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Improving the Efficiency of Manufacturing Supply Chain Using System Dynamic Simulation

Narjes Sadeghiamirshahidi*, Jafar Afshar, Ali Reza Firouzi, Syed Ahmad Helmi Syed Hassan

Faculty of Mechanical Engineering, Department of Industrial Engineering, Universiti Teknologi Malaysia, 81300 UTM Johor Bahru, Johor, Malaysia

*Corresponding author: najes.sadeghiamirshahidi@gmail.com

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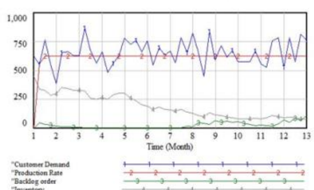
Graphical abstract



Abstract

Supply chain is a network of different business units which focuses on integration among all units in order to produce and distribute end products to the customer. Nowadays, due to increased uncertainty in customer demand, it is necessary to be sure that the supply chain networks operate as efficient as possible in order to satisfy the customer demand at the lowest cost. Enhancing the efficiency of the supply chain necessitates the interaction between different members of the supply chain which can be achieved through supply chain management. Hence, the development of modeling approach in order to understand and analyze the dynamic behavior of supply chains is brought into consideration. This paper proposes a system dynamic simulation model for manufacturing supply chain. System dynamic is used as suitable method to understand and analyze the interactions of various components via feedback structure. The objective of this paper is to simulate the manufacturing supply chain of an electronic manufacturing company in Malaysia. The simulation model is used to study the system's behavior (in terms of production rate, inventory levels, and backlog orders) under two different operational conditions (named as fixed and varied capacity policies) and compare their efficiency in terms of total cost. The analysis shows that the proposed operational condition, which is varied capacity policy, improves the system efficiency in terms of cost.

Keywords: Supply chain; system dynamic; production capacity; cost analysis

■1.0 INTRODUCTION

Supply chain is a complex system that consists of different independent business units in order to produce and distribute products or services to the customer [1]. Nowadays, due to high demand uncertainty, modeling and analysis of the dynamic behavior of manufacturing supply chain is critical. One of the most prominent issues in the area of manufacturing supply chain is decision making in capacity allocation. Since capacity has a cost, a company should forecast the demand and determine how to match the production rate with the customer demand. In other words, the company should make decision whether to produce based on fixed capacity and incur the inventory holding/order backlog costs, or follow the customer demand by changing capacity [2].

System dynamics methodology provides a comprehensive framework to investigate the dynamic behavior of supply chain as a complex system [3]. Therefore, system dynamic model can be used in order to gain more insights into the dynamic nature of supply chain [4]. This helps managers to understand the consequence of each decision making policy. System dynamic models have been widely applied to analyze the system's behavior in order to reduce the system's costs. Barlas and Aksogan worked on the development of inventory management policies [5]. They developed a system dynamics simulation model and proposed the inventory policies to increase the profit and reduce costs. Al-Refaie *et al.* used system dynamic method in an airline fuel system to reduce inventory cost while avoiding stock out while Jeong *et al.* evaluated the environmental cost of a reverse supply chain through using Activity-Based Costing concept and system dynamic model [6, 7]. Regarding to the importance of cost saving which is one of the important concerns of each decision maker, this paper focuses on improving the efficiency of manufacturing supply chain for an electronic manufacturer in terms of total cost through using system dynamic method.

■2.0 MATERIAL AND METHOD

This paper attempts to simulate manufacturing supply chain through using system dynamic modeling. A manufacturing company in Malaysia is selected as a case study. The supply chain networks consist of different Suppliers, one Manufacturer and one Distributor. It is assumed that the supply chain has no interaction with any company outside of the chain. Also it should be mentioned that the focus of this study is on the Manufacturer section. The Distributor collects all demands from all customers and sends order to the Manufacturer. The Manufacturer determines production quantity based on the customer demand and inventory level for each period. The customer demand follows normal distribution and 12 months (48 weeks) time horizon is considered for simulation model which is constructed using Vensim PLE v5.4b software.

