are presented in Table 1.

Cost analysis

Process modelling

Two inspection process models were developed for ABC modelling. Both models depict the process flow for inspection request and inspection follow-up. For this research, the authors selected a sewer pipe installation in four civil projects. We believe that the pipe installation process provides an environment adequate to the application of ABC. Another reason a sewer pipe installation was chosen is that a pipe installation inspection is one of the most frequently repeated inspection processes in these projects. Table 2 presents the abstract description of reference projects.

Table 1 Source of data

Variables		Source
The unit cost of resources (i.e. hourly wage)	Inspectors	Korea Construction Consulting Engineers Association (2009)
	A contractor's personnel	Human resource representative
Consumption of resource by activities		Interviews with personnel (all figures were the average of four projects)
Volume of activity cost driver		Interviews with personnel (all figures were the average of four projects)

Table 2 Description of reference projects

Project name	Sewerage pipe rehabilitation project in Moonkyung city	Sewerage pipe rehabilitation project in Wonju city	Sewerage pipe rehabilitation project in Han river	Sewerage pipe rehabilitation project in Wooljin-Gu
Location	Moonkyung city, Kyoungsang North Province	Wonju city, Kangwon Province	Namyangju city, Kyonggi Province	Wooljin-Gu, Kyoungsang South Province
Period	09.02–12.11 (45 months)	09.04–12.10 (42 months)	06.12–10.10 (46 months)	08.09–11.09 (37 months)
Construction cost	US$82 mil	US$91 mil	US$98 mil	US$72 mil
Work description	1. Sewage pipe • Waste pipe • Rainwater pipe • Manhole repair work • Manhole type pump station 2. Drainpipe 3. Maintenance system	1. Sewage pipe • Waste pipe • Rainwater pipe 2. Drainpipe	1. Sewage pipe • Waste pipe • Rainwater pipe 2. Drainpipe 3. Drainage box	1. Sewage pipe • Waste pipe • Rainwater pipe 2. Drainpipe 3. Manhole repair work 4. Repair/reinforcement

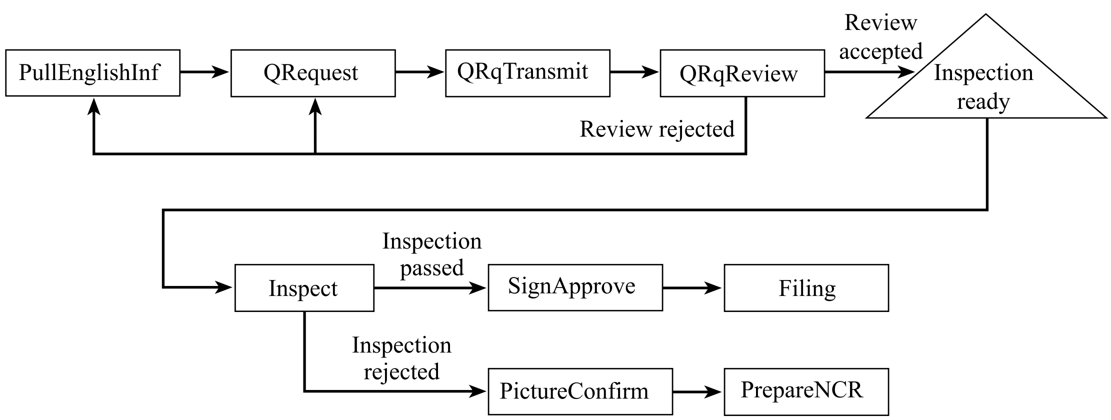

Figure 5 Inspection process (traditional)

The first model shows a 'traditional inspection process' (Figure 5) to represent the baseline condition prior to the implementation of a new inspection system. As shown in Figure 5, no data integration is found, let alone automation. Table 3 describes the activities in the process model.

