Role of JIT Principles in a Dyadic Supply Relationship- A System Dynamics Simulation Analysis

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In today's changing business environment, supply chain management is a significant source of gaining competitive advantage. Competitive advantage can be obtained by virtue of competing on price, quality, and time to deliver, which can be attained by exploring and elimination of the sources of waste in different stages of the production process. This paper focuses on studying the impact of implementing Just in Time (JIT) technique in a dyadic supply relationship on inventory, cost, and profits. System Dynamics approach of modeling and simulation consisting of a supplier and manufacturer is developed and simulated for the study of multiple scenarios. A comparative analysis is made to study the impact of JIT on inventory, cost and profit. The simulation results indicate that JIT deliveries would enhance the operational efficiency of the firm and helps the firm to gain a competitive edge. Based on the findings, implications have been drawn for effective implementation of JIT.

Field of Research: Management, Supply chain, Just In Time, System Dynamics.

1. Introduction

The increase in competition due to globalization has compelled firms to explore all possible alternatives to reduce their costs without compromising on customer satisfaction. As a consequence, firms are focusing more on cost cutting strategies and have shifted their attention towards Lean Manufacturing, and in particular, just-in-time (JIT) practices that are used to reduce and eliminate waste and inefficiency from the system. Schorr (1998), highlighted that firms today compete against each other with their entire supply chain and not individually. Supply Chain Management (SCM) encompasses all the activities used to efficiently integrate suppliers, manufacturers, warehouses, transporters, retailers, and customers. The objective of SCM is to deliver the right product in the right quantities to the right locations at the right time with minimum cost. Lean manufacturing and JIT play an important role in better functioning of SCM.

JIT is a problem solving technique. It was first conceptualized and implemented by the Japanese manufacturing industries in the 1970's, and Toyota motor company was the first to adopt it. With JIT, supplies and components are delivered to the manufacturing line as and when they are needed and this helps in minimizing the waste. The objective of this strategy is to reduce cost, eliminate waste, and use all employees as efficiently as possible. Inventory and time are not exceeded in a JIT system so any costs related with unnecessary inventory are eliminated (Heizer and Render, 1996). Researchers have labeled JIT as a philosophy with

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the following objectives: making quality better and providing on time production, and shipment of products.

A lot of research has been carried out to study the advantages of JIT along the assembly line of a plant and supply chain in general. But no work is focused on eliciting the advantages of JIT in a supplier-manufacturer material movement.

Thus the current study explores role of JIT principles in eliminating waste in a dyadic supply relationship (A dyadic supply relationship is the relationship that exists between a supplier and a manufacturer in a supply chain (Shin et al., 2000)) and study its impact on inventory, cost and profit.

The paper is organized as follows: The first section begins with the introduction to the area of work, a brief introduction about supply chain and JIT is discussed. The second section deals with the literature review where past work related to the research topic is reviewed and conclusions are drawn. The third section deals with the methodology adopted to carry out this research and subsequently a model of a dyadic supply relationship is developed. The fourth section deals with the simulation results and interpretation of the same. The fifth section deals with the conclusions drawn from the research and the future scope of work.

2. Literature Review

The history and development of JIT: JIT is a manufacturing philosophy, which was first developed by the Japanese in the early 1970’s. The Toyota manufacturing plant was the first to adopt the technique, under the leadership of Taiichi Ohno. Toyota realized that JIT would be successful only if all of the individuals within the plant were committed to accept the philosophy. The method was such a success that Taiichi Ohno was named father of JIT. The automotive industry is one of the largest that have been adopting the just in time method (Aghazadeh, 2004).

Supply chain Management: A supply chain encompasses all activities associated with moving goods from raw material stage to end user. A supply chain consists of a variety of firms ranging from raw material suppliers to wholesalers and retailers. It also includes all types of organizations engaged in transportation, warehousing and materials handling. The essence of SCM philosophy is that waste reduction and enhanced supply chain performance come only when there is interfirm and intrafirm functional integration, sharing and cooperation (Brewer & Speh, 2000).