2.1 Developing the Model

The proposed model consists of different important parts. The first part is related to Demand Forecasting (DF) which is calculated based on the first order exponential smoothing of the Customer Demand (Equation 1). It means that the customer demand in each period is calculated based on the forecasted demand in previous period plus the difference between customer demand and forecasted demand in current period.

$$FD_t = FD_{t-1} + \alpha\,(CD_t - FD_t) \quad (1)$$

The second part corresponds to customer order fulfillment. The amount of customer order which cannot be satisfied in each period considered as order backlog (BKLOG) which should be fulfilled in next periods (Equation 2). According to the equation, the amount of order backlog in each period is calculated based on the order backlog in previous period and order backlog rate in current period. The order backlog rate is the difference between the customer demand and shipment rate.

$$BKLOG_t = BKLOG_{t-1} + (CD_t - SHIPMENT_t) \quad (2)$$

The Third part is dedicated to determine the Desired Production Ordering (DPROD). It is determined based on forecasted demand, work-in-process adjustment (WIPA), and inventory adjustment (INVA) (Equation 3). The WIPA is the difference between the desired work-in-process and current level of work-in-process. The INVA is calculated based on the difference between the desired inventory level and the current level of inventory.

$$DPORD_t = FD_t + WIPA_t + INVA_t \quad (3)$$

The other part is related to shipment of product to the Distributor which is defined as a function of the inventory in hand and the Desired Shipment rate (DSHIP) to ensure that the shipment rate does not exceed the inventory in hand (Equation 4). Inventory in hand is calculated based on the current level of inventory and current production rate. The desired shipment rate is the amount of order backlog plus customer demand in current period.

$$SHIPMENT_t = MIN(INV_t + PROD_t\,,\ DSHIPMENT_t) \quad (4)$$

3.0 MODELING CONDITIONS AND EXPERIMENTS

3.1 Current Operating Conditions

The system is first simulated under current conditions, whereby the production quantity (which is based on fixed production capacity) and number of workers during all periods are constant. The results obtained by simulating the system under current conditions will be used to compare the system efficiency under suggested condition which is presented later. It should be noted that efficiency of the system is examined based on cost analysis. The current state of system (also named Fixed Capacity Policy) is simulated based on customer demand which is generated in random normal distribution with mean and standard deviation of 625 and 170 units per week respectively. The system's behavior (simulation results) in terms of the customer demand, production rate, order backlog, and inventory level in different periods is achieved (see Figure 1). Based on Figure 1, the graph suggests the production quantity during all periods is constant. Hence inventory is built when demand is lower than production capacity and backlogs are generated when demand is higher than capacity. It is clear that extra inventory in lower demand periods and lack of inventory in higher demand periods both impose more cost to the system. In addition performance of the system in terms of customer satisfaction in high demand periods is low.

