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# ACTIVITY-BASED COSTING FOR PROCESS IMPROVEMENTS

**Taehoon Kim[1] and Yong-Woo Kim[2]**

## ABSTRACT

Current construction industry requires effective process improvement to enhance the productivity and managerial capability. However, construction projects are found to have a limited number of tools for process management on construction sites. Activity-based costing (ABC) technique can provide insightful information on areas for process improvement to minimize waste or non-value-adding activities. However, the ABC has the limitations in reflecting complicated and interactive nature of construction processes. This paper explores how ABC can be practically used for construction process improvement with the support of discrete event simulation (DES) technique. Activity hierarchy is presented as a way to allow sustainable activity cost tracking. The proposed approach can contribute to facilitating easy and practical process control on a basis of more accurate cost information.

## KEYWORDS

Activity-based costing, discrete event simulation, process improvement.

## INTRODUCTION

Current environments in the construction industry demand effective process management to enhance the productivity and management efficiency. As the construction projects have become more uncertain and complex, the construction industry is suffering from increased waste, poor performances such as overrun and behind-schedule, and adversarial relationships (CMAA 2010). In order to properly respond to such challenges, organizations in the construction industry make continuous efforts to improve their technical and managerial capability among which efforts to improve processes are being made at the process level.

Activity-based costing (ABC) technique can provide very insightful information to an organization regarding areas needing process improvement. The ABC identifies activities in an organization and assigns the cost of each activity resource to all products and services

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according to the actual consumption by resource and activity. Thus, this technique allows the organization to predict the actual costs incurred to perform a work process (Back et al. 2000, Kim et al. 2011). Companies can identify areas for process improvement to minimize waste or non-value-adding activities without relying on speculation and intuition.

However, the ABC has the limitations in establishing more accurate process modelling. In general, construction processes has the complicated, interactive, and dynamic nature. Thus, construction activities may be changeable in their duration, cost, frequency of occurrence, or precedence relationship with other activities (Back et al. 2000). However, the ABC model has the limitations in reflecting those changes without support of a process modelling technique. In especial, discrete event simulation techniques provide a vehicle to overcome the analytical difficulties in complex construction process structures (Back et al. 2000).

The objective of this paper is to explore how ABC can be practically used for construction process improvement with the support of simulation technique. This paper focuses on presenting how to bridge the gap between activity-based costing and process simulation. For this purpose, the use of appropriate activity hierarchy between two systems and strategy for sustainable process improvement are proposed. In addition, a hypothetical case study on pipe installation inspection task was conducted to show the effects of the proposed approach. Through coupling process simulation with activity-based costing, companies can not only better manage process change and develop strategic plans for process improvement, but also predict the performance outcomes in a more accurate way.

## ABC IN COSTRUCTION

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).

Unlike resource based costing using a one-stage allocating, which assigns resources to the cost object (i.e. products or services), ABC uses a two-stage costing, traces resources to processes, and then assigns processes to products and services. 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. 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 each activity in the process. 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.

Several efforts have been made to apply the ABC in construction domain. Kim and Ballard (2001) explored the relationship between ABC and lean construction and presented an example of applying ABC to construction. In this paper, they presented a cost hierarchy to identify cost drivers in construction. Some researchers and companies (Matteson, 1994, Kim and Ballard 2005, Kim et al. 2011) applied ABC to allocate home office and project overhead costs. Back et al. (2000) and Maxwell et al. (1998) linked process modelling and simulation with ABC. However, they did not allocate activity costs to cost objects. Moreover, their model concentrates on field operations, neglecting activities of overhead resources.

## ACTIVITY HIERARCHY

As presented above, compared to ABC, DES can provide more accurate information on resource consumption of each activity by modelling the interdependence of activities. However, if ABC model uses all activities of DES model in allocating activity costs (i.e., ABC uses the same level of activity detail), ABC model will lose its practical value and accuracy in two ways. First, if ABC uses activities at daily-task level with batch-level cost driver such as "the number of inspections", the model loses the accuracy of tracking activity costs in that resource consumption fluctuates each time activity is performed. Second, if ABC uses time-tracking just as DES, the model cannot be sustained due to its maintenance requiring plethora of efforts.