The next process model addresses a prototype IT-assisted inspection process (Figure 6). Task information and project database are integrated with a quality inspection system. Mobile technology (i.e. a PDA equipped with wireless network) enhances the inspection process by enabling the external integration of information with a third party inspector. With information technology, data can be instantly and accurately captured and transferred. Efficiencies are improved through reduced durations and the elimination of activities related to documentation and transmittal. For example, activities associated with retrieving

Table 3 Activity information (traditional inspection process)

Activity	Definition
PullEngInfo	Retrieve information for inspection preparation
QRequest	Develop quality inspection request
QRqTransmit	Transmit request documents to a third-party inspector
QRqReview	Review request documents
Inspect	Inspect
SignApprove	Sign and approve the inspection
Filing	File inspection documents
PictureConfirm	Take pictures on deviations from specs & drawings
PrepareNCR	Prepare a non-conformance report

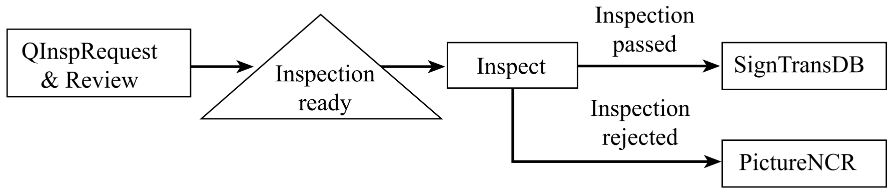

Figure 6 Inspection process (IT-assisted)

Table 4 Activity information (IT-assisted inspection process)

Activity	Definition
QInspRequest	Retrieve information and develop/ transmit request using PDA
Inspect	Inspect
SignTransDB	Sign and transmit to a project database
PictureNCR	Take picture and develop/transmit NCR using PDA

information and generating an inspection request document were integrated into a single activity (QInspRequest). Many activities associated with documentation were either automated or eliminated. Table 4 describes activities in the process model.

Time-driven ABC modelling

Resources and the unit cost of resources

Six resources identified during the data acquisition are: inspector I, inspector II, quality engineer, clerical, project engineer (GC) and project engineer (SC). In many cases, a task may involve more than one resource. For example, an inspection task involves three resources (i.e. inspector, quality engineer and field engineer). The unit costs of resources (c_i) are acquired through the publication of the Korea Construction Consulting Engineers Association (2009) and a contractor's human resource representative (Table 1). The values (c_i) representing hourly wage of each personnel are as follows:

- Inspector I: $18/hour
- Inspector II: $23/hour
- Quality engineer/manager (GC): $30/hour
- Clerical: $8/hour
- Project engineer (GC): $25/hour
- Project engineer (SC): $20/hour

It is noted that inspectors and employees of a subcontractor are outside the organizations, but their wages are included because their activities are important in the inspection process. Admittedly, these wage rates may differ from actual wage rates depending upon geographical markets.

Resource consumption matrix

A resource consumption matrix ($R_{i \times j}$) that represents how many resources each activity consumes in two cases is shown in Tables 5 and 6. Resource consumption refers to time spent in performing a transactional activity (j). The numbers in a resource consumption matrix show the average unit times for activities. The time estimates were obtained by interviews with key personnel. For example, an activity of 'PrepareNCR' consumes 0.5 hour of Inspector I and 0.2 hour of Inspector II to handle one non-conformance report (Table 5).

Activity cost driver rate (C_j)

The activity cost driver rate for activities can be calculated using Equation 1. Figure 7 shows the calculation process of the activity cost driver rate (C_j).

Volume of cost drivers and cost analysis

Once the activity cost driver rate is developed, the volume of cost drivers must be measured to accurately perform a cost impact analysis for the study period. The researchers relied on the scenario-based analysis as the prototype inspection process was tested only for a couple of months. Using historical data on the four projects, the researchers assumed a scenario whose details are addressed in Table 7. The quantity of cost drivers was estimated from interviews with key personnel.

