

Implications of Activity-Based Costing/Management for Decision-Making in Order Management

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Abstract

Activity-based costing and management is an accounting and management approach for determining accurate costs especially the overhead costs. Activity-Based Costing/Management (ABC/M) can overcome some of the limitations of traditional cost accounting for decision-making in order management. The combination of ABC in orders management decision-making models of can improve the quality of decision. Most of order management decision support models only consider material flow and capacity constraints and don't consider the profitability factor. This paper proposes multi objective mixed integer programming model to could take into account profitability for managing order decisions effectively, subject to capacity constraints by using ABC. Illustrative example shows that the proposed model satisfies a favorite quantity of orders completely and accepts a selective number of orders partially by increasing the profitability and minimizing residual capacity simultaneously.

Keywords: Activity-based costing, order management, decision-making, multi objective mixed integer programming

INTRODUCTION

Organizations have been under increasing pressure to adapt to the changing business environment. Escalating over the past two decades, various management accounting techniques have been introduced in order to enhance this adaptation in fundamental areas of the organization. As an alternative costing system to traditional volume-based costing, Activity-Based Costing (ABC) has been one of these initiatives (Moll, 2005).

Activity-based costing and management is an accounting and cost management approach which attempts to address the existing deficiencies in the most of the current cost accounting methods. In ABC we first identify the production process activities, and then estimate the cost of each activity individually. These cost estimates will include all the labor, material, equipment, and the overhead costs. It results in a more accurate estimation of the overhead costs in the manufacturing processes for each product, rather than the traditional accounting systems.

The attention of the paper focus on the advantages of ABC/M system as valuable provider of information for order management decision making process and in modeling the related cost management system. This paper intends to integrate this powerful accounting system into an order management problem and operations management problem. Hence, the main contribution of this paper is elaborating more the role of ABC/M as a supportive management decision making approach and as a business objective harmonizer between financial and operational departments.

The rest of this paper is organized as follows: section 2 provides a literature survey on the applicability of ABC/M in developing mathematical decision support systems. Section 3 presents the mathematical model in MADM process for order management problem. Section 3 includes an illustrative example to show the advantages of the new model with the older approaches. Section 4 contains results, discussion, conclusion and future research guidelines.

Literature Review

Many business management concepts have been developed since the global competition had become serious. Organizations have started to practice their improvement of competitiveness. In order to achieve this goal they have started to use modern and advanced process and cost management techniques such as activity-based costing, kaizen costing, total quality management, process improvement, etc. All these kinds of techniques are being used for the sake of process improvement and for increasing the competitiveness of the organizations.

Competition for logistics and transportation companies is severe and they are under the pressure of demanding business conditions. Logistics are becoming more and more important because the cost of logistics has a considerable proportion in the total cost of products. Physical distribution cost estimates range from 7.93% to 30% of sales (Davis, 1991). This is generally because of increasing product and/or service differentiations. Therefore, the proportion of logistics costs attract interests of researchers because the improvement of logistics cost has a direct impact on the total cost of products.

ABC has appeared during the 1980s' with the studies of (Cooper, 1988). Cost calculation of the products and/or services in traditional previous term costing is based next term on the determination of direct costs and indirect costs and then summing them to find the individual cost of each element. Traditional previous term costing next term involves collecting indirect costs from departments and then allocates them to products or services (Tsai and Kuo, 2004). In order to address the problems of traditional cost systems, companies reengineer their accounting systems by incorporating their understanding of cost drivers and applying these drivers to the cost of products in proportion to the volume of activity that a product consumes. This view was termed activity-based costing and primarily used to analyze decisions such as pricing, product mix and product sourcing. The increased knowledge of cost drivers has prompted many companies to reengineer their business processes by monitoring each of their processes and then, eliminating (or improving) the processes which are non-value added (Keegan and Eiler, 1994).

