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Activity-Based Costing and Management applied in a hybrid Decision Support System for order management

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ABSTRACT

This article introduces a new Cost Management and Decision Support System (DSS) applicable to Order Management. This model is better fit and compatible with today's competitive, and constantly changing, business environment. The presented Profitable-To-Promise (PTP) approach is a novel modeling approach which integrates System Dynamics (SD) simulation with Mixed-Integer Programming (MIP). This Order Management model incorporates Activity-Based Costing and Management (ABC/M) as a link to merge the two models, MIP and SD. This combination is introduced as a hybrid Decision Support System. Such a system can evaluate the profitability of each Order Fulfillment policy and generate valuable cost information. Unlike existing optimization-based DSS models, the presented hybrid modeling approach can perform on-time cost analysis. This will lead to better business decisions based on the updated information.

1. Introduction

Decision Support Systems (DSSs) play a crucial role in today's rigorous global competition business environment. By providing on-time and reliable information, DSS assist management decision making in rendering the company more profitable, leaner, more responsive, and agile. In the area of Supply Chain Order Management, DSSs can be formulated through three different theoretical modeling approaches: Available-To-Promise (ATP), Capable-To-Promise (CTP), and Profitable-To Promise (PTP).

The first two modeling approaches emphasize the capacity availability in order to decide whether to accept or reject an order, whereas the PTP approach considers the opportunity cost of accepting or rejecting an order as a main decision evaluation factor. In fact, PTP examine decisions based on the possibility of assigning the available capacity by not accepting an order today to another order with higher profit margin which has been predicted to take place in the future.

Regardless of the modeling approach used, management requires a complementary tool that can assist them to analyze the impact of the decision implemented on the business status changes. For instance, with respect to ATP and CTP, management needs to know the availability of their production resources after fulfilling each order. However, PTP management needs to monitor and control the costs and profit changes after taking any decision dynamically. The traditional optimization-based models cannot fulfill this requirement. They are only able to provide relevant information based on the business static status.

Moreover, the PTP model needs to be developed based on an accounting approach which can accurately estimate the value of consumed resources. Generally, a production process requires three inputs: Direct Labor, Direct Material, and Manufacturing Overhead (MOH). The first two are categorized as direct costs, which are traceable to a specific cost object (*e.g.* service, product, order). The latter represents a mixture of both direct and indirect costs (*e.g.* maintenance, security, safety) which represents a challenge to assign them to the cost objects.

The Traditional Cost Accounting (TCA) allocates, as opposed to assigning, MOH costs either by using a plant-wide rate or departmental rates; either case may distort the final production cost amount. Especially in a case where there is a highly customized and low volume production process. Unrealistic cost estimation, may lead to mispricing and compromise the firm's growth and profitability.

Activity-Based Costing and Management (ABC/M) is a relatively new cost accounting and management approach that enhances the level of understanding about business operation costs; especially MOH costs. ABC/M is an accounting approach which assigns, instead of allocating, MOH costs to the activities. Although the application of ABC/M does not eliminate MOH costs allocation, it can reduce it to some facility-level costs (*e.g.* facility utility costs, facility managing costs).

The importance of hybrid Supply Chain DSSs has been shown comprehensively in a recent study presented by Martinez-Olvera [24]. "As real-life business environments have become really complex,

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supply chains members have been forced to use hybrid business models (that is, the integration of features of two different business models)." The other three studies which have paid attention to this subject are: [19], [20], and [26]. Martinez-Olvera [24] also discussed the optimization-based simulation models as a potential future work.

This article explains how ABC/M can be utilized as a powerful approach to develop a hybrid Mixed-Integer Programming (MIP) and System Dynamics (SD) Decision Support System for Order Management problems. It also introduces a new approach in integrating ABC/M information with SD simulation modeling technique, which results in a more reliable and precise cost monitoring tool.

The rest of this article is organized as follows: Section 2 provides a brief literature review, Section 3 elaborates the discussed general Order Management problem, Section 4 incorporates the ABC/M-based Mixed-Integer programming (MIP) decision support model, and Section 5 provides an illustrative numerical example for the developed MIP model. The System Dynamics (SD) cost monitoring model and the hybrid DSS all are explained in Section 6. In Section 7 the relevant conclusion and future work are explained. Finally, the SD model variables' information is given in Appendix.

2. Background

ABC/M is a two-stage process, (1) associating cost to resource (activity), and (2) selecting an appropriate activity measurement (activity cost driver), [6]. Kee [14] named the two steps as; (1) breaking overhead costs into different cost pools and (2) assigning overhead costs through different activity cost drivers to products or orders. As a result, a more accurate overhead costs assignment is achieved.

