SUPPLY CHAIN COSTS ANALYSIS USING ACTIVITY-BASED COSTING: CASE STUDY IN REBAR SUPPLY

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ABSTRACT

The activity-based costing method was used to compute rebar supply chain costs. This paper describes the model developed, the calculated costs, and sensitivity analysis results, followed by the relatedness to lean principles. Many literatures and consulting companies discuss how to reduce total costs in supply chain. But the first question to improve supply chain profitability should be to understand where the costs are spent in your supply chain and where the opportunity for improving your profits exists.

Many opportunities to reduce total cost in supply chains, which are responsible for unnecessary overhead costs. The activity-based costing method was used to develop supply chain costing model. This paper discusses the benefits of activity-based costing in supply chain costs using a case study in rebar supply chain. This paper contributes to the knowledge of lean construction domain in that the activity-based costing method is adopted in supply chain costing so that stakeholders can make use of the ABC costing data to reduce total supply chain costs to achieve the project objective, not their internal production objectives.

KEY WORDS

Supply chain costs; rebar supply; activity-based costing

INTRODUCTION

Many literatures and consulting companies discuss how to reduce total costs in supply chain. But the first question to improve supply chain profitability should be to understand where the costs are spent in your supply chain and where the opportunity for improving your profits exists. Anderson (2004) argued that many opportunities to reduce total cost in supply chains, which are responsible for many unnecessary overhead costs such as resources to generate forecasts and production planning, inventory control, place purchase order, and receive materials.

Reinforced concrete structures are commonly preferred with steel structures in building construction. While reinforced concrete structures comprise thousands of components, a structural framework is constructed in three basic sequential activities: preparing formwork, installing rebar and pouring concrete. Supply chains for the components need to be well managed in order to achieve project goals. Among the

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components, the supply system of reinforced steel bar to construction is critical in meeting budget and schedule goals of a construction project (Polat and Ballard, 2005).

This paper describes a case study to investigate the supply chain cost analysis of rebar supply to construction sites. The goal of this research has three folds: 1) to develop cost model using time-driven activity-based costing, and 2) to identify critical variables that have influence on total supply chain costs.

RESEARCH METHOD

TIME-BASED ACTIVITY-BASED COSTING

Activity-Based Costing (ABC) is a method of assigning the organization's resource costs through activities to the products and services (Cokins, 1996; Cooper 1990). Traditional costing system does not trace administrative costs because all overhead costs including administrative costs are grouped into one single category. Activity-Based Costing (ABC), however, can trace administrative costs by associating resources to activities (Kaplan and Anderson, 2004). ABC is found 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) argued that the construction industry needs to adopt ABC to gain its competency. However, traditional ABC also 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 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 (TDABC), a revised version of ABC, solving these problems, without losing the benefits. The most important characteristic of this technique is its simplicity, as only two kinds of parameters need to be estimated: the number of time units (e.g. minutes) consumed by the activities related to the cost objects and the cost per time unit (Kaplan and Anderson 2004).

The researchers use TDABC instead of traditional ABC because we see the resources consumed by activities along rebar supply chain varies over time and updating costing system takes additional resources. DABC also provides more accurate cost-driver rates by allowing unit times to be estimated even for complex, specialized transactions. In the time-based ABC model, overhead expense categories such as salaries of key personnel, energy consumptions of main equipment in a project sites, the rents for assembly yards, and transportation methods and distance were identified. This cost data could be obtained from interview, observation, and documentation.

The time-based ABC system for this project was developed in five steps: 1) identifying activities as well as determining system boundary, 2) estimating the cost per time unit as well as the number of time units consumed by the activities related to the cost objects, 3) deriving time equation for each activity, 4) measuring the volume of activity cost driver on each activity, 5) analyzing activity costs and drivers.

DATA COLLECTION METHOD

A high-rise condominium construction project (Enso Condominium) in downtown Seattle is investigated for this research. All structural rebars were delivered using prefabrication and JIT on the project. We collected information to develop activity-based costing model through interviews, direct observation, and archival study.

Interview

Interviewing is the most commonly used form of qualitative research. The research team prepared open-ended questionnaires for the interviews with key personnel of the project including material procurement managers and project engineers. The questions included overall rebar processing steps and activities, organizational structures, contribution of employees to the activities, main equipment usage, energy consumption, distances of material transportation, frequency of delivery, and other qualitative information in each stakeholder. We visited project sites including a prefabrication plant and an assembly yard in Tacoma, and a construction site in Seattle.

