Detecting Structural Changes in the Supply Chain and Extensions to the Service Enterprise

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Abstract

The new forces of globalization, the World Wide Web, the appearance of new methodologies/tools to integrate engineering and business functions, the development of electronic commerce and their complex interrelationships are shaping the competitive landscape of business. This paper introduces the modeling and optimization of the supply chain but taking into consideration the dynamic nature of it. The modeling considers how to take advantage of the changes in structure during the evolution of a supply chain and means to detect the shifting of constraints. Two scenarios are discussed to outline the ideas.

Keywords: supply chain management, system dynamics, causal loops, stocks, flows, pattern recognition, s-curves.

1. Introduction

Supply chain management has been evolving from other paradigms such as material resources planning (MRP), just-in time (JIT), and the enterprise resource planning (ERP) systems that boomed during the last decade. In addition, the new advances in computer technology, Internet and the development of new optimization methodologies have made it possible to fulfill some of the promises.

New computer systems and application software enabled the development of MRP in the early 1970s [2]. "MRP brought a strategic breakthrough in business performance and became the standard process for manufacturing in the early 1980s." This dramatically changed the competitive landscape. On the other hand, Japanese electronics and automotive companies introduced a new process change in the late 1970s denominated as JIT. JIT was not a continuous change from MRP but a disruptive one. The performance characteristics of the dual nature of JIT (i.e., philosophy and processes) shortened manufacturing cycle times, increased quality, reduced inventory, lowered manufacturing costs, and cultivated an environment of continuous improvement and closed relationships with suppliers. The Toyota production system is one of the classical examples of this transformation and success. Again, the competitive balance shifted in many industries. As stated by Womack et al. [7] "the auto industries of North America and Europe were relying on techniques little changed from Henry Ford's mass-production system and that these techniques were simply not competitive with a new set of ideas pioneered by the Japanese companies, methods for which we did not even have a name."

The implementation of client-server architecture into the old MRP model gave birth to Enterprise Resource Planning (ERP) systems. Significant investments in ERP systems occurred during the 1990s (actually, these investments still continue today). However, ERP did not necessarily create a significant performance improvement. ERP was not a new disruption; rather, it was a continuing phase of MRP. Indeed, ERP helped to solve some of the integration problems that remained unsolved by MRP. The vision developed by ERP was one beyond a manufacturing division. In nutshell, ERP brought information of companies of companies to the corporate office. This integration powered

the enterprise to manage the nexus of suppliers, resources, capabilities and customers. This new opportunity is the fundamental new concept denominated as an integrated supply-chain (ISC). ISC opens new opportunities to increase business performance by lowering inventory, reducing cash-to-cash cycle times, abbreviating manufacturing cycle times, and increasing operational agility. Internet-based technology, advanced software architectures, optimization technologies, knowledge management and reference models have given rise to a new process-improvement curve: integrated supply-chain [1,3].

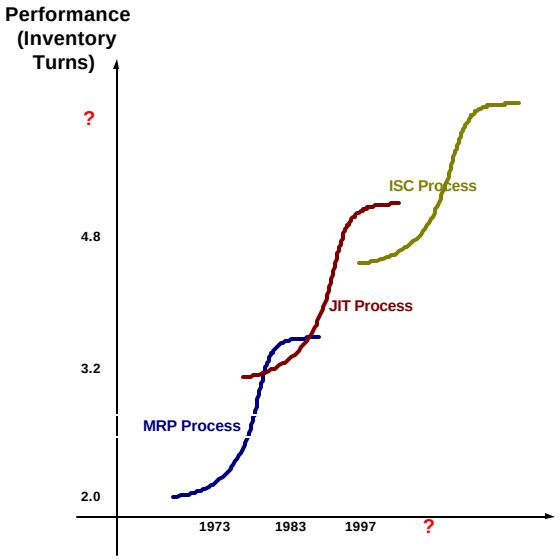

Figure 1. S curves for MRP, JIT, and ISC (Modified from [2]. However, we disagree with the concept of [2] with respect to the initial time of ISC. According to [2] ISC started to rise in late 1990's. We think that ISC has not started to rise in late 1990's, maybe in early 2000's)

"The traditional supplier/customer relationship emphasizes products and product support, whereas an integrated supply relationship is focused on the processes associated with the reduction of the total cost of the supply-chain, including, but not limited to, procurement, inventory management and product deployment. A totally integrated supply-chain enables an end-user to more effectively and cost-efficiently manage inventory and transaction costs. In a true integrated supply relationship, the customer and the integrated supply partner analyze every aspect of the supply-chain process (acquisition, storage, inventory management, shipping, transportation, post-shipment support, information systems, etc.) and then streamline each component, eliminating redundancy of effort and cost, and improving service levels." [9]