According to the ‘Cycle view’ of a supply chain, a supply chain network consists of a series of cycles each performed at the boundary between two successive stages. Each cycle is separated from other cycles by an inventory, such that each cycle can function independently, enhancing its own processes and is not hindered by problems in other cycles (Chopra, 2001). A good example for this approach would be a system consisting of a retailer and a processor. Here the retailer’s inventory is replenished by processor and the processor’s inventory is replenished by production output. In a cycle view, processes, roles and responsibilities at every stage is clearly defined.
Krisztina Demeter et al. (2011) studied how companies could improve their inventory turnover performance through the use of lean practices. They found a significant relationship between lean practices and inventory turnover.

Upton (1998) has defined JIT as a managerial function or an operational philosophy whereas Narasimhan et al. (2006); Flynn et al. (1995) define JIT as techniques and practices that are used to implement and support lean philosophy.

The characteristics of JIT are outlined as set-up time reduction, supplying components in small quantities, adhering to the daily supply schedules, use of kanban cards etc. (Mackelprang & Nair, 2010; Motwani, 2003).

Researchers began to highlight the importance of JIT in purchasing and inbound logistics once they started realizing the benefits of JIT in production process (Mistry, 2005; Kaynak, 2002). It is also pointed out that Vendor-kanban for raw materials and pull systems for logistics can be used to obtain JIT deliveries from supplier (Sakakibara et al. 1993; Koh et al. 2007; Lamming, 1993).

Further, it has been observed that under pull production system, the components are manufactured and shipped as per the demand and this can be accomplished by using kanban cards (Monden, 1981).

The process of collecting small lots of ready to use components from suppliers located in a particular area at regular intervals of time as per the daily supply schedule and delivering it to the place of demand is called JIT delivery (Jones et al., 1997).

The JIT production system' is defined by Sakakibara et al. (1997, p. 1247), as manufacturing “only the necessary products, at the necessary time, in the necessary quantity”.

Hence from the above literature, it can be concluded that, in a dyadic supply chain where the inventories are continuously replenished by many suppliers, the quality of the product, timing of replenishment and the cost are of utmost importance to maintain competitive position in the market. These competitive priorities can be achieved by studying the supply chain activities and eliminating the sources of waste and Non-Value Adding activities. Therefore the problem statement of this research is to identify the sources of waste in a dyadic supply relationship and study the impact of its elimination on inventory, cost and profit. Lean manufacturing and JIT play an important role in better functioning of SCM. Some of the lean manufacturing principles are: JIT inventory principle and JIT production principle. The present research involves the role of JIT principles in a dyadic supply relationship.

Although, the advantages of JIT were observed in internal operations such as reduction in inventory turnover and it was proposed that JIT could be applied in purchase and inbound logistics, no study is focused to empirically test the advantage of JIT in a dyadic supply relationship.
Hence the objective of this paper is to design a model of dyadic supply chain for a manufacturing system using a System Dynamics simulation modeling approach and to study the influence of JIT technique on inventory, cost and profit.

3. Research Methodology

3.1 System Dynamics

System Dynamics approach of modeling and simulation as proposed by Forrester (1994), is employed in the current research. The research steps in the proposed methodology as highlighted by Sushil (1993) include: Problem identification, System Conceptualization, Model formulation, Simulation & validation, and Policy analysis & improvement. Vensim®, the simulation software which is used in this research is developed by Ventana Systems, Inc. (Harvard, Massachusetts), and it is widely used software for SD modeling & simulation. Its purpose is to help companies to find an optimal solution for various situations that need analysis and where it is necessary to find out all possible results of future implementation or decision. Vensim® is able to simulate dynamic behavior of systems that are impossible to analyze without appropriate simulation software, as they are unpredictable due to many influences, feedback etc. It helps with causality loops identification and finding the leverage points. While originally being designed for the analysis of industrial enterprises, nowadays system dynamics is applied to a variety of systems that change over time, in particular to socio-economic systems (Sterman, 2000). With reference to previous literatures a Causal Loop Diagram (CLD) is developed. A CLD is a schematic representation of the effect of the various independent variables on the dependent variable of the system.