There are many studies that demonstrate the benefits of ABC/M implementation in different manufacturing/service industries. Nachtmann and Al-Rifai (2004) examined the benefits of its implementation in an air conditioner manufacturing industry. Singer and Donoso (2006) studied the benefits in a steel manufacturer and Rezaie et al. (2008) in a flexible manufacturing system in a forging industry. Krishnan (2006) showed the application of ABC/M in a higher learning institution.

The application of cost information in the management decision making process has been a key research topic in cost accounting for the last two decades (Boyd and Cox, 2002). The presented survey by Boyd and Fox (2002) results showed the importance of cost accounting information in production decision making areas such as, product pricing, product profitability, make vs. buy, and plant expansion. Among the cost accounting systems, ABC/M is a more appealing approach to supply chain management (SCM) decision making process since it provides a more detailed and a hierarchical cost structure. One possibility is integrating ABC/M cost structure and information into SCM mathematical decision support systems (DSSs). ABC/M and mathematical programming are two synergic approaches for creating data-driven models to analyze decisions about managing the firm's resources (Shapiro, 1999). Gupta and Galloway (2003) introduced ABC/M as a supportive information system in operations decision making processes such as, product planning, product design, quality management, process design, process improvement, inventory management, and investment management.

Robert Kee (1995) proposed initially an ABC/M-based mixed integer programming (MIP) model to identify the optimal product mix from concurrent evaluation of the cost, physical production resources, and market demands. ABC/M was integrated to the model by applying the homogenous cost pool structure by Cooper and Kaplan (1991).

MATERIAL AND METHODS

In this section, we show how activity-based costing (ABC/M) integration in order management mixed-integer programming (MIP) model can assist the model to support the business in perusing its short and long term objectives such as short-term profitability, short-term profitability and Customer loyalty, long-term stability.

The new model is taking into account the fulfillment of a favorite quantity of orders completely due to the importance of selective customers' satisfaction and the possibility of satisfying the rest of the orders partially, with the objective of minimizing the residual capacity. In this section, we first discuss the applied cost structure. Then the proposed model is presented.

ABC/M Cost Structure

The industrial factory overhead costs refer to all indirect costs that are incurred to keep the factory operational. Costs such as the utilities that are consumed by the production unit, any kind of depreciation on equipment and building, and factory personnel (excluding direct labor) can be considered as typical examples of overhead costs. Calculating those costs and finding the consumption of each per unit of product is one of the big challenges for the companies. ABC/M assigns the overhead costs to the products through the required production and manufacturing activities. This provides a more accurate estimation of production and manufacturing costs per unit of each product. Cooper and Kaplan (1991) presented a framework for manufacturing cost which assigns the overhead costs to four specific cost pools:

- Unit-level activities (machining time, material, direct labor, etc.) costs that vary directly with the number of units produced.
- Batch-level activities (planning and tactical management, material handling, setup, etc.) costs which are invoked whenever a batch is processed.
- Product-level activities (process engineering, design, etc.) costs which come into play whenever a particular product is manufactured.
- Facility sustaining activities costs such as rent, utilities, maintenance, and facility management.

This approach helps to show and clarify the role and source of each overhead costs in a production and manufacturing processes. According to the manufacturing environment presented as well as Cooper and Kaplan's (1991) framework; overhead costs are distributed among unit-level, batch-level, and product-level. The following section contains the mathematical model developed.

Proposed Model

Our proposed model has the following assumptions:

- Processing times are deterministic.
- Transit time between cells is considered negligible.
- Each product is manufactured in equal-sized batches under a pull system.
- Demand for each type of product per order is deterministic.
- Each order consists of just one type of product.
- No possibility for increasing the production activities capacity.
- There is a possibility to satisfy the orders partially, completely, or even reject them.
- A desirable amount of orders should be fulfilled completely.
- The overhead costs are distributed among three levels of activities (Unit-level, Batch-level, and Product-level).

In the following of this section, we present our model:

The p_i represents the preference coefficients for the model different objectives. The other assumption for this model is $p_1 > p_2$ which indicates that the capacity stretching policy is more expensive than not using the capacity completely; in fact, there is not any possibility for enlarging the capacity in this

problem. Moreover, $p_3 > p_4$ shows that the goal of minimizing the residual capacity is more significant than making profit.

