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MAXIMIZING CUMULATIVE VARIANT PROFIT THROUGH EVALUATION OF SUPPLY CHAIN STRATEGIES

A Thesis in

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by

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ABSTRACT

Analyzing supply chain strategies for a product with seasonal demand provides significant insight into the cost associated with the supply chain in different seasons. Due to the variability in demand, retailers tend to place orders late so as to reduce their demand forecast error. In most cases, manufacturers have limited production capacity and coping with huge last minute demand results in varying overtime costs, order cut costs and customer service issues. Overall cumulative variant profit is introduced as a measure that determines the overall profitability of a supply chain strategy considering periodic variation in the parameters that affect the supply chain profitability. It takes into account parameters that are most crucial in determining the cost of the supply chain. Selection of these parameters was done after an extensive survey of literature on all parameters that affected the total cost associated with a supply chain operation.

In this thesis, simulation models of different supply chain strategies for a multi-echelon supply chain constituting of raw material suppliers, a single manufacturing unit and five different distribution centers were developed to determine the overall cumulative variant profit. When all periods were considered together, the Just-in-Time strategy with doubled capacity had the highest overall cumulative variant profit. On the other hand, when individual periods were considered, it was observed that in different periods different strategies had better overall cumulative variant profit. The overall cumulative profit of the period was related to the inherent characteristics of that period. This helped conclude that depending on the time frame, different strategies can be employed so as to yield a higher overall cumulative variant profit.

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Chapter 1

Introduction

1.1 Problem Statement

The evolution of business strategies has resulted in competition not only at the product level, but more so at the competitive efficiency of the product's supply chain. A supply chain involves a series of activities that an organization uses to deliver value, either in the form of a product, service, or a combination of both to its customers (Archibald et al., 1999). Supply chain management aims at achieving a sustainable competitive position and maximizing shareholder value by optimizing the relationship of process, information, and physical goods among internal and external trading partners (Archibald et al., 1999).

Supply chain performance is impeded by the presence of uncertainties in decision-making (Van der Vorst et al., 2000). Uncertainties such as late deliveries, machine breakdowns and order cancellations lead to increased inventories, additional capacities or unnecessary slack time (Davis, 1993). Being able to maintain the supply chain at its most effective state depends on the ability to make timely decisions. In order to achieve this, it becomes necessary to re-evaluate the supply chain strategy constantly to see if the supply chain strategy is successful or not. Most organizations rethink their strategy only after they are directly faced with a crisis. Analyzing the supply chain strategy beforehand enables the supply chain leaders to know if they will have profits or losses in the period, and whether they should consider redesigning their supply chain configuration.

Supply chain redesign involves analyzing the important parameters related to a particular supply chain strategy and finding its effect on the profitability of the supply chain. Adopting a supply chain management strategy involves applying a business philosophy where more industrial nodes along a logistic network act together in a collaborative environment, pursuing common objectives, exchanging continuously changing information, but preserving at the same time the organizational autonomy of each single unit (Terzi and Cavalieri, 2004). It is necessary to evaluate the success of adopting alternative supply chain strategies beforehand, and no measure in literature has been convincing enough that does this. Hence, a new measure is needed that will enable supply chain leaders to comfortably adopt a supply chain strategy based on the most important parameters affecting any supply chain.

1.2 Objective

This research work aims at introducing a new measure called overall cumulative variant profit to gauge the productivity of a supply chain strategy. The parameters that affect overall cumulative variant profit were selected after an extensive literature survey on supply chain parameters. Overall cumulative variant profit evaluates the performance of a supply chain in terms of fixed cost parameters and varying cost parameters. The major costs that are associated with a supply chain are due to varying factors such as fluctuation in demand that results in overtime being scheduled, varying inventory holding cost, seasonal order cut costs and fluctuating gas prices that affect transportation cost. The fluctuating nature of these factors implies that the productivity of the supply chain will also fluctuate, and hence the cumulative variant profit between periods will also fluctuate.