The model is developed in five phases: problem articulation, formulating a dynamic hypothesis, formulating a simulation model, testing, and policy design and evaluation which is as shown in Figure 1.

Figure 1: Overview of a system dynamics modeling process (Source: Sterman, 2000)
Phase 1: Problem Articulation (Boundary Selection)
The model must be developed keeping in mind the problem statement and only those parameters that influence the system. Hence the entire complexity of the system need not be considered. This can be explained with the analogy of a map. The purpose of the map is to solve the problem of a location by providing the necessary information to commute between two points. If the map is developed without considering the core purpose and includes all intricacies of the region, it may shift the focus to complexity thus reducing its utility. Therefore, it is desired to have a specific goal while developing the model so that a specific problem is solved instead of attempting to imitate the entire structure in detail. Hence the model boundary and scope can be fixed.

Phase 2: Formulating a Dynamic Hypothesis
The researcher’s knowledge, available literature and the opinions of experts of the associated industry forms the basis for the development of the hypothesis. In the process of formulating hypothesis, the various opinions that arise must be captured. Only endogenous variables (i.e. the variables that have direct impact on the working of the model) are considered while developing the model and exogenous variables (i.e. external factors which are uncontrollable) are either considered partially or completely excluded. Parameters that are not interconnected to the problem are omitted as they just add to the density of the model without offering any extra benefits. While formulating the hypothesis, different SD tools such as causal loop diagrams, stock and flow diagrams are used. The various parameters influencing the supply chain are identified and their causal relationships are analyzed using causal loop diagram as shown in the model development phase.

Phase 3: Formulating a Simulation Model
Formulated dynamic proposition (by considering all the opinions that had surfaced while formulating), a simulation model is developed to capture the interrelationships between the dynamic systems. The various ideas developed in phase 2 will be represented in the form of equations in this phase. This phase systematizes the conceptual model so that it can be simulated for a given number of conditions. This is achieved through repeated processes until the desired outcome is achieved which matches the real world situations. Based on the observations the model is continuously refined until an acceptable model is obtained. Finally, the identified variables are interrelated using mathematical relationships.

Phase 4: Testing
Testing of the model occurs throughout the modeling process; however an extreme conditions test must be conducted once the final version of the model is available. These tests may include testing of the model under hypothetical conditions the likelihood of which is rare in real life known as ‘extreme conditions’, but these tests have to prove that the model responds to such situations realistically. Scenarios such as complete production stoppage due to machine breakdown, shortage of raw materials, and an abrupt increase in orders and so on are examples of extreme conditions. The model should also tested for verifying the mathematical formulae and units of the variables. Finally the variables must represent the real world.

Phase 5: Policy Design and Evaluation
A dyadic supply chain is conceptualized by referring to past literatures during the formulation stage and tested continuously during the testing phase in order develop a robust model, with a
proper structure and representation of the real world. Hypothetical values resembling the actual scenario form the basis for simulation. This enables the model to be self-learning. Existing data are keyed, in accordance with the existing policies and practices. The output generated by the model indicates normal running situation of the company. Then, to attain the desired state by implementing new policies and decisions, the relevant data are induced and the model is simulated again. Better results denote improvement, and worse results indicate a need for another attempt. In this phase, the model will be ready to produce results under multiple scenarios.

3.1.1 Model Validation

The process of ensuring that the developed model is accurate for the specific purpose is called Validation (Stewart, 1997). No model can be 100% accurate because a model is a replica of the complex system. It is developed to understand the complex system which is otherwise difficult to analyze (Pidd, 1992). The major problem simulation analysts are facing over the years is to determine if the developed model is the true representation of the system being studied, for the stated objectives. Hence a wide variety of tests have been developed to reveal the flaws in model and improve its performance.

