Supply Chain Cost Model in Integrated Approach

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ABSTRACT

'Supply chain management’ emerged as a concept when benefits of collaboration within and beyond the capacities of individual organizations were witnessed. It was found that the collaborative efforts in reducing total supply chain costs were effective in a fragmented supply chain. The challenge in supply chain cost analysis is posed in interface costs where multiple organizations are involved in occurring costs. Many of the overhead costs in a supply chain are interface costs impacted by the business process of upstream or downstream stakeholders as well as their own. Difficulty in developing a cost model pertaining to overhead costs leads to challenges in developing a supply chain cost model.

The paper proposes a metric-based supply chain cost model using activity-based costing to help understand how each activity impacts total supply chain costs, followed by a case study. A supply chain coordinator needs to understand not only the whole supply chain costs but also the costs of primary processes, many of which are interdependent. The paper contributes to the knowledge of construction supply chain management in that a supply chain cost model using activity-based costing is presented.

Keywords: supply chain costs, rebar supply, time-driven activity-based costing; prefabrication integrated design, team integration, sustainable high-performance project delivery

INTRODUCTION

‘Supply chain management’ emerged as a concept when benefits of collaboration within and beyond the capacities of individual organizations were witnessed. It was found that the collaborative efforts in reducing total supply chain costs were effective in a fragmented supply chain. One of the primary tasks in reducing total supply chain costs is to understand where the costs occur in a given organization’s supply chain and how each activity impacts the costs regarding total supply chain (Kim and Bae 2009). However, most construction supply chains in construction usually involve multiple entities, each one in a different process in most cases. A rebar supply chain, one of the critical supply chains in construction, is one of the examples where many entities are involved in different processes from engineering to fabrication and installation (Kim et al 2007). Othman and Rahman (2010) note that supply chain complexities and performance challenges can be addressed with better management of interdependencies within the chain.
Numerous academic analyses and reports provided by consulting companies discuss how to reduce total costs in supply chain systems. One of primary tasks in reducing total supply chain costs is to understand where the costs occur in a given organization’s supply chain. However, most construction supply chains in construction usually involve multiple entities, each one in a different process in most cases. Recent trend, so called “integrated delivery” such as design-build or integrated project delivery, reinforces such complexity. With more complex organization, costing different processes where multiple entities are involved becomes more challenging. Especially, supporting activities presented in “overhead” costs in a rebar supply chain are usually hard to track and analyze compared to direct activities.

However, traditional cost accounting systems have failed to trace overhead costs in that they are buried in a single overhead pool (Johnson and Kaplan, 1987). Therefore, traditional cost accounting system failed to find the key decision variables that affect total cost, particularly overhead costs, and thus prove inadequate for managerial cost concerns (Johnson and Kaplan, 1987). Many companies and managers believe that traditional accounting systems are “too late, too aggregated and too distorted” to support decision-making processes (Kaplan and Cooper, 1997). Such claims is more valid in a collaborative working environments where more than one entity are involved and cost drivers are affected by outside a company’s boundary.

This research aims to developing supply chain cost model in a situation where multiple entities are involved in different processes. To this end, the researcher developed a matrix-based activity-based costing model based on TDABC. As a case study, the model is applied to the rebar supply system.

MODELING TIME-DRIVEN ACTIVITY-BASED COSTING FOR REBAR SUPPLY SYSTEM

Activity-Based Costing (ABC) and Time-Driven Activity-Based Costing (TDBC)

Activity-based costing has been developed as a solution to the problems of traditional accounting systems by Cooper and Kaplan(1988). Activity-Based Costing is a method of assigning the organization’s resource costs through activities to the products and services (Cokins, 1996; Cooper 1990). The traditional costing system groups all overhead costs, including administrative costs, into one single category and divides these aggregated costs according to the volume of direct costs, including direct material and direct labor. Contrary to this “macro approach” of the traditional accounting system, ABC traces administrative costs by associating resources to activities (Kaplan and Anderson, 2004). Conventional ABC was found by providing management with a more detailed cost analysis of activities and processes, and assisting management in understanding what actually causes certain costs (Kim 2002; Kim and Ballard 2005). Kim (2002) argues that the construction industry needs to adopt ABC to gain its competency. However, this conventional ABC also appears to cause two significant problems. First, setting up a conventional ABC system can be very costly, especially if the current accounting system does not support the collection of ABC information. Second, the system needs to be regularly updated, which further increases its cost (Kaplan and Anderson, 2004; Kim, 2002). Such limitations motivated Kaplan and Anderson (2004) to develop time-driven activity-based costing, a revised version of ABC, solving these problems, without losing the
benefits. One of the most important characteristics of this technique is its simplicity, as only two kinds of parameters need to be estimated: the unit cost of resources and the time required to perform an activity (Kaplan and Anderson 2004).