Therefore, the leverage of ABC model coupled with DES as a practical process improvement tool requires appropriate activity hierarchy. The activity hierarchy should be developed to show relations between activities in DES and those in ABC model. This allows for continuous and sustainable activity-cost tracking.

In ABC model, the activity hierarchy affects its cost driver and eventually how its cost would be tracked and calculated. Kim and Ballard's work (2001) differentiates activities based on the intrinsic nature of activities, the costs of which increase or decrease. Similarly, the activities are categorized in (1) functional level, (2) batch level, and (3) daily-task level for this study, as shown in Figure 1. In ABC, you can identify any number of activities with any level of detail. It is challenging to determine the right level of detail; but, in most cases, activities in ABC system are found to be ranged between daily-task level and functional level.

(1) Functional Level: This level includes supporting activities to sustain a project or an organization. Quality control can be activity at a functional level. In many cases, each department in an organization corresponds to each function.

(2) Batch Level: Activities in a batch level, which are related to a group of products or services, are used in ABC. Their cost drivers are directly related to the instance of the activity. The major reason why they are used in ABC is the easiness of updating the volume of cost drivers. Inspection can be an example of activity at a batch level where the number of inspection can be a cost driver.

(3) Daily-task Level: Activity at a batch level can be decomposed into numerous activities at a daily-task level. They are equivalent to activities in most process simulation models. For example, retrieving updated drawing and specification is an example of activities at a daily-task level. Due to fluctuation of resource consumption, the activities at a daily-task level should not use a batch-level cost driver; instead, they use cost drivers at a resource unit level such as time.

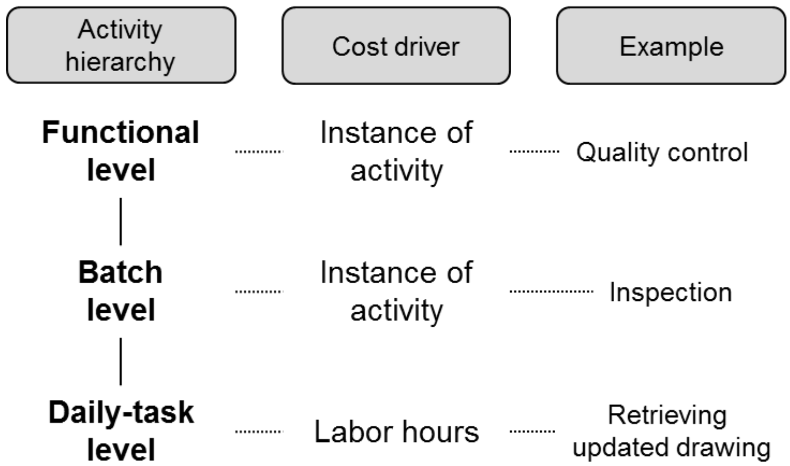


Figure 1: Activity Hierarchy in ABC

The use of activities at a daily-task level in ABC model elicits the problem that the model cannot be sustainable because it is too time-consuming to track durations for detailed activities on a regular basis to update the ABC system. For the same reason, simulation process models are usually developed and run in a planning stage while they are not regularly updated to see if their plan (modeled operation) is operationalized. In other words, the simulation model fails to be used for a control purpose. The key to coupling ABC system with process modeling or process simulation is in the link between activities at a batch level and activities at a daily-task level.

# STRATEGY FOR PROCESS IMPROVEMENT WITH ABC (PIABC)

(1) Develop ABC system using activities at a batch level

In order to develop ABC system, an organization's management should first define existing process including process boundaries and individual activities. While this should include all activities necessary to fully specify products and services, most activities are made up at a batch level corresponding to the objective of the system (i.e., process control and improvement). The next step is to identify resources, and cost drivers and their rates of each activity.

(2) Identify activities that need process improvement

Once ABS system is established, the management should seek activities which improvement is required. The comparison with status of other organizations or projects cost helps you identify activities that need process improvement. Suppose the cost driver rate of inspection activity in current project becomes $120 per an instance, while the average rate from other projects showed $80. Then, you will feel a need to enhance the current process for the inspection.