Archival Study

Another qualitative research method involves using various kinds of documents (Have, 2004). The research team collected and reviewed the internal documents of the stakeholders, such as various forms of schedules, amounts of installed rebar assemblies, equipment specifications used within the supply chain, contract documents, and material cost, especially rebar cost. Studying these documents allowed the research team to understand the internal strategies and processes for the rebar delivery systems.

Observation

Observation refers to methods of generating data which entail the researcher directly involving herself or himself in a research setting so that they can experience and observe first-hand a range of dimensions in that setting (Mason, 2002). The research team visited the construction site, the rebar prefabrication plants, and a rebar assembly yard and recorded specific observational data from participation in project implementation processes and other activities devoted to planning, controlling, and managing rebar delivery processes.

REBAR SUPPLY Systems

The tradition of the construction industry has long been to deliver rebar from a rebar supplier or the warehouse of a contractor to the construction site in large batches, fabricate (i.e., cut and bend) rebar on-site and position it for assembly. The traditional rebar supply system requires large on-site yard and holding costs. Since people recognized the holding costs including yard space requirements, a new method has gained industry attention especially in construction projects in metropolitan areas. A new rebar supply system uses off-site cut & bend (i.e., prefabrication) with a frequent delivery of small batches. Even though this new system requires more frequent deliveries, it removes yard space requirements and deliveries within the sites (i.e, on-site yard to building).

A recent study showed that a lean rebar supply system, prefabrication of building products and Just-in-Time delivery, reduces the need for storage space on sites and improves productivity due to prefabrication (Arbulu and Ballard 2004). While most relevant research regarding supply systems focused on how lead time can be reduced using either process improvements or external integration with suppliers (Kim et al. 2007; Arbulu et al. 2003; Akel et al. 2004), few research studies have investigated the supply chain costs. This research focuses on a prefabricated rebar supply system.

SCOPE OF COSTS

Many activity-based costing deal with only overhead costs because direct costs such as material and labor costs can be traced (Cokins 1996). However, this study included not only overhead costs including energy costs but also direct costs such as rebar material costs and labor costs in that the cost model should provide a holistic view on rebar supply chain costs.

ACTIVITY DEFINITION AND COST DRIVERS

A list of activities identified and analyzed for this study are described below.

PJ4. Generating shop drawings by the SC

This activity categorized into two different subgroups, which are generating the shop drawings and revising the shop drawings. The number of shop drawings was defined as a cost driver of this activity.

PJ5. Reviewing The Shop Drawings By The GC

The general contractor reviewed the shop drawings which were generated by the SC (subcontractor) and forwarded them to the A/E. Usually 2 sheets of shop drawings per each day, total 10 sheets per week were delivered from the SC. The number of shop drawings was defined as a cost driver of this activity.

PJ6. Approving The Shop Drawings By The A/Es

The Architect/Engineers reviewed the shop drawings forwarded by the GC and determined whether the drawings were to be approved or not. The number of shop drawings was defined as a cost driver of this activity.

PJ7-1. Place Fabrication Order By The GC

After the submitted shop drawings from the GC were approved by A/Es, the project engineer in the GC ordered the SC to fabricate rebar products to their installation schedule. The number of orders was defined as a cost driver of this activity.

PJ7-2.Order To Revise Shop Drawings

When the A/E rejected the shop drawings, the project engineer in the GC ordered the SC to revise the drawings. The 5 percent of the submitted shop drawings to the A/Es is assumed to be rejected in this study. The number of orders was also defined as a cost driver of this activity.

PJ8. Generating Cut Lists By The SC

The SC generates cut lists to fabricate the rebar products. The cut lists include information such as the shape, quantity, and thickness of rebar. The 3 percent of generated cut lists requires rework for some reasons. The number of cut lists was defined as a cost driver of this activity.

PJ9. Scheduling Rebar Fabrication By The Prefabrication Plant

The project engineer in the prefabrication plant scheduled and arranged the fabrication of the rebar products to their production schedule taking into account their work loads and capacity. The number of production runs was defined as a cost driver of this activity.

PJ10. Ordering Raw Rebar By The Prefabrication Plant

The project engineer in the plant ordered a rebar supplier to deliver raw rebar to the plant based on the estimation of the biweekly consumption of the plant. The rebar scrap would be sold to a rebar mill. The number of orders was defined as a cost driver of this activity.

PJ14. Fabricating The Raw Rebar In The Prefabrication Plant

The fabrication process is divided by two main sub-processes; (1) cutting & bending the raw rebar and (2) marking, packaging, checking, and loading the fabricated rebar.

PJ16. Delivering The Fabricated Rebar To The Construction Site Or Moving Them To An Assembly Yard Nearby The Plant.