ABC/M supporters highlight two principal objectives, [11] and [27]: (1) to provide detailed information about the costs and consumption of activities in a specific process and (2) to provide accurate information for managers to improve decisions. This has also been corroborated by Gosselin [7] regarding a pilot and full ABC/M implementation studies. However, the use of ABC/M has been limited to a cost accounting approach, rather than as a managerial technique (Gosselin [7]; Kaplan and Anderson [13]; Gosseling [8]).

ABC/M advantages, and constructive effects, on a firm's performance have been determined through numerous studies and dissertations. Kennedy and Afleck-Graves [15], Ittner et al. [12], and Cagwin and Bouwman [5] attested ABC/M as a preferable accounting approach compared to the TCA systems. Some studies such as; Novićević and Antić [25] and Cagwin and Barker [4] showed evidence of a positive impact of ABC/M on lean manufacturing components like Just-In-Time (JIT) and Total Quality Management (TQM).

The preeminence of ABC/M in providing detailed cost information represents a potential powerful approach for developing PTP Supply Chain Decision Support Systems. Malik and Sullivan [22] developed an ABC/M-based Mixed-Integer Programming (MIP) decision support model for product mix problems. Kee [14] integrated some aspects of the Theory of Constraints (TOC) in ABC/M-based MIP modeling for the product mix problem and named it "Expanded ABC/M model." The model identifies the firm's optimal product mix by evaluating simultaneously the resources and product cost, the production resources availability, and the business marketing opportunities.

In Supply Chain Order Management, [17] and [18] presented a PTP–MIP model for accepting or rejecting orders by implementing ABC/M homogeneous cost pools' structure originally introduced by Cooper and Kaplan [6]. The purpose of the model was to gain insight into how significant Order Management decisions are in maximizing profitability when the firm has insufficient production resources to satisfy all the demand. Khataie et al. [16] added the possibility of pursuing two main different goals simultaneously, reducing the residual capacity and increasing the profitability to the previous models.

A powerful PTP Order Management tool assists management to monitor, analyze, and foresee the consequences and outcomes of each decision, and monitors their business competitiveness factors dynamically. SD is a simulation approach that was developed in the mid 50s by J. Forrester from Massachusetts Institute of Technology (MIT) to understand the dynamic behavior and status alternation of complex systems over a certain period of time with learning ability.

Lately, SD has been applied on numerous diverse areas of research by upcoming the advanced generation of SD simulation software. However, the survey presented by Braines and Harrison [3] showed the limitations of SD modeling in the manufacturing sector from the business and/or operational perspective. This represented a diversification from its original purpose, which was to serve as a decision support tool for manufacturing processes at the operational level. Instead, and according to the survey, SD have been broadly used in the modeling of resource management at national and global level decision support processes, and in the service sector at operational levels.

A limited number of studies using SD approach for financial decisions have been reported. Abdel Hamid and Madnick [1] used SD for software development cost estimation. They implemented the SD simulation technique to see the effects of multi-variable changes in the model. Marquez and Blanchar [23] applied SD to support investment decisions in high-technology business. Macedo et al. [21] developed a real-time cost monitoring model for the reengineering process of a gelatinous substance at the microbiology laboratory by integrating the ABC/M and SD. However, the developed model was acting as a real-time cost calculator rather than a System Dynamics model. There were no positive or negative learning loops in the proposed model.

3. General illustrative problem

A Flexible Manufacturing System is selected as a pilot production facility in a simplified three-echelon Supply Chain including supplier, producer, and customers. The system can set up two different production processes or models: Basic and Deluxe. Direct material is similar for both models and there is no restriction for direct material supply. The manufacturing process, Fig. 1, starts by injecting the common direct material into the system. Second, the FMS alternates between two types of setup based on the assigned production plan. Lastly, the manufacturing products are stored for shipping to the customers.

The firm's management follows a pull-production strategy, therefore it develops the aggregate production plan (AP) based on the received orders per month. Not all the orders can be fulfilled completely due to machining hour capacity per period; as a result, the firm's management has to choose the fulfillment rate of each order. The Order Management policy is fulfilling completely, or partially, or rejecting the orders according to the production system availability and order's profitability factors.

The problem and parameters have been extracted from a managerial accounting educational business case study known as "Willow Company" from [10]. The production costs have been split into two groups; prime costs (which include Direct Materials and Direct Labor) and overhead costs. The latter is divided into five homogeneous cost pools with a particular activity cost driver for each one. The case study assumes that the overhead unit-level costs are completely traceable and are included in the prime costs.

There are two different batch-level cost pools introduced in the case study; material handling and setups. Their respective cost drivers

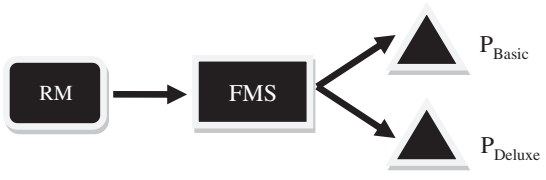

Fig. 1. Manufacturing process flow.