Each supply chain is unique and has certain aspects that differentiate it from others. None of the papers that were surveyed in literature addressed multi-echelon supply chain problems for a product with extremely seasonal demand. Accordingly, in this thesis we fill this void. One area of interest deals with supply chains that have supplier products with a short shelf life that causes huge variations in the profit of the finished goods. We consider the supply chain for a product whose demand is largely seasonal and the raw materials that go into manufacturing the product have a short shelf life but are required in large quantities. The profit margins are very volatile and it becomes necessary to analyze the supply chain strategies that are being used to keep the profits appreciable. In such a case, overall cumulative variant profit serves as a unique factor in identifying the supply chain strategy that will result in maximum productivity of the supply chain.

A case study supply chain with these unique characteristics is selected, and data obtained from the organization is used to build a simulation model of the base strategy that is employed at present in the organization. Different supply chain strategies are simulated to identify the major constraints and come up with a strategy that will yield the maximum productivity measured in terms of overall cumulative variant profit.

1.3 Case Study Supply Chain

The supply chain of the case study company deals with manufacture and distribution of French Fried Onions. French fried onions have huge demands during the holiday season especially Thanksgiving where it is a key ingredient in green bean casserole. Demands during the other months are minimal, but in order to be able to meet the demands during the holiday season, inventory is built months in advance. Also, the crucial ingredient that goes into the manufacture of the product, onions, is required in large quantities, but it has a short shelf life and needs to be used immediately.

French Fried Onions are crispy deep fried batter-coated sliced onions with a limited shelf life of 24 months. They are used to complement salads as well as dishes. French Fried Onions are stored in air tight containers since presence of moisture can make the product less crispy. They are available in various packages such as 2.8 Oz. and 6 Oz. cans and 24 Oz. packs.

Figure 1. French Fried Onions

The case study supply chain constitutes of raw material suppliers, a single manufacturing facility and five distribution centers. Only the major raw materials that are seasonal in nature are considered for the simulation model as raw material suppliers. Since this supply chain revolves around the productivity of the manufacturing facility, it becomes the major component in the simulation model. The distribution centers are spread across the United States, and each receives orders from local retailers. Understanding the manufacturing process is crucial in developing the simulation model. Accordingly, further details are provided below.

Manufacturing Process

The production of French Fried Onions has several stages starting from when the onions are received up to the point where they are packaged. Raw onions are received at the receiving dock and directly transferred to huge storage bins that can hold close to six truck loads of raw onions. Onions that are stored in these bins need to be aerated so that moisture content is minimum and the chance of the onions rotting is reduced. Figure 2 shows the different stages in the manufacturing process.

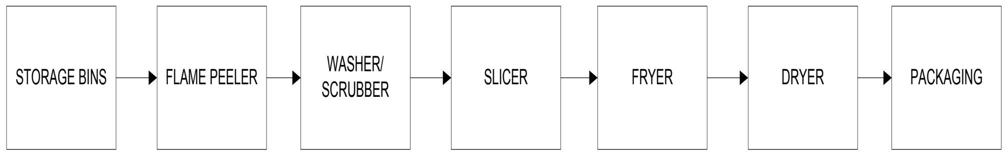

Figure 2. Process Flow in the Manufacturing Process of French Fried Onions

The first step in the process involves peeling the onions using the flame peeler. The flame peeler exposes the raw onions to temperatures of up to 1000 F for a very short duration of time, thereby burning off only the skin, and leaving the onion intact. Due to the varying sizes of the onions, the temperature is kept constant even if it means that there is some sacrifice of product in the process.

The raw onions are then cooled down to an acceptable temperature by cold water sprinklers located after the flame peeler. The flame peeler also results in burnt skins that are still part of the raw onions. These burnt skins are largely removed by washing and scrubbing the raw onions with the washer-scrubber unit. The washer-scrubber unit initially sprays jets of water at high speeds so that any onion peels that are attached to the onions can be removed. The scrubber brushes scrub the onions so that all onion peels are removed and the onions are hence clean and ready for the next step in the process.