PJ18. Ordering The Missing Rebar Products Or Replacements By The GC

If the GC found any defect on the rebar products, the project engineer (GC) ordered the prefabrication plant to fabricate the missing rebar products or replacements. The 3 percentage of the original order was considered for this category. The number of orders was defined as a cost driver of this activity.

PJ19. Installing The Rebar Assembly By The GC

The GC and the SC installed the rebar assembly using diesel-powered tower cranes and propane-powered forklifts. It is assumed that the project engineers and two laborers in the GC spent 8 hours each and the project engineer and ten laborers in the SC also spent 8 hours each for this activity. The number of assemblies was defined as a cost driver of this activity.

MODEL DEVELOPMENT

Estimating The Cost Per Time Unit.

The research team estimated the cost per time unit of each human resource as shown in Table 1.

The research team also acquired data on raw rebar prices, rebar scrap prices, and energy prices such as electricity in Seattle and Tacoma through internet and archival search. The resource prices per unit are shown in Table 2.

Table 1: Hourly Wages

Stakeholder	Position	Hourly Wage
A/Es	Sr. A/E	$47
	A/E	$34
GC	Proj. Mgr.	$63
	Engineer	$40
	Labor	$40
	Rebar Keeper	$12
SC	Proj. Mgr.	$57
	Shop Dwgr.	$30
	Engineer	$33
	Labor	$40
Mill	Labor	$40
Prefab. Plant	Proj. Mgr.	$48
	Engineer	$34
	Labor	$30

Table 2: Resource Prices Per Unit

Resource		Price per Unit
Energy	Electricity	$0.0653/kWh
	Diesel	$0.58/liter
	Propane	$0.173/liter
Material	Raw Rebar	$882/ton
	Rebar Scrap	$184/ton
Assembly Yard Rent	Traditional Method (Seattle)	$1.06/sf•week
	Prefab.-JIT Method (Tacoma)	$0.17/sf•week

Estimating the Number Of Time Units Of Activities

We estimated the number of time units (i.e., hours) consumed on each activity. These numbers were obtained through interviews with employees and direct observation. It is important to stress that the question is not about the percentage of time an employee spends doing an activity but about how long it takes to complete one unit of that activity.

Deriving time equation

To construct appropriate time equations, we performed a thorough activity analysis through interview, survey, and direct observation at the general contractor's site office, the subcontractor's site office, and supplier's site office. In order to derive cost-driver rate we built time equations based on the thorough analysis of the activities within the scope of the research. The cost-driver rates were calculated by multiplying the two input variables: the cost per time unit of supplying resource capacity and the unit times of consumption of resource capacity. The results were summed to calculate the total time for the activities. The time equations on activities are shown in Table 3.

Table 3: Time Equations

	Activities	**Total Time Needed Per Activity Equations (In Hours)**
4	Generate and Revise Shop Dwgs	0.2(SC PM)+2.5(SC SD)+if shop dwgs revised*[0.3(SC PM)+4(SC SD)]
5	Review Shop Dwgs	1.5(GC E)+if shop dwgs revised*[2(GC E)]
6	Shop Dwgs Approval	2(A/E)+if shop dwgs rejected*[3(A/E)]
7-1	Place Order	0.08(GC PM)+0.5(GC E)+0.3(SC PM)+0.5(SC SD)
7-2	Order Missing Dwgs or Replacements	if missing dwgs order required*[0.08(GC PM)+0.5(GC E)+0.5(GC E)+0.3(SC SD)]
8	Generate Cut Lists	0.05(SC PM)+1(SC SD)+if cut lists regenerated*[0.05(SC PM)+1(SC SD)]
9	Schedule Rebar Fabrication	0.5(Plant PM)+1(Plant E)+if reschedule required*[0.5(Plant PM)+1(Plant E)]
10	Order Raw Rebar	1(GC E)
14	Prefabricate Rebar	
a	Cutting and Bending	0.2(Plant PM)+0.3(Plant E)+3(Plant L)+if remanufacturing required*[0.2(Plant PM)+0.3(Plant E)+3(Plant L)]
b	Marking, packaging, checking, and loading the fabricated rebar	0.05(Plant E)+1(Plant L)+if remanufacturing required*[0.05(Plant E)+1(Plant L)]
16-1	Without Assembly	
a	Deliver Rebar to Construction Site	1.7(Plant L)+if rebar products rejected*[1.7(Plant L)]

Table 3: Time Equations (Continued)