(3) Develop a process simulation model

Next step is to construct the current process model by using a discrete-event simulation (DES) technique. First, you need to decompose the activity at a batch level (i.e. inspection) into sub-activities at a daily-task level, such as retrieve drawing, fill out the inspection request form, transmit the form, on-site inspection, fill out the inspection results, and issue non-conformance report (NCR) (Figure 2). Then, you should identify resource consumption and duration of each sub-activity, and work sequence.

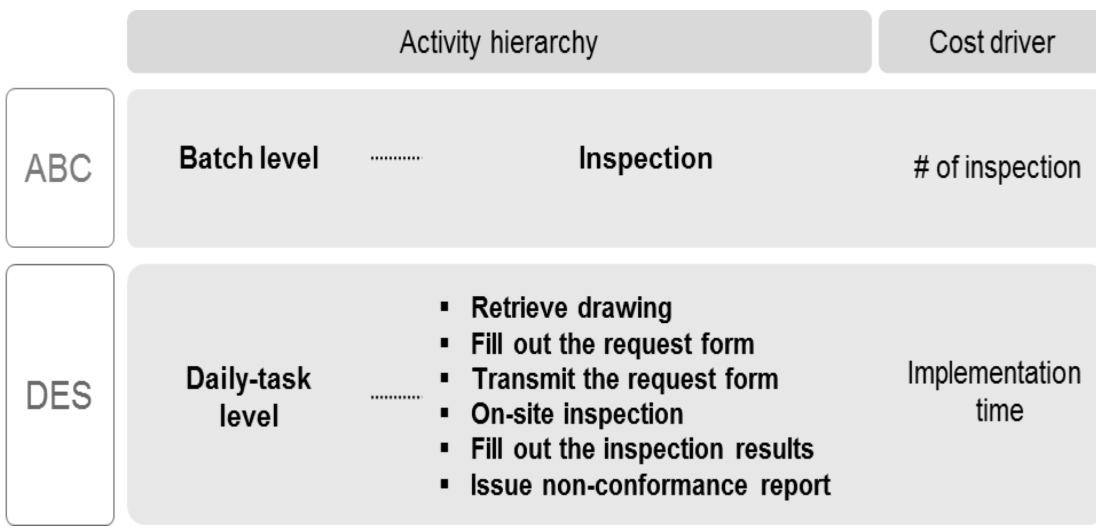


Figure 2: Comparison of Activity Hierarchy and Cost Driver in ABC and DES

(4) Assess the performance and develop the improvement plans

The current performance is assessed in terms of total process time and cost. The performance can be improved through reducing cycle time, cost, errors, and rework or increasing customer and employee satisfaction. Technical, organizational, and/or structural changes are considered. Once an improvement initiative is regarded effectively, you should implement further actions to eliminate process errors and simplify the process.

(5) Update the ABC system and reiterate the processes above.

Once you estimate the total process time and cost through modified DES model, the cost of activity at a batch level (i.e. A NEW COST DRIVER RATE) is determined. You should update the information into the ABC system and track the volume of cost drivers at a batch level.

You should reiterate the processes above as a vehicle of continuous process improvement.

## EXAMPLE

Suppose that there is a construction company which conducts sewerage pipe rehabilitation project. The ABC system can consist of many activities in a batch level, such as set up, procurement, pipe installation, and inspection. Among them, a pipe installation inspection can be one of the most frequently occurring tasks, which requires careful management. In ABC system, the activities related to this task can be composed of two cost pools: 1) Inspection (including retrieve information, develop and transmit inspection document, inspect, approve, etc.), 2) NCR (including take picture and issue NCR).

Table 1 and 2 shows the resource consumption rate and activity cost incurred during a week for two activities (i.e. Inspection and NCR). Resource consumption rate represents what percentage of time during a week each resource consumes in two activities. The values can be obtained through interviews with each personnel. Activity cost can be calculated by multiplying the resource consumption rates by weekly wage of resources ($1,625 for GC, PE; $1,800 for GC, QE; $1,475 for SC, PE; $825 for Clerical; $1,550 for INSP, II; $1,450 for INSP, I). As a result, in ABC system, weekly activity cost will be $2,322.25 for inspection and $556.50 for NCR. Furthermore, assuming 12 inspections and 1 NCR happen for a week, the activity cost driver rate will be $194 for inspection and $556 for NCR.