The raw onions are then ready to be cut and sliced. Cutting and slicing of the raw onions are performed using the slicer equipment. The slicer equipment consists of sharp blades that slice the raw onions into fine pieces. The slicer can be adjusted for varying thickness of slices. If there are onion skins still present at the end of the conveyor feeding to the slicer, they can jam the slicers, and hence extra care is taken so that there is minimum skin going into the slicer. The slices of the raw onions are then sent to the coating drum. The coating drum is a vessel where the raw onions get coated with the batter. The coating drum rotates such that the onion slices are coated sufficiently and thoroughly with the batter. The batter is made from soy flour, corn flour, dextrose and a few other ingredients. The batter coated raw onions are then sprinkled with the batter flour to make it crispier. This is followed by the fryer. The fryer is one of the most crucial stages in the production process of making fried onions. Pre-heated palm oil is circulated through the fryer, maintaining the oil temperature as well as the oil level in the fryer constant. One crucial factor that is considered in the frying process is the amount of time the batter coated onions spend in the fryer. If they spend too much time in the fryer, they end up over-fried and charred. If there is more moisture in the batter coated onions, greater will be the loss of temperature on the fryer. Less time in the fryer means that the batter is not crispy enough and remains uncooked. The ideal frying time is also dependant on the temperature. The onions are fried until they become golden brown in color.

Drying the fried onions to remove excess oil from the product is the next step in the process. The dryer consists of various temperature zones ranging from higher temperatures to lower temperatures. Drying is a slow process that results in fried onions that are crispy and contain lesser oil. If there is excess content of oil in the fried onions, they can easily become damp and lose their crispiness.

After the dryer, the product is coated with extra flavors, if any, like cheddar, and is then ready to be sent to the packaging units. The packaging process is independent for the cans and the bags. Finally the cans and bags are packed in pallets so that they can easily be shipped to the logistics centers.

1.4 Thesis Organization

This thesis looks at a new measure for gauging the productivity of a supply chain strategy: the overall cumulative variant profit. It is necessary to identify parameters that most influence overall cumulative variant profit. Chapter 2 analyzes the parameters that have been dealt with in the published literature, which focuses on a supply chain's productivity. It is based on an extensive survey of supply chain productivity as well as supply chain strategies. In it, supply chain parameters are divided into cost related parameters, time related parameters and quantity related parameters. As per this review, parameters that have the most influence on the supply chain productivity are selected to form factors that most influence overall cumulative variant profit.

Chapter 3 begins with an outline of the reason for selecting simulation as opposed to any other method in evaluating supply chain strategies. It also defines overall cumulative variant profit and outlines the parameters that most influence it. A description of the simulation model of the supply chain is then detailed with characteristics of the different supply chain strategies.

Chapter 4 discusses the simulation results of different supply chain strategies. Each supply chain strategy is discussed in detail in terms of the relation of distinct periods and parameters. The focus is on parameters that vary between periods and affect the overall cumulative variant profit. This is followed by a comparison between certain parameters across all strategies. Periodic variation in cumulative variant profit among strategies is then discussed giving insight into the benefits of a mixed strategy.

Chapter 5 summarizes the interpretation of results with conclusions on the best strategy that can be employed. Finally, avenues for future research are suggested so that strides can be made in increasing accuracy of calculating overall cumulative variant profit.

Chapter 2

Literature Review

2.1 Introduction

The initial step in identifying parameters that influence the supply chain productivity was to analyze all the parameters that were discussed in literature. A comprehensive excel sheet was created that compared the different parameters used in various relevant research work. This literature review is a summary of those findings and is organized into the following sections: (1.) Cost related parameters, (2.) Time related parameters, (3.) Quantity related parameters, and (4.) Other parameters. After the most influential parameters were identified, their potential in affecting the overall productivity of a supply chain was examined in Chapter 3.

2.2 Cost Related Parameters

2.2.1 Holding Cost

Holstein et al. (2006) define holding cost as the cost associated with having one unit in inventory for a period of time. According to them, holding cost consists of four components: 1) capital cost, 2) inventory service cost, 3) storage space cost, and 4) inventory risk cost. Axsäter (2006) considers capital cost as the major contributor to holding cost. The other components such as inventory service cost, storage space cost and inventory risk cost are sometimes called out-of-pocket holding costs. When there is inventory in stock, there is always an alternative use for the money and thus an opportunity cost should be considered (Axsäter, 2006). Money that is not tied up in an investment can be used to give a certain yield. This is one reason why capital costs would be closely related to the return on an alternative investment (Holstein et al, 2006). Tax and insurance are examples of inventory service cost. Rent, heating and lighting of a facility are examples of storage space costs. These costs are usually included in handling nd transportation, and get added to inventory holding cost when they vary with the inventory on hand. Costs for obsolescence and damage of the components are categorized under inventory risk costs (Holstein et al., 2006). Huo and Lu (2008) considered holding cost as a major contributor to supply chain profit and also placed a capacity constraint on it.