The exact amount of m_j, m_l and the other coefficients will be discussed in the next section. The new approach presented allows orders to be fulfilled partially, which allows the company to minimize the residual capacity. The model also has the possibility of indicating the amount of orders that need to be fulfilled completely based on the company's policies and customer relationships. This makes the model more customer oriented by allowing us to make a decision based on customers' credentials. Accordingly, the mathematical model developed, using weighted goal programming (WGP) modeling technique, follows two goals simultaneously; to maximize the profit margin and to minimize the residual capacity. The model notation followed by the objective function and constraints are indicated below.

Notation

i	product index
t	period index
r	raw material index
v	supplier index
j	activities at Unit- level index
k	activities at Batch- level index
l	activities at Order- level index
o	order index
d_i^+	amount of over capacity production (capacity surplus variable)
d_i^-	amount of under capacity production (capacity slack variable)
x_j	cost rate of performing Unit- level activity j
a_k	cost rate of performing Batch- level activity k
v_l	cost rate of performing Order- level activity l
c_{rv}	unit cost of material r from supplier v
g_{ir}	required amount of resource r to produce product i
h_i	holding cost of product i per period
c_{mh}	holding cost of common part
q_{ij}	required amount of time to perform activity j for product i
	required amount of time to perform activity k at batch- level related to activity j at
u_{ijk}	Unit- level for product i
f_{il}	required amount of time to perform activity l for product i
b_{ij}	batch size of product i at activity j
p_i	sales price of product i
p_1	cost of stretching the production capacity
p_2	cost of not using whole capacity
p_3	preference coefficient of maximizing profit
p_4	preference coefficient of minimizing residual capacity
O	desirable full order amount
R_{rvt}	supplier capacity of raw material r in period t
D_{iot}	demand quantity of product i in order o due in period t
O_{jt}	total available time to perform activity j in period t
U_{kt}	total available time to perform activity k in period t
F_i	total available time to perform activity l
I_{it}	Inventory amount of product i in period t
C_{mit}	common part inventory amount in period t
P_{ijt}	amount of product i produced in period t in machine j
S_{io}	quantity of product i in accepted order o in period t
B_{ijtk}	number of batches of product i produced in machine j by applying setup k in period t
Y_{iotl}	The proportion of accepted order o from product i in period t by applying production line of l
Y^{New}_{iotl}	The binary form of Y_{iotl}

The Model

$$\begin{aligned} \text{Max } Z = & p_2 \times (\sum_t \sum_o \sum_i p_i \times S_{iot} - \sum_t \sum_i \sum_v \sum_r \sum_j \sum_k g_{ir} \times c_{rv} \times p_{ijt} - \sum_t \sum_i \sum_j x_j \times q_{ij} \times P_{ijt} - \sum_t \sum_i \sum_j \sum_k a_k \times u_{ijk} \times \\ & B_{ijtk} - \sum_t \sum_o \sum_i \sum_l Y_{iotl} \times f_{il} \times Y_{iotl} - \sum_i \sum_t h_i \times I_{it} - \sum_t c_{ph} \times C_{Pit}) - p_4 \times \\ & (\sum_i m_1 d_i^+ + m_2 d_i^-) \end{aligned} \quad (1)$$

Subject to:

Raw material constraints

$$\sum_i \sum_j g_{ir} \times P_{ijt} \leq \sum_v R_{rvt} \quad \forall r, t \quad (2)$$

Unit- level activities constraints

$$\sum_i q_{ij} \times P_{ijt} + \sum_i \sum_k u_{ijk} \times B_{ijtk} \leq Q_{jt} \quad \forall j, t \quad (3)$$

