

On Exploiting System Dynamics Modeling to Identify Service Requirements

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Abstract

SOA provides a flexible framework for better-integrated systems that meet business needs. However, the existing methods are not successful in helping business analysts to devise appropriate business services. Herein, a novel approach is presented to address service identification and thereby developing sound SOA. In contrast with conventional methodologies, we press on the criticality of exploiting the information of dynamic business behavior to develop business services.

1. Introduction

To cope with the increasing speed of the business changes and the increasing pressure of revenue and cost optimization, enterprises are looking for ways to align their IT organizations more closely with their business requirements. SOA is a strong candidate to solve this problem. One challenge in developing SOA solutions is identifying service requirements at business level. This study focuses on this problem.

Conventional software development methods are not totally applicable to SOA development. New means to identify and define services in a dynamic business environment is needed [5].

In this paper, we present a case study of defining supply chain business services in the domain of demand-supply-offering (DSO) conditioning. We use System Dynamics [1] which captures business requirements in feedback control type of formalism.

2. DSO Conditioning Scenario

We detail our study case in the manufacturing process and provide a base for choosing business services we need to support the business operation. From complexity viewpoint, the manufacturing process could be separated as the front end, the back end and the integration between them [2].

In the front end of a supply chain, business owners are mainly concerned with the market investment environment. Based on customer purchasing behavior, competitors' share, business potential, the business owner makes a decision to offer a valuable product to an existing market. Proper pricing strategy is established to attract different levels of customers based on its own pricing objective (maximizing revenue, maximizing profit, getting quality leadership, surviving in the constrained market). For instance, quantity discount is offered to large buyers, seasonal discount is offered during Christmas, promotion discount is offered to stimulate sales. Our study related to the front-end is limited to demand forecast. Customer satisfaction is taken into account through penalization of the longer order backlog. Pricing correlated to customer demand and competitors.

In the back end of a supply chain, business owners are mainly concerned with having stable and flexible supply for products. In order to guarantee business continuity, business owners adopt various contract structures and optimize enterprise supplier portfolio. For instance, buyers can lock into low price through forward contract. In the IBM PCD/Lenovo case, multiple suppliers setup hubs near its manufacturing sites and manage part inventory for Lenovo directly. This reduces part acquisition leading time to zero and reduce bullwhip effect for suppliers.

Integration is responsible to manage the manufacturing process and hook up the both ends. In order to achieve optimal profit margin in uncertain and competitive world, business owners need to establish policy and decision rules to manage inventory and order policy from suppliers and satisfy market demand. There exist both information flow and material flow during integration. That information flows from customer to manufacturer and to supplier; while material flows from suppliers to manufacturers and to customers. Information sharing allows participants to make better planning.

In terms of long term planning, business owners need to consider their business based on their strategic direction. In the front-end, they need to answer how much market they want to occupy, what is the predicted business growth rate. In the back-end, they select suppliers and partners, and determine the order frequency and quantity overall, and sign contract to have continuous supply. In the integration layer, they prepare their resource capacity and determine their production scale. In the short term, business owners need to adjust operations based on unpredictable situations. In practice, business owner introduces a conditioning phase. The conditioning processes in IBM PC Division are explained in [3] and can serve as a good example. When an imbalance between demand and supply of components and products is detected, proactive actions can be taken to correct the situation [4]. The basic supply chain structure with conditioning process is shown in Figure 1. There are three decision points in this figure representing different types of conditioning.

- Supply conditioning: When the committed supply cannot meet the demand, it is possible that we can chase additional suppliers or adjust supply among different supply chain components among geographies.
- Demand conditioning: Through price change and promotion, we can provide incentives to customer to choose product alternatives.
- Offering conditioning: When there are some excessive parts, we can create and offer new configuration models to consume these parts.

We refer to assembled products as Machine Type Models (MTM). Components procured from suppliers are assembled to form major building blocks, which can be further assembled to make the MTM. Customer order creates demand on the MTMs and is backlogged into the order system (a pull model). The incoming part supply replenishes the inventory and makes parts being available for assembling (a push model). The demand-supply imbalance would be measured by the following expression:

$$\left| \sum_i p_i - \sum_j c_{i,j} m_j \right|$$

where m is the vector representing demand amount for each MTM, p the vector of available parts for major building blocks, and c the BOM (bill of material) matrix – how a MTM is built-up from multiple parts.