Table 1: Resource Consumption Rate in Pipe Installation Inspection

| **Activities** | **Resource consumption rate (%)** | | | | | |
|---|---|---|---|---|---|---|
| | **GC, PE** | **GC, QE** | **SC, PE** | **Clerical** | **INSP, II** | **INSP, I** |
| Inspection | 20 | 25 | 25 | 8 | 35 | 40 |
| NCR | - | 5 | - | 2 | 15 | 15 |

Note: GC(General Contractor), SC(Specialty Contractor), PE(Project Engineer), QC(Quality Engineer), INSP(Inspector), NCR (Non-Conformance Report)

Table 2: Weekly Activity Cost

| **Activities** | **Activity cost ($)** | | | | | | **Total** |
|---|---|---|---|---|---|---|---|
| | **GC, PE** | **GC, QE** | **SC, PE** | **Clerical** | **INSP, II** | **INSP, I** | |
| Inspection | 325.00 | 450.00 | 368.75 | 66.00 | 542.50 | 580.00 | 2,322.25 |
| NCR | | 90.00 | | 16.50 | 232.50 | 217.50 | 556.50 |

If the cost driver rates related to pipe installation inspection task are higher than those in other projects, detailed process modeling should be developed for the process improvement. As the construction-related process are essentially an interrelated network of discrete activities, this study uses a discrete-event simulation technique called cyclic operation network (CYCLONE) (Halpin and Riggs 1992), which is one of the most widely used simulation methods in the construction industry (Hong and Hastak 2007, Luo and Najafi 2007).

The process model for pipe installation inspection was developed based on Kim and Kim (2011) as shown in Fig.3. The model includes both inspection and NCR related activities because inspection activity directly affects the occurrence of NCR. Activity duration can be obtained by actual measurement in the construction site. Rejection of transmitted inspection documents and inspection approval is occurred about 1% and 10%, respectively.