	Activities	**Total Time Needed Per Activity Equations (In Hours)**
b	Marking, packaging, checking, and loading the fabricated rebar	0.05(Plant E)+1(Plant L)+if remanufacturing required*[0.05(Plant E)+1(Plant L)]
16-1	Without Assembly	
a	Deliver Rebar to Construction Site	1.7(Plant L)+if rebar products rejected*[1.7(Plant L)]
b	Unload & Inspect Rebar Assembly	1(GC E)+2(GC Labor)+1(SC E)+2(SC L)+if rebar products rejected*[1(GC E)+2(GC L)+1(SC E)+2(SC L)]
16-2	With Assembly	
a	Move Rebar to Assembly Yard	0.2(Plant L)+if assembly rejected*[0.2(Plant L)]
b	Assemble Prefabricated Rebar	40(SC L)+if assembly rejected*[40(Plant L)]
c	Deliver Rebar Assembly to Construction Site	1.7(Plant L)+if assembly rejected*[1.7(Plant L)]
d	Unload & Inspect Rebar Assembly	1(GC E)+2(GC L)+1(SC E)+2(SC L)+if assembly rejected*[1(GC E)+2(GC L)+1(SC E)+2(SC L)]
18	Order Missing Rebar Assemblies or Replacements	0.5(GC E)+0.5(SC SD)
19	Install Rebar	4(GC E)+8(GC L)+4(SC E)+40(SC L)

Notes:

* indicates “dummy” variables

(organization, position of employee)

GC=general contractor, SC=subcontractor, L=labor, E=Engineer, SD=shop drawer

Developing Activity Costs

The research team analyzed the overhead costs, especially salaries, rent, and energy as well as direct labor and rebar material costs associated with rebar supply from the supplier to the construction site. The activity costs, weekly activity costs, and the total weekly costs associated with rebar supply chain are shown in Table 4.

Table 4: Activity Costs

	Activities	Cost Driver	Vol. of Driver (weekly)	Activity Cost	Weekly Activity Cost
4	Generate and Revise Shop Dwgs	Number of Dwgs	10 0.3	$87 $138	$870 $41
5	Review Shop Dwgs	Number of Dwgs	10 0.3	$59 $79	$594 $24
6	Shop Dwgs Approval	Number of Dwgs	10 0.3	$68 $102	$677 $30
7-1	Place Order	Number of Orders	5	$57	$285
7-2	Order Missing Dwgs or Replacements	Number of Orders	1	$51	$51
8	Generate Cut Lists	Number of cut lists	5 0.15	$33 $33	$165 $5
9	Schedule Rebar Fabrication	Number of prod. runs	5 0.15	$58 $58	$289 $9
10	Order Raw Rebar	Number of Orders	0.5	$34	$17
a	Cutting and Bending	Number of Operating hours	5 0.15	$14,018 $14,018	$70,092 $2,103
b	Marking, Packaging, checking, and loading the fabricated rebar	Number of Operating hours	1 0.03	$32 $32	$32 $1
16-1	Assembly		-	-	-
a	Deliver the assembled rebar to a construction site	Number of Deliveries	2 0.06	$57 $51	$113 $3
b	Unload and inspect the delivered rebar assembly	Number of Inspections	1 0.03	$239 $239	$239 $7
16-2	Without Assembly		-	-	-

Table 4: Activity Costs (Comtinued)

	Activities	Cost Driver	Vol. of Driver (weekly)	Activity Cost	Weekly Activity Cost
a	Move the fabricated rebar to an assembly yard	Number of Movements	20 0.6	$7 $7	$146 $4
b	Subassemble the Fabricated Rebar in the assembly yard	Number of Assemblies	4 0.12	$443 $443	$1,771 $53
c	Deliver the assembled rebar to a construction site	Number of Assemblies	4 0.12	$74 $74	$295 $9
d	Unload and inspect the delivered rebar assembly	Number of Inspections	4 0.12	$234 $234	$936 $28
18	Order Missing Rebar Product or Replacement	Number of Orders	0.15	$35	$5
19	Install Rebar	Number of Assemblies	4	$1,118	$4,474
TOTAL					**$83,369**
Total Cost/ton					**$1,042**

RISK ASSESSMENT AND SENSITIVITY ANALYSIS

The research team investigated what variables influence greatly on total supply chain costs after we developed activity-cost model (Table 4). To this end, we conducted a sensitivity analysis using a computational risk management software (@Risk).

Variables and Probabilistic Distribution

The research team used normal distribution for the input variations. The normal distribution is a continuous probability distribution that describes data that clusters around a mean or average. The graph of the associated probability density function is bell-shaped, with a peak at the mean, and is known as the bell curve. The research team ran the three scenarios differing standard deviation. The 10, 30, and 50 percent of the input variables were used as the standard deviations of the scenarios. Most of the time variables of the stakeholders and the cost driver variables were normally distributed in the simulations expect the maintenance time in the traditional method and the assembly yards rents.