The total inspection costs for both cases using Equation 2 were calculated. The cost for each activity was calculated by multiplying the activity cost driver rates by the quantity of the activity cost driver (Table 7). The technology cost refers to costs a contractor pays every month to its subsidiary IT company for the use of technology, including equipment and software, which is not considered in ABC modelling. The contractor pays a subsidiary IT company for the inspection-related IT service, which includes equipment rental and operational costs. In

Table 5 Resource consumption matrix (Rij), traditional (per activity driver)

			Resources					
		Cost driver	GC, PE	GC, QC	Clerical	SC, PE	INSP, I	INSP, II
Activities	PullEngInfo	# of request	0.65	0.1		0.25		
	QRequest	# of request	0.45	0.1		0.2		
	QRqTransmit	# of transmit	0.1		0.2			
	QRqReview	# of request					0.5	0.15
	Inspect	# of inspection		0.7		0.7	0.7	
	SignApprove	# of inspection		0.1			0.1	0.05
	Filing	# of inspection			0.3			
	PictureConfirm	# of inspection		0.2			0.2	
	PrepareNCR	# of NCR					0.5	0.2

Note: GC = general contractor, SC = subcontractor, PE = project engineer, INSP = inspector.

Table 6 Resource consumption matrix (Rij), suggested model (per activity driver)

			Resources					
		Cost driver	GC, PE	GC, QC	Clerical	SC, PE	INSP, I	INSP, II
Activities	QInspRequest	# of request	0.1	0.1		0.1	0.1	
	Inspect	# of inspection		0.7		0.7	0.7	
	SignTransDB	# of inspection					0.1	0.1
	PictureNCR	# of NCR					0.3	0.2

$$C_j = \begin{vmatrix} 0.7 & 0.1 & 0 & 0.3 & 0 & 0 \\ 0.5 & 0.1 & 0 & 0.2 & 0 & 0 \\ 0.1 & 0 & 0.2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0.5 & 0.2 \\ 0 & 0.7 & 0 & 0.7 & 0.7 & 0 \\ 0 & 0.1 & 0 & 0 & 0.1 & 0.1 \\ 0 & 0 & 0.3 & 0 & 0 & 0 \\ 0 & 0.2 & 0 & 0 & 0.2 & 0 \\ 0 & 0 & 0 & 0 & 0.5 & 0.2 \end{vmatrix} \times \begin{vmatrix} 25 \\ 30 \\ 8 \\ 20 \\ 18 \\ 23 \end{vmatrix} = \begin{vmatrix} 24.25 \\ 18.25 \\ 4.10 \\ 12.45 \\ 47.60 \\ 5.95 \\ 2.40 \\ 9.60 \\ 13.60 \end{vmatrix}$$

(a) Activity cost driver rate, traditional

$$C_j = \begin{vmatrix} 0.1 & 0.1 & 0 & 0.1 & 0.1 & 0 \\ 0 & 0.7 & 0 & 0.7 & 0.7 & 0 \\ 0 & 0 & 0 & 0 & 0.1 & 0.1 \\ 0 & 0 & 0 & 0 & 0.3 & 0.2 \end{vmatrix} \times \begin{vmatrix} 25 \\ 30 \\ 8 \\ 20 \\ 18 \\ 23 \end{vmatrix} = \begin{vmatrix} 9.30 \\ 47.60 \\ 4.10 \\ 10.00 \end{vmatrix}$$

(b) Activity cost driver rate, IT-assisted

Figure 7 Calculation of activity cost driver rate (C_j)

terms of project cost accounting, the monthly fee of $1500 is the only expense for the inspection IT service with no initial investment.

The cost analysis shows that the difference in inspection costs would be $45 960 when the current inspection process is replaced by a new inspection prototype using a project database and mobile technology. If a project requires more inspection activities, the benefits will increase as the cost driver volume increases, assuming that the resource consumption rates remain constant.

Table 7 Project scenario

Project type	Sewer pipe installation
Duration	12 months
Number of inspections	100 per month
Technology cost (not reflected in ABC)	$1500 per month

Discussion

Unlike most literature on ABC dealing with overhead allocation, this research applied ABC as an economic assessment tool for process improvement. This research also introduced a resource consumption matrix that represents how many resources each activity consumes as a method for implementing ABC. The resource consumption matrix for the same process is assumed constant unless the resource configuration (e.g. changes of personnel implementing the activities) changes for a certain period. Once the resource consumption matrix is developed, the costs can be calculated by simply tracking the number of cost drivers.