When the component supply is constrained, we have the option of choosing the allocations of

components to different MTMs using different policies, such as priority, proportional allocation and optimizing allocations to maximize the profit. Which rule is used might effect the long term instability and the overall profit measure.

3. DSO System Dynamics Model

System dynamics modeling can be used to study the dynamics of operation and understand the causality relationship and feedback loops in the system. Since business is exposed to uncertain world, demand from customers, replenishment from suppliers and competition from competitors, all influence the business profit. A simulation model would be very useful to simulate such uncertainty and evaluate efficiency of the operation. Identified positive/negative feedback loops in the operation provide us to effective control mechanism to reduce dynamics. Its simulation can be used evaluate its efficiency and stability of the mechanism. In fact planning and scheduling for certain activities is related to how to handle dynamics of a business.

We present a System Dynamics model to capture supply and demand conditioning process and demonstrate inventory evolution under conditioning. Such a model can be exported and its parameters can be exposed to configuration tool. Then the user can do some experiments and simulate the effect under different circumstances. Also the model can be used to find out optimal solution for chosen objective, like minimizing cost for certain periods; maximizing revenue for other periods or minimizing backlog in certain periods, whenever the goal fits enterprise strategic direction. System dynamics model representing conditioning process is shown in Figure 2. It is marked in 5 parts for easy description. Below we explain two parts. More detailed explanation can be found in [5].

Part 1 is for part inventory processing. Replenishing from supplier would increase the inventory level and usage from assembling line would decrease its level. The initial inventory is indicated by the net position. Note that the replenishment rate is affected by both the committed supply through contract and additional supply due to supply conditioning action. Supply 0 aggregated part cost and additional amount of supply contribute to the formulation of profit rate (in Part 3). Another contributor to profit is the part inventory holding cost. When a different supplier profile context is put into the model, the total cost associated with the supplier would be evaluated and compared.

Part 3 is used to evaluate the performance of processing. It aggregates profit due to sell product, labor cost for assembling product, holding cost for finished product, the penalty for not meeting demand, the holding cost for part inventory, and cost for ordering additional supply

$$\begin{aligned}
 \text{ProfitRate} = & w_1 * \text{MtmPrice} * \text{FulfilmentRate} \\
 & - w_2 * \text{LaborCostPerDay} * \text{AssemblingRate} \\
 & - w_3 * \text{UnitProductHoldingCostPerDay} * \text{Max}(\text{SDGap}, 0) \\
 & - w_4 * \text{PenaltyForBacklogPerDay} * \text{Max}(-\text{SDGap}, 0) \\
 & - w_5 * \text{UnitPartHoldingCostPerDay} * \text{PartInventory} \\
 & - w_6 * \text{UnitPartCost} * \text{AdditionalSupply} .
 \end{aligned}$$

An assumptive profile is obtained through the integration along the timeline. w_i 's denote weights that we choose for the profit rate. In fact, the profit rate here does not map to real profit. What we formulate is an objective function by combining multi-objectives. By changing weight among the contributors of profit formula, we virtually switch among different objectives to fit current enterprise strategy. The defined objective could achieve maximum value at specific points of adjustable space. In other words, the output of optimization runs would give us choice of value to use and appreciate actions to take to achieve best performance align with strategic direction.

We describe a scenario in which the SD model is used to determine what action should be taken to reduce imbalance between supply and demand. First, we use customer order historical data to forecast future demand for certain time horizon (say 13 weeks). Second, the model is configured and has regular parameters is set. Since we focus on reducing imbalance, we choose w_3, w_4 and w_5 being nonzero and other weight to be zero. Third, the model runs as it is using the forecast demand data. When the imbalance situation is detected, we set price change range to be in 20% of the original price and additional supply limit up to 500. Finally, the optimization run gives "to be" situation. For instance, it suggests raising 12% price on Mtm1 and reducing 3% price on MTM2, and/or ordering additional 250 800Mhz CPU chips, and/or substituting 400G hard disk by 300G for MTM3.

The second step is to determine which suppliers to use to get additional 250 800Mhz CPU chips and outsource assembling machine task to which provider. We choose w_1, w_2 and w_6 being nonzero to evaluate revenue and cost. The run will be carried out for each supplier and service provider. By comparing among these profit numbers, we obtain the best portfolio of

suppliers and providers for this short term supply conditioning.