The research used TDABC instead of conventional ABC because the researcher observed that the amount of resources consumed by activities along the rebar supply chain varies over time and that updating costing system takes additional resources.

The TDABC model for the case study was developed using a four-step process: 1) estimating the unit cost of each resource, 2) estimating the rate of resource consumption of each activity, 3) deriving cost-driver rates, and 4) analyzing of costs.

Scope of Costs

Many previous ABC studies have dealt with only overhead costs because direct costs such as material and labor costs can be traced easily (Cokins 1996). However, this study included not only overhead costs such as energy costs but also direct costs including rebar material costs in order to provide a holistic view on the rebar supply system. It is noted that equipment depreciation was not considered in the analysis.

Model Development

The researchers analyzed the overhead costs (e.g., management salaries, rent, and energy costs) as well as direct labor and rebar material costs associated with rebar supply from the supplier to the construction site. The researchers formulated the weekly cost of each activity and the total rebar supply chain cost of project k. The total cost may be expressed as follows:

\[
TC_k = LELC_k + DM_k
\]

\[
= \sum_{j=1}^{m} \left( \frac{d_{jk}}{D_j} \times C_j \right) + DM_k = \sum_{j=1}^{m} (d_{jk} \times c_j) + DM_k
\]

\[
= \sum_{j=1}^{m} \left( d_{jk} \times \sum_{i=1}^{l} (c_i \times r_{ij}) \right) + DM_k = \sum_{i=1}^{l} \sum_{j=1}^{m} (d_{jk} \times c_i \times r_{ij}) + DM_k (equation 1)
\]

Variables defined below:

\(TC_k\): weekly total cost for project \(k\)

\(LELC_k\): weekly labor, energy, and land leasing costs for project \(k\)

\(DM_k\): direct material cost for project \(k\)

\(i\): \(i\)th resource

\(j\): \(j\)th activity
Based on equation 1, the researchers calculated the rebar supply chain costs of project k by building the matrices of cost driver volumes (Dm), resource consumption rates (Rml), and the unit cost of resources (Cl). First, the resources were identified. Then their unit costs (i.e., hourly wage) were estimated (matrix Cl) and listed vertically. Second, the rates of resource consumption by each activity were estimated (matrix Rml). Third, the cost driver rates were driven by multiplying matrix Cl by matrix Rml. Finally, the weekly rebar delivery costs for project k were calculated. The cost driver rate matrix was inversed to be multiplied by the volume of the cost driver (matrix Dm). After multiplying the inversed matrix \((Rml \times Cl)^{-1}\) by matrix Dm, the direct material cost (DMk) was added to the result to calculate the total rebar delivery cost. The resulting formula is shown in equation 2.

\[
TC_k = D_m \times (R_{ml} \times C_l)^{-1} + DM_k = \sum_{j=1}^{m} \left( \begin{array}{c}
  r_{11} & r_{12} & r_{13} & \cdots & r_{1l} \\
  r_{21} & r_{22} & r_{23} & \cdots & r_{2l} \\
  r_{31} & r_{32} & r_{33} & \cdots & r_{3l} \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  r_{ml} & r_{ml} & r_{ml} & \cdots & r_{ml}
\end{array} \right) \left( \begin{array}{c}
  c_1 \\
  c_2 \\
  c_3 \\
  \vdots \\
  c_l
\end{array} \right)^{-1} + DM_k
\]

EXAMPLE

The rebar supply chain of a condominium construction project in downtown Seattle was selected to examine our TDABC model in a rebar delivery system. The project is comprised of a 19-story residential tower, 16-story office building, and several commercial stores. The project uses the prefabricated rebar fabricated at the rebar shop. Those prefabricated rebars are delivered to the site and assembled on site.

System Boundary and the Analysis of Activities

The system boundary of our rebar delivery system for the TDABC model includes 1) the generation, review, and approval of shop drawings, 2) fabrication and assembly of raw rebar, 3)
transportation, and 4) site installation. Figure 2 shows the system boundary of the delivery system and process information including cost driver information and weekly activity costs. A structural engineer, GC, SC, fabricator (prefabrication plant), and rebar mill were identified as key stakeholders in the rebar supply system. Process at the rebar mill and the supply chain after installation of the rebar products are not included in this study.