2. System Dynamics

"System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems. In fact it has been used to address practically every sort of feedback system. While the word system has been applied to all sorts of situations, feedback is the differentiating descriptor here. Feedback refers to the situation of X affecting Y and Y in turn affecting X perhaps through a chain of causes and effects. One cannot study the link between X and Y and, independently, the link between Y and X and predict how the system will behave. Only the study of the whole system as a feedback system will lead to correct results." [10]
The agents in a system interact through feedback loops, "where a change in one variable affects other variables over time, which in turn affects the original variable, and so on." In short, the whole System gets affected. System dynamics asserts that these causal relationships form a complex underlying structure for any system. This structure may be empirically or theoretically discovered which may be further analyzed.

The creation of a formal dynamic model of a system requires the identification of the causal relationships that form the system's feedback loops. Generally, feedback loops are thought to be either negative or positive. A negative feedback loop is a series of causal relationships that tend to move behavior towards a goal. In contrast, a positive

feedback loop is self-reinforcing [6]. Causal loop diagrams are important tools for representing the feedback structure of the systems. A causal loop diagram consists of variables connected by arrows denoting the causal influence among the variables.

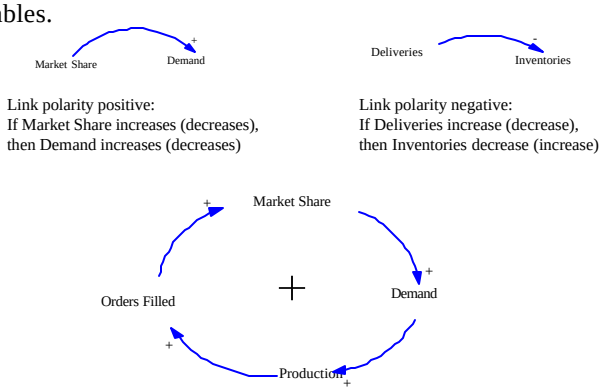

Figure2. Causal Loop Diagrams

Causal loop diagrams are able to represent interdependencies among the elements of the system and representing their feedback processes. They are used at the start of a modeling project to capture mental models. Now, that we have elicited and captured the mental models, we can start developing a stock and flow structure of the system.

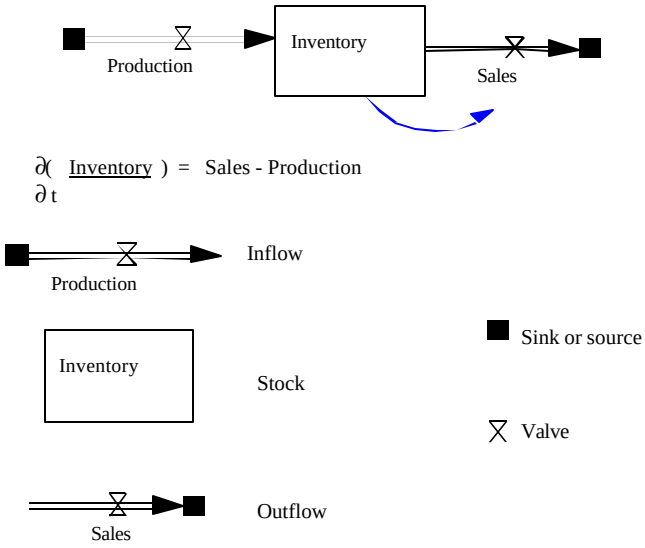

Figure 3. Stocks and flows concepts.

Stocks are accumulations of information. They characterize the state of the system and generate the information upon which decisions and actions are based. Stocks create delays by accumulating the difference between the inflow and outflow of a process. Flows (outflows, inflows) are rates, which are added or subtracted from a stock. This graphical description of the system based on stocks and flows can be mapped into a mathematical description.

3. First Scenario

There are several types of loans that a mortgage industry can provide to the customer according to the needs of the customers. Various factors like change in condition of market, supply chain interruption and change in operational process can immensely affect the loan execution process.

The process starts with providing the loan program, which will be the best fit to the customer according to his/her needs and available resources. After this the loan application form is completed immaculately. After the customer completes the application the lender company start looking forward to the documentation that validates the credit

and property information. Later on, the finals steps will be to analyze and approval of the case and the loan closing step. In a nutshell, the mortgage industry can be described in three phases: Origination, Process and Closing phase. In all the phases the supply chain interacts and impacts the processing time to complete the loan process. The major players as a supplier are considered as: Appraisers, Lawyers, Engineers, Title Companies, Credit Reporting Agencies, Private Mortgage Insurance Companies and Hazard Insurance Companies. They interact in all the three phases.