Batch- level activities constraints

$$P_{ijt} = b_{ij} \times \sum_k B_{ijtk} \quad \forall i, j, t \quad (4)$$

$$\sum_i u_{ijk} \times B_{ijtk} \leq U_{kt} \quad \forall j, k, t \quad (5)$$

Order- level activities constraints

$$S_{iot} = D_{iot} \times \sum_l Y_{iotl} \quad \forall i, o, t \quad (6)$$

$$\sum_i \sum_o \sum_t f_{il} \times Y_{iotl} - d_i^+ + d_i^- = F_l \quad \forall i, o, t \quad (7)$$

$$\sum_i Y_{iotl} \leq 1 \quad \forall i, o, t \quad (8)$$

$$\sum_i \sum_o \sum_t \sum_l Y^{New}_{iotl} \geq 0 \quad (9)$$

$$Y_{iotl} \geq NY^{New}_{iotl} \quad \forall i, o, t, l \quad (10)$$

$$D_{iot} > \sum_l Y_{iotl} \quad \forall i, o, t \quad (11)$$

Inventory balance constraints

$$I_{io} = 0 \quad (12)$$

$$I_{i(t-1)} + \sum_{j=2} P_{ijt} - I_{it} = \sum_o S_{iot} \quad \forall i \quad (13)$$

Inventory balance constraints for common part

$$C_{Pi0} = 0 \quad (14)$$

$$\sum_i \sum_{j=2} P_{ijt} - P_{ijt} + C_{Pit-1} = C_{Pit} \quad \forall t \geq 1 \quad (15)$$

Binary and non-negativity constraints

$$P_{ijt} \geq 0 \quad \forall i, j, t \quad (16)$$

$$B_{ijtk} \geq 0 \quad \forall i, j, t, k \quad (17)$$

$$0 \leq Y_{iotl} \leq 1 \quad \forall i, o, t, l \quad (18)$$

$$Y^{New}_{iotl} = 0 \text{ or } 1 \quad \forall i, o, t, l \quad (19)$$

The objective function consists of two parts which are required to pursue the two goals previously described; increasing the profit margin and decreasing the residual capacity. The first part of the objective function consists of seven mathematical terms. The first term calculates the revenue which is the multiplication of sales by the product price. The next six terms calculate the process costs including the cost of work in process (WIP) inventory. The second part of the objective function serves to minimize the residual capacity. According to this term any violation from the available capacity has a certain penalty cost. In order to decrease the residual capacity, the possibility of accepting the orders partially is added to the model by replacing the acceptance and rejection binary decision variable in the previous versions (Y_{iotl}) with proportion fulfillment decision variables (Y^{New}_{iotl}). This decision variable can take any value between 0 and 1 which represents the proportion of order fulfillment.

The first set of constraints is established to limit the consumption of the raw material and the subcomponent to the available quantities that can be purchased. Constraints (3)

and (5) ensure that the available Unit-level and Batch-level capacity, respectively, are not exceeded. Constraints (4) allow the variety in batch sizes to exist, the constraints (6) make sure that the production quantity meets the order commitments, and constraints (7) are the capacity variation constraints. Constraints (8) to (11) define the amount of desirable orders which should be fulfilled completely based on the company’s policy. Finally, constraints (12) to (15) calculate the amount of inventory for the final products and for the common part or WIP at the end of each period. The rest of the constraints are self explanatory.

An Example

In this section we consider an example to evaluate our proposed approach. The defined example consisting of 14 orders from 4 different types of product in 14 periods is presented in order to compare the model with the possibility of acceptance of partial orders with the previous models that are developed based on accepting or rejecting orders completely. The related operational and financial parameters are also presented.

This study uses a pull production system which consists of two different types of suppliers, supplier of part A and supplier of part B who are trading directly with the producer. Each supplier has the capacity to provide 25 units of raw material “A” and 25 units of sub-component “B”. The producer is manufacturing four different types of product (P1 to P4). It is also assumed that there are no delays in transporting the parts or/and raw material along the supply chain and between cells. This example is originating from the article of O’Brien and Sivaramakrishnan (1996) and has been also discussed in Umble et al. (2001) and Kiriche et al. (2005).