6. Future Work and Concluding Remark

In this paper, we have presented an approach for identifying business services by exploiting the information of dynamic business behavior obtained through System Dynamic Modeling. By doing so, we have gained the advantage of devising business services in a more accurate sense by considering not only the services interface but also expected business dynamics for desired business services. System Dynamics provides a useful design tool to help business analysts to identify service boundaries and their dynamic relationships. Through our experience, we conclude that the enrichment of current service-oriented methodologies with dynamic modeling ingredients, e.g. System Dynamics, is a powerful approach to identifying business services and developing a service-oriented architecture. We will continue to extend and apply this methodology to other areas by focusing on building tools for enabling business analysts and service developers to develop SOA using dynamic service-oriented modeling and analysis methodology.

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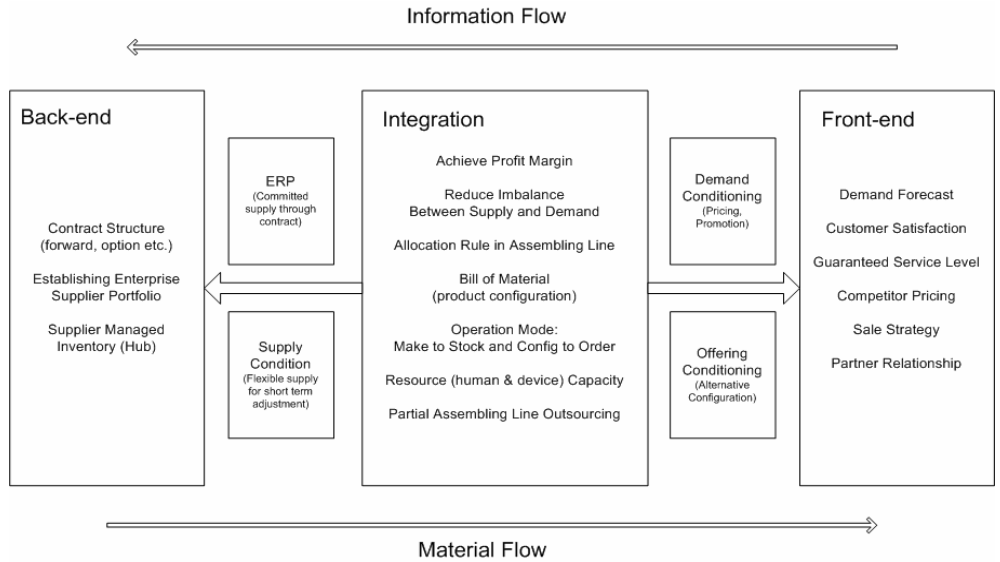


Figure 1: Supply Chain Conditioning Process

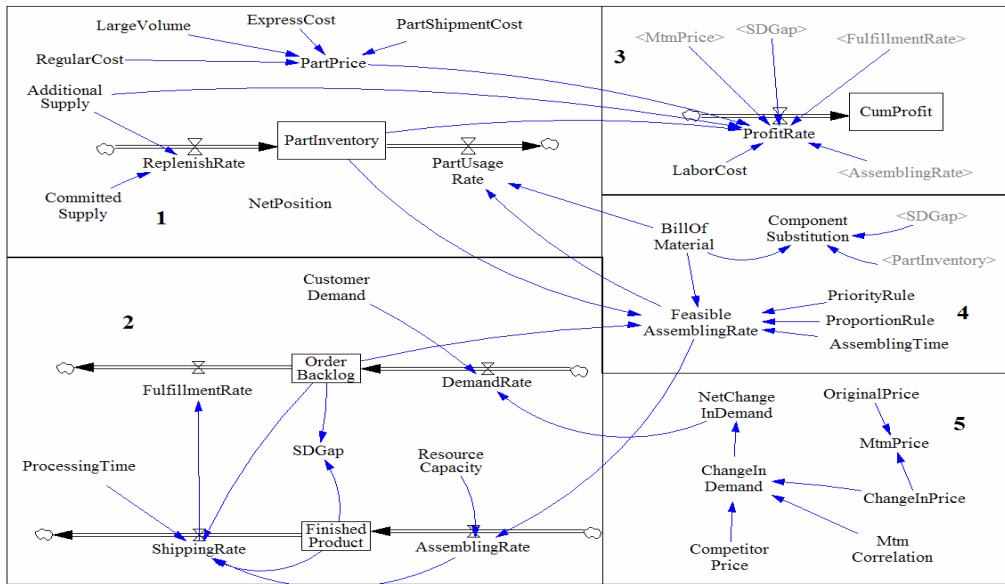


Figure 2: System Dynamics Model of Conditioning Process