Let's analyze the interaction between lender and supplier. In the Origination phase, after completing the loan application, the lender starts identifying what kind and who will be the supplier to the required documents in that phase. The suppliers are: appraisers, lawyer and engineers. The lender assigns duties to the suppliers according to the property location. The documents are presented by the supplier in the Process Phase.

Some of the situation that delay the Process Phase are: (1) suppliers lead time, (2) lenders lead time, (3) volume assigned to suppliers, (4) unnecessary documents required to the customer (depending on the evaluation), (5) not well pre-evaluation process and (6) reduction in interest (increment in volume). There are continuously processes in receiving new application, for that reason any delay can create an increment inventory waiting to release to the customer.

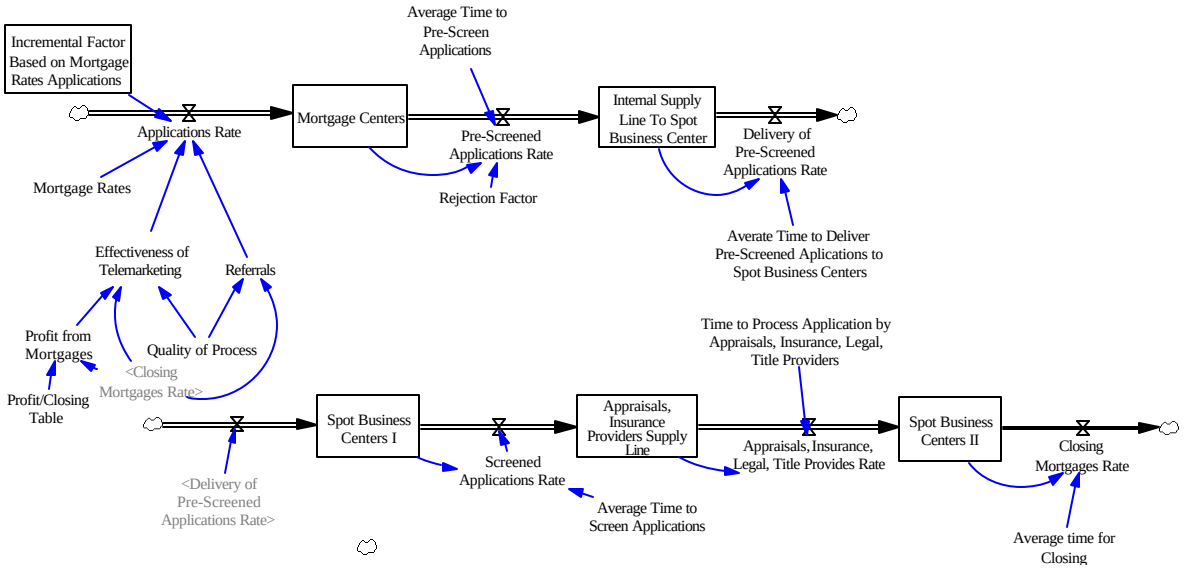

Figure 4. Simple model to illustrate the opportunities (using Vensim from Ventana Systems).

In practical conditions, we can imagine that there will be disruptions in the market or some other external factors can and will influence the market with which this company is dealing with. In our framework, we use pattern recognition schemes based on neural networks and support vector machines to study the external and internal changes in the company. This also can include hybrid techniques by studying the deviations of a well-calibrated model with reality. Before the changes in structure, the model of the system was providing certain level of accuracy. Using extended Kalman filtering techniques it is possible to review the unobservable variables and see how they behave relative to what actually happens. Neural networks, then, can interpret these results and identify the need for changes. The detection of structural changes are then matched to appropriate configurations of the supply chain.

In Figure 5, we can appreciate that after a stable period of time (when the current policies maintain a relative low inventory level and the customers are serviced well, the inventories suddenly go low up to a level that even demand can not be met (for a certain period of time). This was due to sudden and sporadic change in demand of the product by the market.

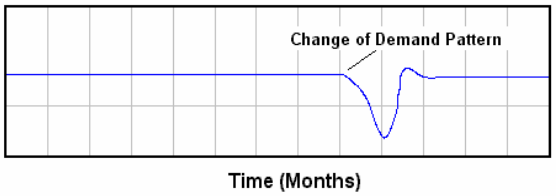

Figure 5. The system as it is. There is a disturbance (a change in demand pattern).