Simulation Results

The research team used a commercial software of @RISK, which uses the technique of Monte Carlo simulation. Each simulation was iterated 10,000 times. The mean value of weekly total costs is $70,603 with the standard deviation of $1,679 (Table 5).

Table 5: Weekly Cost Results Overview

	Min	Mean	Max	Standard Deviation
Prefab-JIT Method	$68,028	$70,603	$73,101	$1,679

Sensitivity Analysis Results

The sensitivity analysis, which identifies significant inputs, is carried out using regression analysis and correlation analysis. The results of a sensitivity analysis are shown in Table 6. The analysis shows that total rebar supply costs are is mainly affected by logistics (i.e., the number of batches and distances) as well as labor productivity. The stakeholders (i.e., different contractors and suppliers) can make collective efforts to reduce the volume of critical variables. Such analysis does not directly reduce the supply chain costs. Rather it provides relevant information for decision making on how to reduce the supply chain costs.

Table 6: Sensitivity Analysis

Rank	Variables	Activity	Stakeholder	Regr	Corr
1	# of Batches, Distances	Move the fabricated rebar to an assembly yard	Plant	0.544	0.520
2	Labor in SC	Sub-assemble the Fabricated Rebar in the assembly yard	SC	0.474	0.458
3	Labor in SC	Install Rebar	SC	0.472	0.456
4	# of Shop Dwg Sheets	Generate and Revise Shop Dwgs	SC	0.443	0.445

Notes:

Regr= regression coefficient

Corr=correlation coefficient

Discussion & Conclusions

Benefits of ABC in Supply Chain Costing

Improved insight into across-organizational costs. The major advantage of using ABC for supply chain cost calculation is that it yields more accurate costs and gives better insights into across-organizational cost structure. The cost analysis using ABC provides a process view by generating activity costs of resources while the traditional overhead cost analysis method does not. Managers can see how much resources are consumed for each activity triggered by cost objects. If activities are outside organization the chances to have such process view become lower.

Data for inter-organizational collaborative productivity improvements. Any productivity improvement movements including lean construction make an effort in reducing resources by identifying unnecessary processes such as waiting time.

However, lean construction is different from other traditional productivity improvement movements in that waste is identified in terms of customer's value and work flow along the supply chain in which different stakeholders are involved. The cost model (Table 3 & 4) using the activity-based costing provides cost data which can be used to reduce costs through collaborative management efforts. If risks and profits can be shared through contractual agreements such as IPD (integrated project delivery) agreement (Ballard and Kim 2007) such collaborative efforts can be easily made compared to current commercial contracts which promote adversarial relationship between stakeholders.

Analysis of financial implications of resource and practical change. The strength of such a detailed cost accounting method lies not only in the analysis of the actual situation, but also in the possibility to calculate cost impacts under the scenario where possible process changes are made. For example, if the number of batch size or travel distance changes, the financial implications are easily calculated using the ABC model (Table 3 & 4) by changing the number of cost drivers or resource consumption rate.

Conclusions and Moving Forward

Lean construction pursues eliminating wastes. The wastes in lean are well-documented and classified by Ohno (Ohno 1988). People try to identify and eliminate wastes to reduce costs. However, wastes do not manifest themselves in the supply chain including rebar supply chain.

You need to find these cost drivers in order to eliminate them. However, many organizations see resources cost drivers which are the causes of the costs. It is because the costing system assumes that resources are directly assigned to cost objects. That leads to the shared norm that you should eliminate resources to reduce your costs! That is not necessarily true! Real challenge is that you should understand cost drivers that are related to your customer /suppliers business process as well as your own business process.

This paper contributes to the knowledge of lean construction domain in that the activity-based costing method is adopted in supply chain costing so that stakeholders along the supply chain can make use of the ABC costing data to reduce total supply chain costs to achieve the project objective, not their internal production objectives. Management typically pays more attention to visible costs than invisible costs, even though the latter are quite real, often risky, and are melting the bottom line. Most invisible costs are buried in overhead costs. Many of overhead costs in supply chain are interface costs which are impacted by your customer/supplier's business process as well as your own business process. We see through a case study that ABC provides a process view in supply chain in that activities and associated costs are revealed through the supply chain, thereby helping reduce or eliminate wastes or non-value added activities. When all stakeholders understand their own and channel participants cost, they can work together to lower overall costs and improve customer satisfaction.

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