Bhattacharjee and Ramesh (2001) suggest that the effect of different holding costs on the final profit is not significant in any period. According to Yang and Wee (2002), both the buyer and the vendor incur a holding cost, with the holding cost of the buyer being greater than that of the vendor. Nachiappan and Jawahar (2007) suggest that the holding cost is inversely proportional to channel profit, and the change in holding cost only slightly affects the optimal sales quantity.

In order to consider all aspects of the holding cost, factors that force it to vary in different seasons as well as factors that are fixed across all periods should be considered.

2.2.2 Transportation Cost

Eksioglu et al. (2006) studied a multi-period profit maximizing model for a retail supply chain with transportation cost having no constraints on transportation capacity. Transportation cost function was considered to be concave with respect to the amount shipped. They assumed that facilities in a period would either ship the entire quantity or none at all. Hence, the cost for transportation is either zero or a fixed value depending on the facility and the time period. In practical scenarios, however, there usually is a constraint on the transportation capacity and shipments can occur even if the total demand is not met.

Liu and Ma (2008) call transportation cost as the transfer cost, and consider it to be fixed. Merzouk (2001) assume only one transporter is assigned to deliver products between assembly facilities with a fixed cost for each delivery. In the present economic scenario, transportation cost varies dramatically due to factors such as fluctuating gas prices. Seliaman et al (2008) considered transportation cost in making production and inventory decisions. Huo and Lu (2008) considered the transportation cost in profit distribution for an upstream supply chain.

Nachiappan and Jawahar (2007) use a variable termed as distribution cost. Distribution cost is the product of flow cost and transportation resource cost. Flow cost is the direct mileage and carrier contract cost per unit, while transportation resource cost per unit is the indirect cost such as mode of transportation, human router cost and administrative costs.

In the model proposed by Chan and Chan (2005), transportation cost is considered to be one of the performance parameters that vary for different suppliers. Their conclusion was that transportation cost is not a critical factor in the supply chain performance model.

Elmaraghy and Majety (2008) consider a global supply chain scenario where they evaluate transportation modes (economy and priority) using multi-criteria optimization. By a sensitivity analysis of the different factors used in their supply chain design framework, they show that transportation cost is one of the critical costs in the total global supply chain cost.

Liu and Zhang (2008) consider pricing, inventory and transportation cost simultaneously to design coordinated supply chain strategies in a decentralized supply chain. Each supplier has limited capacity and limited homogenous vehicles to transport goods. Their transportation cost includes both gas cost as well as the salary cost. Most manufacturing firms that manufacture fast moving consumer goods make use of external freight carriers to transport their goods. Yearly contracts are signed, and costs for fluctuating gas prices are shared between the carrier company and the manufacturer. Manufacturers tend to add a unit transportation cost per item that remains fixed in a period to the manufacturing cost of the item. Since it becomes difficult to track varying gas prices and its effect on a variety of products, unit transportation cost is considered as part of the manufacturing cost.

In this thesis, transportation cost was considered as a fixed cost since variations would only be due to fluctuating gas prices and number of trailers used. Most supply chains have external carriers that are responsible for transportation. Agreements with carriers are signed based on regions as well as the number of trailers used in a period. An estimate of the cost per can is calculated and added to a parameter called other fixed cost. Since transportation cost was averaged out between all the periods and goods, this additional cost per can takes care of the transportation cost sufficiently.

2.2.3 Ordering Cost

Ordering cost includes the cost of order forms, postage, telephone calls, authorization, typing of orders, receiving, inspecting, following up on unexpected situations and handling vendor invoices (Peterson et al., 1998). Bhattacharjee and Ramesh (2001) suggest that with increasing ordering costs, the final profit function monotonically decreases for various values of holding costs in a fixed period. Several published works such as Lu (1995), Balkhi and Benkherouf (1996), Bhattacharjee and Ramesh (2001), Chen (2001), Yang and Wee (2002), Zhou and Min (2007) and Liu and Zhang (2008) consider a fixed ordering cost per order.