Each activity box in Figure 1 includes the weekly volume of cost driver and activity costs. An activity cost driver is defined as any factor that causes a change in the consumption of an activity by other products, suppliers, or customers (Cokins, 1996; Raffish and Turney, 1991). A cost driver for each activity was defined through interviews with employees. The following section in the paper discusses the cost calculation process. The researchers used TDABC to trace related overhead costs such as energy costs as well as direct labor costs.

**Weekly Rebar Delivery Cost Calculation**

The unit cost of each resource was estimated by dividing the total cost of each resource by the total working hours per week. Various project participants from each stakeholder were assigned for this project: A/E allocated a structural engineer; GC allocated a project manager, a
project engineer, laborers, and an inventory keeper; SC allocated a project manager, a project engineer, a shop drawer, and laborers; the prefabrication plant allocated a project manager, a project engineer, laborers; the rebar mill allocated truck drivers for this construction project. Data on raw rebar prices, rebar scrap prices, and energy prices, diesel, and propane prices were also acquired. The costdriver rates were calculated by multiplying the unit cost of each resource (cl) by the consumption of resources by activities (rhi).

The weekly rebar supply chain cost was calculated based on equation 2. As described in the model development section, matrices were developed to calculate the weekly rebar supply chain cost as shown in Figure 2. The unit cost of resources matrix (Cl) presents the hourly salaries of personnel working at stakeholder companies, unit prices of energy, and unit leasing costs of an assembly yard. In order to work out the cost driver rates matrix, this matrix (Cl) was multiplied by the resource consumption matrix (Rml), which shows the time spent by resources for the one-time implementation of each activity. The cost driver rates matrix (Rml×Cl), the result of the multiplication of the two matrices, was inversed to be multiplied by the volume of cost driver matrix (Dm). The volume of cost driver matrix (Dm) demonstrates the number of cost drivers during one week. After multiplying the inversed matrix by matrix Dm, the direct material cost was added to calculate the weekly rebar supply chain cost. The case study project consumed 82.4 tons of raw rebar and recycled 2.4 tons of rebar scrap. The prices of the raw rebar and rebar scrap were $882 and $184 per ton, respectively. The weekly direct labor cost, overhead, and weekly rebar supply chain cost are $6,697, $5,667, and $84,600, respectively.


DISCUSSION

The major advantage of using ABC for supply chain cost calculation is that it yields more accurate costs and gives better insights into cross-organizational cost structure. The cost analysis using our TDABC model provides a process view by generating activity costs of resources while traditional overhead cost analysis method does not. Managers can see how much resources are consumed for each activity triggered by cost objects. Contrary to the process-based approach of TDABC, the traditional accounting system aggregates all overhead costs into one category and establishes a rate of overhead, which comes from experimental data. When stakeholders operate more than one project concurrently, they assign total overhead to each project proportionally to the volume of direct cost. In order to calculate the overhead of the supply chain of the case study project, each stakeholder needed to calculate overhead for the case study project in the proportion of the volume of the direct cost. Although both the traditional accounting system and TDABC result in the same direct cost, the weekly rebar supply chain costs in two systems may be different because the two accounting systems may have different overheads.

In addition to accurate supply chain costs, the analysis presenting a matrix shows how each participant in different organizations contributes to each activity. As such, the analysis provides information from which collective efforts and rewards to improve the performance of
an activity (e.g., reducing activity duration or cost driver volume) can be quantified. For example, activity # 7 of reviewing a shop drawing takes four participants in two organizations (i.e., a subcontractor and a general contractor) with the number of hours each participant contributes being presented as shown in Figure 2.

CONCLUSIONS

Although the cost impact has been one of the important criteria in the decision making process in construction process planning, the traditional accounting system cannot address the details of overhead processes with accuracy. Activity-based costing can provide the accurate cost information of processes. The process manager (e.g. GC) in a construction project may understand not only the whole supply chain costs but also the costs of major processes, many of which are interdependent.

The paper presented a supply chain cost model based on TDABC model on rebar supply system. The model uses a metric-based analysis to present the relationship showing how each participant contributes to perform each activity. This paper contributes to the knowledge of supply chain management in that the ABC method was applied for cost analysis. The paper also showed that TDABC provides a process view in that activities and associated costs are revealed through the supply chain. When all stakeholders understand costs without organizational boundary, they can work together to lower overall costs and improve customer satisfaction.

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REFERENCES