Modeling and analysis to gain a better understanding of the system complexity and to predict system performance are critical in the system design stage, and often valuable for system management (Biswa et.al, 2004). Simulation modeling can provide valuable insights into the operational characteristics of SC. Variability and uncertainty are endemic in all systems, and certainly so in SC (Chatfield et.al, 2006). By accounting for uncertainty while modeling SC, an insight into the impact of these factors can be gained. Thus, simulation modeling provides an important tool for understanding SC behavior under changing conditions and can give the information necessary to make informed decisions regarding SC design and management.

The advantages of JIT in internal production process are well documented as inferred from the literature review. To assess if JIT provides the same benefit in inbound logistics, a supplier-manufacturer supply relationship can be modeled and simulated. A comparative evaluation of results before and after implementing JIT is to be made. Hence SD proves to be an effective tool for the purpose.

3.2 Model Development

3.2.1 Assumptions in Model Development:

The following assumptions are made while developing the model:

- A supplier supplies raw materials and semi-finished goods (indicated as components in the current research--‘components’ are the semi-finished products received from supplier which are used by the manufacturer in the manufacturing process) to the manufacturer which the manufacturer uses in the production of final product.
- The logistics cost (i.e. cost of moving the components from supplier to manufacturer) is absorbed by the manufacturer.
The model is simulated taking hypothetical values for the parameters.
Prior to implementation of JIT, the supplies from supplier are received as and when components are ready for shipment irrespective of demand at the manufacturer’s plant. But after implementation of JIT, the supplies are received in lots only when there is a demand for the components at the manufacturer’s plant. This reduces the number of trips which has an effect on logistics cost.

The objective of this paper is to study the impact of JIT implementation on inventory, cost and profit of the firm. The first step taken in this regard is to develop a CLD which can be later converted into a stock and flow diagram to arrive at the simulation results.

To begin with, a dyadic supply relationship was conceptualized by referring to various literatures on supply chain management. Only those factors that affect a supplier-manufacturer relationship were considered and a CLD was established. Since in a dyadic supply chain, the supply of raw materials and sub-assemblies occurs from a supplier to a manufacturer, the model is divided into two parts viz.

1. A manufacturer’s model
2. A supplier’s model.

3.2.2 Manufacturer’s Model

Initially, a model of entire manufacturing process is developed. The manufacturer’s model can be broadly divided into two categories namely the costs of production and the production process. The total cost of production includes the finished product inventory holding cost until shipment, the holding cost of raw materials and semi-finished components, the production cost, the component acquisition cost and the inbound logistics cost. The revenue generated by the manufacturer is a function of selling price of the end product and the demand for the products.

The production process consists of the production line which receives the components from the store, processes it and delivers the final product. The stock of inventory along the production line is termed as work in process inventory or ‘WIP’. While developing the production process, the following parameters are considered- demand for the products, price, inventory of products and raw materials and the safety stock to be maintained. The production is assumed to start according to the desired production start rate or as per the availability of resources, whichever is minimum.
3.2.3 Supplier’s Model

A supplier’s model is developed based on the assumption that the supplier supplies a semi-finished component to the manufacturer which the manufacturer uses in the production process. The supplier’s system is again divided into two subsystems viz.

1. Supplier's cost and revenue.
2. Supplier's manufacturing process.

The major components of cost for a supplier are the manufacturing cost, the component inventory holding cost until shipment and the scrap & rework cost of rejected components. The suppliers production process is assumed to consist of a variety of machinery required to manufacture the given component. The supplier would start the operation based on the order for components from the manufacturer. Among the total units manufactured, the units complying with quality standards are accepted and shipped to the manufacturer and the rejected components are later reworked. Among the reworked components, the one’s that adhere to quality standards are shipped and the rest are scrapped. Reworking and scrapping of units incur additional costs to the business and hence they must be controlled.
These CLD’s are then converted into stock and flow diagram and appropriate mathematical formulas are applied to arrive at the simulation results.
(b) Total cost of production

M's product inventory holding cost rate
M's product inventory holding cost
M's component inventory holding cost rate
M's component inventory holding cost