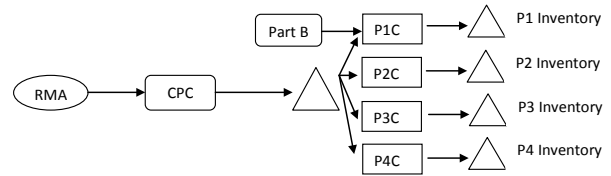


Figure 1. Manufacturing Process Flow

For manufacturing the products, each unit has to go through the production cells; which are formed by a common cell followed by four product-specific cells. Figure 1 shows the manufacturing process, which begins by injecting the raw material “A” into the common part cell, the outcome is defined as common part (CP). Those common parts then transfer to each of their respective product-specific cells. There are four production lines, each one dedicated to one type of product.

The only exception is product number one (P1) which requires an extra part, named Part “B” in addition to “CP” to be completed. The production process finishes by storing the end products in their related warehouse; subsequently, the proper products are shipped to the related customers at the right moment. The related operational parameters such as total available production time, batch sizes, and required setup time which is originally from Yang and Jacobs (1999) are shown in Table 1. The product pricing parameters as well as the relevant cost data are shown in the Table 2: Financial parameters are obtained from Kiriche et al. (2005).

The Order specifications of the problem that have been developed to clarify the advantages of the improved model are shown in Table 3. The objective is to evaluate the 14 orders

Table1. Operational parameters

Activities	Product				
	CP	P1	P2	P3	P4
Mean run time per unit(h)	0.37	0.37	0.37	0.37	0.37
Batch size(units)	6	6	6	6	6
Batch set-up time(h)	0.4	0.3	0.3	0.3	0.3
Total available capacity in each cell per period(h)	10	7	6	7	7
Utilization rate in each cell	0.7	.75	.75	.75	.75

Table2. Financial parameters

	Product				
	CP	P1	P2	P3	P4
Order-level Costs (\$)		167.4	134.2	67.2	48.2
Batch-level Costs(\$)	15.3	9.7	10.2	8.4	7.1
Unit-level Costs(\$)	8.8	6.7	5.8	6.4	5.9
Sales Price(\$)	-	115.0	77.0	85.0	73.0
Inventory Costs(\$)	1.8	2.7	2.1	1.9	1.6

Table3. Order specifications

Order Number	Product Type	Period	Quantity	Order Number	Type Product	Period	Quantity
1	P1	1	60	8	P1	8	38
2	P2	1	90	9	P1	9	70
3	P3	2	54	10	P3	10	40
4	P4	4	34	11	P4	11	30
5	P1	3	30	12	P4	12	40
6	P4	5	45	13	P2	13	57
7	P3	5	58	14	P2	14	45

Table 4. Planned order in with and without partial order acceptance

period	Without Partial Order Acceptance					With Partial Order Acceptance				
	P1	P2	P3	P4	CP	P1	P2	P3	P4	CP
1	0	0	12	0	12	0	0	12	0	20
2	0	0	8	0	8	0	0	12	0	20
3	0	0	16	0	16	0	0	12	0	20
4	0	0	16	0	20	0	24	0	0	20
5	0	0	16	0	20	0	0	16	0	20
6	0	12	16	0	20	0	0	16	0	20
7	0	8	16	0	20	0	0	16	0	20
8	0	16	16	0	20	0	0	16	0	20
9	0	16	16	0	20	0	0	16	0	20
10	0	0	16	0	20	0	0	16	0	20
11	0	0	12	0	20	0	0	16	0	20
12	0	0	12	0	20	0	0	16	0	20
13	0	0	12	0	20	0	0	8	0	20
14	0	0	12	0	20	0	0	8	0	20

Table 5.