However, using the pattern recognition approach these changes can be detected at an early stage. The matched policy is one of installation of extranet (providing the access to the different ERP systems of the retailers, suppliers and logistics providers) and implementing Customer Relationship management policies. This provides a new capability to match the current market scenario as demonstrated in Figure 6.

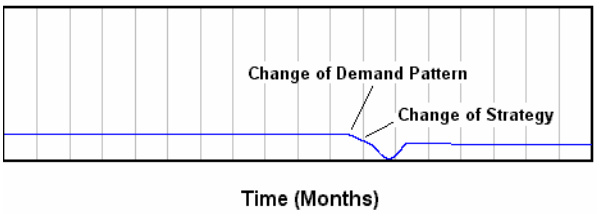

Figure 6. The change in demand pattern is detected and the supply chain management strategy by increasing visibility and implementing a CRM scheme.

4. Second Scenario

Let us analyze one of the problems faced by short-life cycle products. This company specializes in manufacturing garments. The company is based in USA and has a dealer network of distribution for its consumer products. The company has only been responding to the consumer market since its inception. But, due to the recent gulf war, the company was given a large order from military for producing military uniforms. This order has to be responded immediately due its national priority. This sudden change manifests as lead-time for the company due to different planning, scheduling and manufacturing technology required in producing it. Due to this, the inventory of the company starts oscillating periodically. The inventory control method used here is very conventional. The evolved procedure is to check the inventory periodically, comprehend the gap in inventory level and order the amount required to fill that gap (information of sales is used too). The dynamic model shown in Figure 7 illustrates this example.

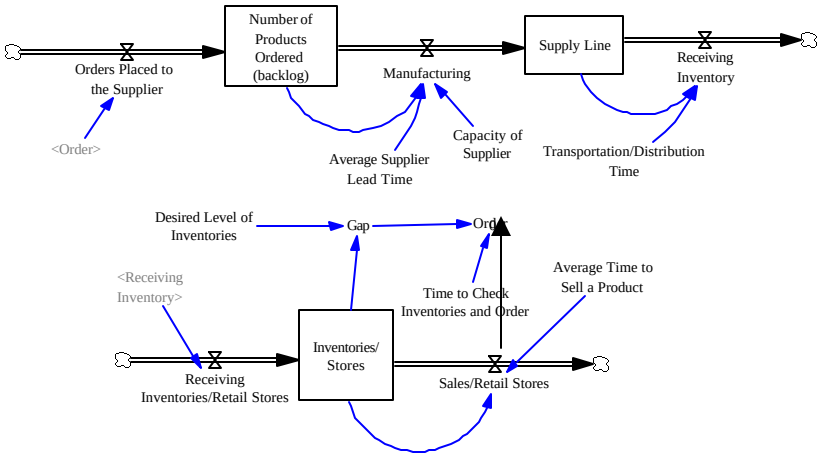

Figure 7. Simple model to illustrate the opportunities

In Figure 8, we can appreciate that after a stable period of time (when the current policies maintain a relative low inventory level and the customers are serviced well, the inventories suddenly go low up to a level that even demand

can not be met (for a certain period of time). This was due to sudden and sporadic change in demand of the product by the market.

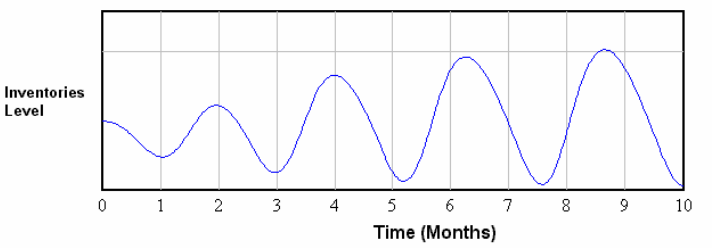

Figure 8. Utilizing the same model of Figure 7. Some supply chain policies might lead to oscillatory and unstable behavior.

$$X = \begin{bmatrix} \text{No. of Product Ordered} \\ \text{Supply line} \\ \text{Inventory/Retail Store} \end{bmatrix}$$

$$\dot{X} = AX + B$$

Time (months)	Eigenvalues
T = 0.03	.9689 + 0.0661i .9689 - 0.0661i 0.8388
T = 1	1.0256 + 0.1426i 1.0256 – 0.1426i 0.7614
T = 2	0.9688 0.8750 0.9687
T = 5	1.0256 +0.1426i 1.0256 – 0.1426i 0.7614

Figure 9. State Vector and Evolution of Eigenvalues.

5. Conclusions

There are possibilities to enhance the current state of the art of the integrated supply chain paradigm. We are still in the stage of "fermentation" and a dominant design is not in the horizon. We will report in future papers some of our on-going work.

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