<price of products>
<inventory of products>

price of products
M's revenue
M's cumulative profits
M's reinvestment in M

M's cumulative investment on supplier
M's costs

<price of products>
<inventory of products>

<Price of components>
<M's component inventory>

Price of components

component acquisition cost

M's production cost per unit
M's production cost

trips per month
cost per trip

logistics cost

logistics cost
cost per trip
trips per month

M's production rate

production cost per unit
M's production cost

M's component delivery cost
M's component acquisition cost

M's cumulative profits
M's reinvestment in supplier

M's cumulative investment for M
Figure 5: Stock and Flow Diagram of Supplier’s Model
(a) Costs and revenues

(b) Production process
4. Results and Discussions

The model was simulated to examine how the system would behave for a time span of 24 months. Initially, the model is simulated normally i.e. all the shipments from suppliers are received at the manufacturers warehouse and then as per the production order they are issued to the production process. In the second scenario, JIT is implemented (i.e. the suppliers shipment rate is equal to the manufacturers production start rate) at the supplier’s end and the shipments are received by the manufacturer as and when components are required for production. This eliminates component inventory and the associated costs of holding the inventory by the manufacturer. The effect of JIT implementation on inventory, cost of production and profit of the firm is depicted in the figures below.

4.1 Effect on Inventory

As seen from the simulation graphs, the inventory of products after JIT implementation has reduced considerably. This is because the supplies from supplier and the shipments of the manufacturer are streamlined with the demand for the products resulting in minimal inventory.

![Figure 6: Inventory of products](image)

4.2 Effect on Cost

The reduction of inventory due to JIT impacts the costs as well. As seen from the simulation graphs, the total production cost after JIT implementation is always at the minimum level. This is due to the fact that when JIT is implemented components are received from the supplier as and when they are required eliminating the component inventory holding cost.
4.3 Effect on Profit

The reduction in the cost due to JIT implementation has stabilized the profits. The profit which shot up initially due to the sales revenue reduced gradually due to the large inventory holding cost of components received from the supplier. After implementing JIT, the components are received from the supplier directly to the production, thereby eliminating the inventory. This reduced the total cost and thereby stabilized the profit.

4.4 Effect of Delays in Supplier Shipment on the Production Rate

So far the model was simulated under ideal conditions i.e. the components would be shipped as per the JIT shipment schedules. But in actual practice, due to operational constraints it would be difficult to strictly adhere to JIT shipment schedules and there may be delays in shipments. Hence as a special case, the model is simulated considering a delay in supplier shipment and its impact on the operations of the manufacturer is discussed.
As observed in the above figures, a delay in receiving components from the supplier will have a negative impact on the manufacturer's operations. As seen from the simulation graphs, the production rate has decreased considerably due to the non-receipt of components. This may eventually lead to total production stoppage resulting in loss to the organization.

It can be concluded from the above discussions that, JIT has a positive impact on the firm’s performance if implemented in the area of inbound logistics. It leads to the reduction of inventory of components and thereby decreases the overall production cost. Thus the impact of JIT in a dyadic supply relationship is established.

5. Conclusions and Future Scope

On the basis of above analysis, it can be concluded that implementing JIT at a supplier’s place has a positive impact on the overall operational performance of the firm in the long term which is reflected in the production cost and profit. A reduction in the inventory of inbound components was observed leading to reduction in costs and increase in profit. Hence the results support the observations that were made while implementing JIT along an assembly line.

From the simulation results, it is evident that the benefits of JIT are realized four to five months after implementation. Hence if a firm is considering long term benefits, JIT would be an appropriate technique to maintain competitive edge in the market. Hence, it can be summarized from the research that implementing JIT at a suppliers place proves beneficial to the firm.

The scope of this paper is restricted to study the effects of JIT implementation on inventory, cost and profit. The supply chain wastes that have been addressed using JIT in the current study are overproduction and waiting. The same model can be extended to study the effects of implementing six-sigma at a supplier's place to control the quality of incoming components and thereby study its impact on profits.
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