Order	Without Partial Order Fulfilling Rate (%)	With Partial Order Fulfilling Rate (%)	Minimum desirable amount of orders which should be satisfied completely						
			1	2	3	4	5	6	7
1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-
3	100%	32%	32%	32%	32%	32%	32%	100%	8%
4	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-
6	-	13%	13%	13%	13%	13%	13%	1%	-
7	100%	-	100%	100%	100%	100%	100%	100%	100%
8	100%	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-
10	-	100%	98%	98%	98%	100%	100%	100%	100%
11	-	-	-	-	-	-	-	-	-
12	100%	6%	6%	6%	6%	6%	6%	6%	6%
13	-	-	-	-	-	-	-	-	-
14	-	88%	-	88%	73%	89%	74%	54%	44%
Profit \$	\$8346.5	\$8346.5	\$734.5	\$7346.5	\$6743.5	\$8786.5	\$8566.5	\$8986.5	\$6786.5

and provide a decision within 14 units of time (14 weeks). It is also assumed that for each unit of product P1 to P4, we need one unit of raw material "A" and for each unit of P1, one unit of sub-component "B" is consumed. The model applied to the nine different scenarios by using the software Lingo Version 10;

- Without partial order acceptance
- With partial order acceptance
- Fulfilling the different desirable number of orders completely

In order to give a higher preference rate to the goal of minimizing the residual capacity compared to maximizing the profit as well as diminishing the impact of preference coefficients on the objective function profit calculation; the amount of p1 to p4 are assumed equal to 1, 0.5, 1, and 2, respectively. In fact, this combination allows the model to calculate the precise amount of profit (\$) in each scenario by reducing the effect of the preference coefficients in the calculation. The related outputs are shown in Tables 4 and 5.

By comparing the outputs in Table 4, it is clear that the utilization rate of our common part cell, which is in fact, the bottleneck of the process, increases significantly if the possibility of partial order acceptance is applied. Based on the operational parameter, the maximum capacity of the common

part cell to manufacture CP is equal to 20 units per period which has been used completely with the exception of period 14. The results of applying the model to the different scenarios, with or without partial order acceptance and with desirable number of orders that should be fulfilled completely are shown in Table 5. The benefit of decreasing residual capacity by accepting the orders partially is illustrated by showing the increment in the profit margin (*Optimum Value*) by \$1,558.48 when compared to the one without partial order acceptance. This also represents a 16% positive increase in the profit margin. The optimal solution is satisfying two orders completely and eight orders partially with different ratios of fulfillment. This yields a profit of \$9,487.57. The model also demonstrates the value of the profit if there is a constraint on the number of orders that should be completely satisfied. The profit decreases as the number of orders that should be satisfied completely is greater than one, since the binding constraint is getting tighter. The model also gives an infeasible solution when it is required to satisfy more than six orders completely, due to a violation of the total available capacity constraints.

The paper focuses on developing a new systematic approach for cost management, cost control, and cost analysis

in the order fulfillment process. The approach presented aims not only at maximizing the profit, but also at how to improve the utilization rate, and how to implement the most appropriate order fulfillment strategy. Using activity based costing and management (ABC/M) as the cost structure gives ABC/M a critical role in the modeling process while increasing the validity of the model output.

DISCUSSION AND CONCLUSION

ABC/M is being evolved from a cost accounting approach to a managerial and cost accounting system. The ABC/M application in management decision support modeling, along with its proven positive effect on the other SC improvement strategies (e.g. Total Quality Management, Just-in-Time), emphasizes more on ABC/M managerial aspects. These also emerge the positional advantages of ABC as a supporting tool for lean manufacturing (LM).

LM focuses on the methodologies and approaches that can help an enterprise to reduce the waste factors in its processes. The traditional cost accounting is a transaction oriented approach, but a LM process requires an activity oriented cost information. ABC/M because of its activity oriented nature can provide useful information to identify the cost effect of each value added (VA) and non-value added (NVA) process activities. This introduces ABC as a lean accounting (LA) approach that can help to analyze each process from LM perspective.

In this paper the new approach of integrating ABC/M cost structure in mathematical decision support models for order management problems is introduced. The new profitable-to-promise (PTP) model integrates the option of fulfilling the orders partially by applying weighted goal programming (WGP) techniques in order to reduce the residual capacity and increase profitability at the same time.

The mixed-integer programming (MIP) model developed also incorporates the concept of management discretionary factor. The model is able to fulfill a desirable amount of orders completely according to the managers' preferences with the possibility of satisfying the rest of the orders partially, with the objective of minimizing the residual capacity.

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