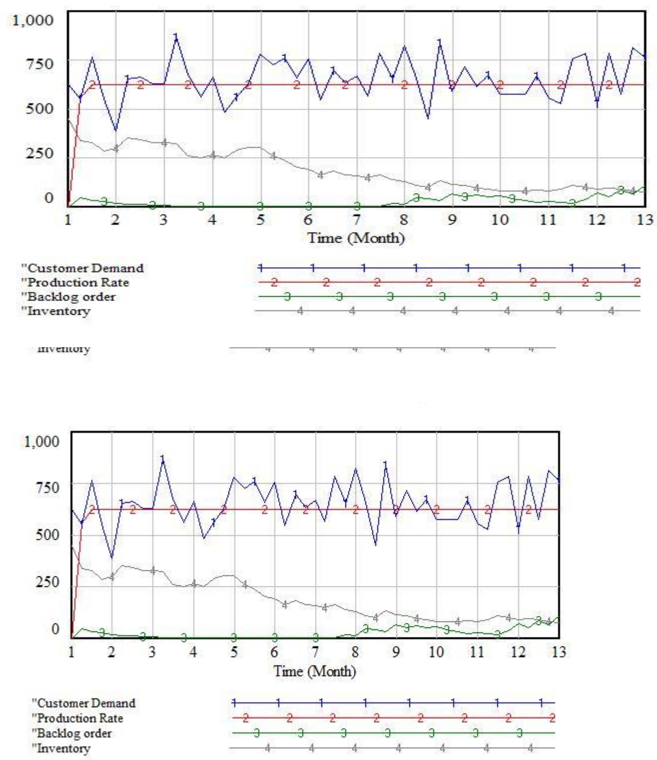


Figure 1 Simulation results for current operating condition

3.2 Proposed Operating Conditions

In proposed operating method (also named Varied Capacity Policy), the number of workers are assumed to be constant (similar to the current operating method), and in order to meet the demand fluctuation, the production capacity should be altered by considering flexible working hours. In other words, the Manufacturer should increase its capacity in order to meet the customer demand. One way to increase the production capacity is planning for producing more products in over time working hours. To do this, at first the amount of extra capacity which is needed to satisfy the customer demand in each period is determined. Next the number of over time working hour that is needed to produce the extra product is calculated based on the production process time. The results of system's simulation under suggested condition are shown in Figure 2. It shows that the customer demand is followed by production rate therefore there are no order backlogs in any periods. Figure 2 also shows that the customer demand is approximately followed by the production rate. The reason is because of considering some unexpected conditions such as machine break down, worker's fatigue or absenteeism and wastages.

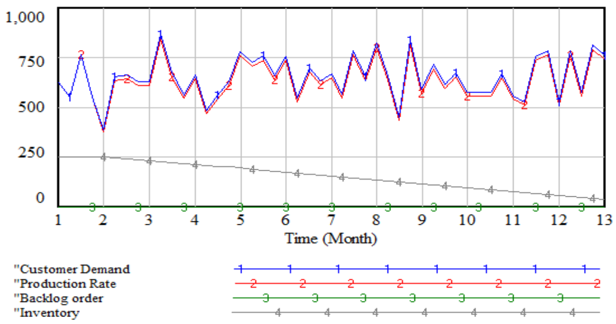


Figure 2 Simulation results for proposed operating condition

■4.0 COST ANALYSIS

Two different capacity allocation policies which are investigated in previous sections (fixed production versus varied production capacity) are compared in terms of total cost. Total cost, which is shown in Table 1, is calculated based on production, inventory holding, order backlog costs, and worker salary in regular and over time working hour (the unit of costs is in Ringgit Malaysia or RM). According to Table 1, comparing total cost of two different capacity policies shows that the second policy imposes lower cost to manufacturer. In terms of detailed cost, the varied capacity policy has higher production cost and workers' salary in over time working hour but lower inventory holding and order backlog costs.

Table 1 Total and detailed cost of two different capacity policies

Policies \ Cost	Total Cost	PROD Cost	INV Cost	BKLOG Cost	Regular time salary	Over Time salary
1) Fixed Capacity	1,667, 735	1,346, 029	92, 216	107, 839	121,651	0
2) Varied Capacity	1,605,871	1,394,106	72,281	0	121,651	17,833

Also the difference between the first and second policies in terms of inventory holding, backlog order costs, and workers' salary in over time working hour (all together) is more than difference of these policies in terms of production cost. As a conclusion the second policy is better than the first one since it imposes fewer costs to system in terms of both total and detailed costs.

■5.0 CONCLUSION

In this paper system dynamic simulation model has been used in order to simulate manufacturing supply chain of an electronic manufacturing company which is located in Malaysia. At first two different capacity policies, named fixed and varied capacity policies have been simulated and the system's behavior in terms of its key parameters during 12 months (48 weeks) is achieved. Next, cost analysis is used to investigate the system efficiency for these policies. Cost analysis results for two different policies shows that the varied capacity policy imposes lower cost to the system therefore improve the system efficiency.

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