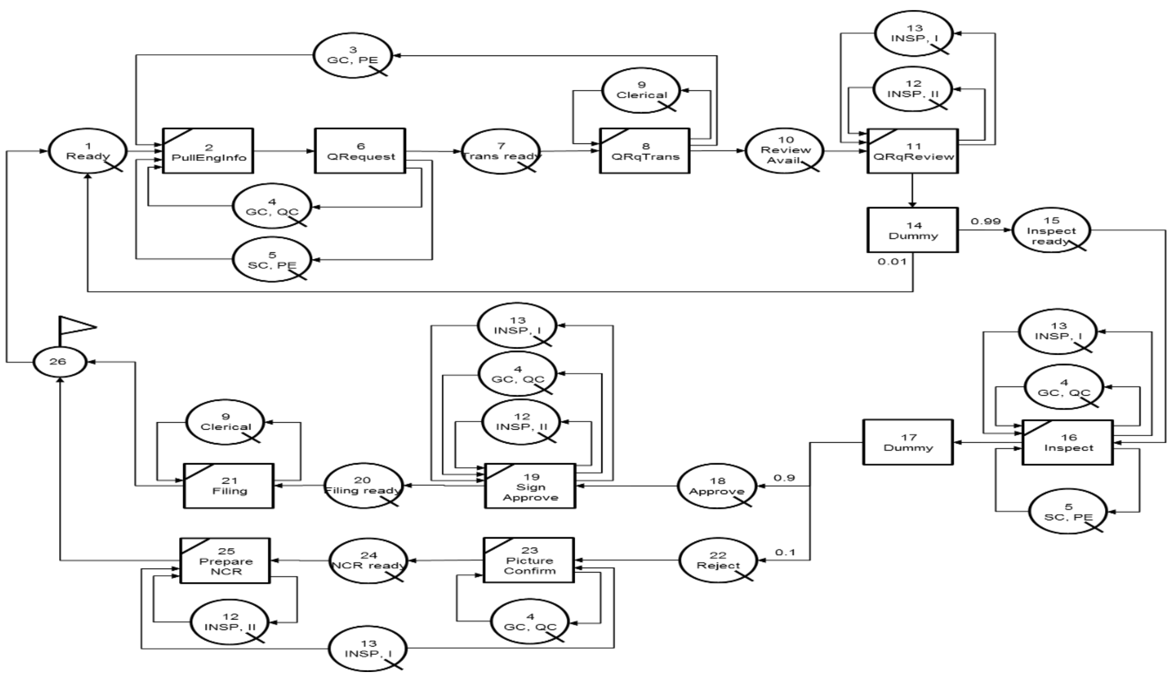

Figure 3: Process Model for Pipe Installation Inspection by using CYCLONE Simulation

Table 3 shows the simulation results for pipe installation inspection process through 1,000 cycles. Average process time and cost per a cycle become 2.95 hours and $170.18, respectively. As a result, in DES model, the activity cost for a week will be $2,042.12 ($170.18×12) under the same assumption (i.e., 12 pipe installation inspections in a week).

Table 3: Simulation Results for Pipe Installation Inspection Process

| Category | Values |
|---|---|
| Total simulation time (h) | 2,953.1 |
| Productivity per time unit (cycle/h) | 0.3386 |
| Average cycle time (h) | 2.95 |
| Cost per cycle ($/cycle) | 170.18 |

In most cases, ABC model uses time-effort % method in which the percentage of each employee's time spent on each activity is tracked. For simplicity and practicality, survey on relevant employees is preferably used. As you can imagine, activity costs using time-effort % method exceed actual usage of resources because time-effort % method does not consider any waste of time such as waiting.

Table 4 shows the comparison result of activity cost for a week estimated from ABC system and DES model. The difference in activity cost would be about $847. It means that actual capability utilization of personnel related to pipe installation inspection task would be about 70% compared to their speculation, assuming that DES model accurately represents the real condition.

Table 4: Comparison Result of Activity Cost

| Category | ABC (*a*) | DES (*b*) |
|---|---|---|
| Weekly activity cost ($) | 2,888.75 | 2,042.12 |
| Difference ($) (*a*-*b*) | 846.63 | |
| Rate (%) (*b/a*100*) | 70.69 | |

# DISCUSSION AND CONCLUSIONS

The example presented in this research shows the following aspects.

(1) ABC model is sustainable in that there is only one cost driver to track on a regular basis (i.e., the number of inspections). PIABC model can be used for control purpose as well by providing the link between activities at a batch level and those at a daily-task level.

(2) The PIABC model has two different activity cost data (i.e., unit activity cost): one from time-effort % method and one from simulation model. The difference is considered to be "unused capacity." Cooper and Kaplan (1992) accounted for the relationship between the costs of resources used and the costs of resources supplied as follows:

Cost of Activity Supplied = Cost of Activity Used + Cost of Unused Capacity

Our approach (PIABC) allows users to estimate their unused capacity by comparing two models. It can be said that PIABC can facilitate the use of more accurate cost driver rate by providing information on used capacity.

In the construction domain, ABC has mainly been applied to allocate home office and project overhead costs. Some researchers tried to link process modelling and simulation with ABC. However, their model used same activities in both ABC and simulation modelling, which seems too time-consuming to track durations for detailed activities on a regular basis. This research focused on presenting how to bridge the gap between the level of activities in ABC and simulation to be an effective tool for construction process control and improvement. For this purpose, activities in ABC should be made up at a batch level, which their cost drivers are directly related to the instance of the activity, while activities in simulation modelling are at a daily-task level. Setting up the right level of detail in activity composition would be the key whether the proposed approach can be practicable and sustainable. The proposed approach can contribute to facilitating simple and practical process control on a basis of accurate cost information.

As seen from the above example, when the two (or more) activities in ABC (i.e., Inspection and NCR) should be included into one simulation process model, simulation result can provide only the total cost (i.e., the cost including both Inspection and NCR). Thus, in order to make the proposed approach more applicable, the researchers are now conducting more tests and case studies on diverse conditions and relations between ABC and process simulation model. We expect to report those in the near future.

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