Table 8 Cost analysis

		Act. cost driver quantity	Act. cost driver rate ($)	Costs ($)/yr
Traditional inspection				
PullEngInfo	# of request	1000	24.25	24 250
QRequest	# of request	1000	18.25	18 250
QRqTransmit	# of transmit	1000	4.10	4100
QRqReview	# of request	1000	12.45	12 450
Inspect	# of inspection	1000	47.60	47 600
SignApprove	# of inspection	1000	5.95	5950
Filing	# of inspection	1000	2.40	2400
PictureConfirm	# of inspection	1000	9.60	9600
PrepareNCR	# of NCR	100	13.60	1360
Total				*125 960*
IT-assisted inspection				
QInspRequest	# of request	1000	9.30	9300
Inspect	# of inspection	1000	47.60	47 600
SignTransDB	# of inspection	1000	4.10	4100
PictureNCR	# of NCR	100	10.00	1000
Additional technology costs[a]				18 000
Total				*80 000*

Note: [a] 12 months × $1500/month.

ABC provides the management or the process re-engineering team with insight on process. The process re-engineering team needs to identify the processes to implement ABC. As shown in the case study, ABC analysis provides activities (or processes) comparing before and after the re-engineering process with process modelling. In this regard, ABC analysis supports process improvement efforts, such as achieving lean production. For example, the company currently uses a lean production system concurrently with activity-based costing.

ABC analysis reveals the cost driver rate before and after the re-engineering process. The cost driver rate indicates how efficiently each activity is performed. In Tables 5 and 6, the resource consumption matrix shows the activity cost driver rate for each activity. In Table 5 (traditional), for example, 0.45 hour (GC/PE), 0.1 hour (GC/QC) and 0.2 hour (SC/PE) were spent in preparing an inspection request. In Table 6 (IT-assisted), the unit times required for the same activity were reduced to 0.1 hour (each party).

ABC analysis reveals the volume of the activity cost driver although the case analysis in this paper does not show the comparison of the cost driver volume before and after the re-engineering process. With this feature, ABC analysis can provide a 'what-if' scenario analysis by manipulating the volume of cost drivers under different scenarios. The case study, for example, shows that the monthly cost of inspection is reduced by $45 960 when the current inspection process is replaced by a new inspection prototype using a project database and mobile technology. In Table 7, the number of inspections for one year was assumed based on average historical data from four reference projects. The process re-engineering team can easily change the volume of cost drivers to see how the cost changes as the volume changes. Quantitative data from the 'what-if' scenario helps the management with the decision-making process.

In addition to the economic impact derived through the cost analysis, some important benefits have also been identified in the course of the research. The interviewees indicated that one important benefit from the suggested inspection process is the increase in the management's time on planning and site supervision, while decreasing the time spent on documentation. Its benefits were not quantified in ABC modelling, but it is not difficult to expect its positive effects on project management.

Although ABC provides many benefits, considerable effort and resources are expended in the setting up and the maintenance of the system. ABC analysis in this research required consultancy fees, as well as employees' time in participating in various interviews and tracking the volume of drivers.

Conclusion

Many top managers in the construction industry are hesitant in adopting information technology to improve process efficiency as they do not have the data to justify the investment. Quality field inspection is an area where information technology can be easily applied for efficiency improvement. An IT-assisted quality inspection prototype system is described, followed by an assessment of cost impacts where ABC is applied. The case study results suggest that an IT-assisted quality inspection improves process productivity through automation and eliminating/integrating tasks. ABC was adopted in this paper as an evaluation tool for process re-engineering in construction projects. For simple and consistent implementation, the resource consumption matrix was developed and tested in the cost analysis. Process re-engineering teams can leverage ABC to carry out a cost analysis associated with their re-engineering processes. The cost analysis results suggest that the ABC approach as an evaluation tool for process re-engineering (1) identifies the inspection activities before and after the re-engineering process; (2) computes the cost driver rate before and after the re-engineering process; and (3) enables the performance of the scenario analysis by manipulating the volume of cost drivers under different scenarios.

The results of this experiment involving ABC as an evaluation tool for process re-engineering also suggests that the method can be used by companies in the engineering and construction industries to assess the impact of such process improvements as the use of IT applications.

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