In this thesis, ordering cost was considered as a fixed component and part of other fixed costs. It was modeled in this fashion because it was seen that ordering cost can never be a major cost, unless the orders are infrequent or out of contract. Our model assumes that orders with suppliers as well as customers are frequent and vary depending on the demand, and hence attribute a fixed cost alone.

2.2.4 Production Cost

Production cost is the cost that is associated with manufacturing a product. Eksioglu et al. (2006) suggest that the pressure of reducing costs in supply chains forces companies to take an integrated view of their production and distribution processes. They investigated a planning model that integrated production, inventory and transportation decisions in a two-stage supply chain. The production cost at each of the manufacturing facilities was considered different. One of their inferences was that production cost was a major factor in determining the profit that is associated with a product. Nachiappan and Jawahar (2007) derived total production cost as the product of amount spent for producing or acquiring a single unit and the aggregate demand. He suggested that production and operational cost along with location and competitiveness of the products are variables that affect the contract price between vendors and buyers. Cao et al. (2008) suggested that when market disruptions cause major change to the market size, they also cause the production costs to increase.

This thesis considers that the cost of raw ingredients vary based on the period or season. Hence, production cost also varies depending not only on the quantity of finished goods, but also on the variation of cost of raw ingredients in specific periods. Costs of raw ingredients in specific periods were based on real data in past periods obtained from the case study company. Overall cumulative variant profit captures this aspect of production cost not specific to the product, but across all products that use the raw material.

2.2.5 Shortage Cost

Oral et al. (1972) define shortage cost as the cost incurred as a consequence of a stock-out, that is, when the demand cannot be fully and immediately satisfied due to stock shortage. They suggest that shortage cost evaluation arises in:

a. determining the total costs incurred when a particular inventory replenishment policy is employed,
b. determining the optimal parameters of an inventory policy where it is assumed that the shortage cost is measurable and included in the objective function, or
c. situations, where it is necessary to compare the cost of a stock-out with the cost of eliminating that stock-out by shipping items from elsewhere.

Bhattacharjee and Ramesh (2001) suggest that in situations where wastage can be completely planned out, there is no need to account for shortage cost in the model and calculations. If the price is a certain markup over the cost, then it is always profitable to sell the item rather than incur a shortage cost due to lost sales. Chen (2001), Yang and Wee (2002) and Lu (1995) do not consider any shortage cost in their models.

Zhou and Min (2007) add budget constraints to their inventory model for perishable items with stock-dependent demand rate and lost sales. This is because the storage-space limitation is equivalent to budget constraint, but when shortages are allowed to backlog, the impact of budget limitation on replenishment policy will be different from that of storage-space limitation.

Hill (1989) derived a central-warehouse multi-retailer model with shortage by using simulation. Benkherouf and Mahmoud (1996) discussed inventory models with the deteriorating items and increasing time-varying demand and inventory model with deteriorating items and increasing time-varying demand and shortages.

When the manufacturer is unable to meet the customers' demand, the manufacturer's reliability is in question, and this results in a tarnished reputation. Most manufacturers have priority customers whose demands they try to meet first. In practical scenarios, each customer is treated differently, and compensated differently based on the contract negotiated between the manufacturer and the specific customer.

2.2.6 Labor Cost

Based on the literature survey, labor cost was not found to be discussed in detail in the past for a multi-echelon supply chain with seasonal demand. This thesis gives labor cost its importance, and defends it as one of the major parameters that affect the efficiency and productivity of the supply chain. Labor cost is prevalent in every step of the supply chain. It can be considered to be fixed in certain stages of the supply chain, while it becomes variant in other stages. In most cases, manufacturing facilities have varying labor cost depending on the quantity of products being manufactured while the other stages of the supply chain have fixed labor costs. In this thesis, the fixed labor cost was considered as part of other fixed costs in relation to cumulative variant profit. Varying labor cost was considered to have two components: (1) regular labor cost and (2) overtime cost. Regular labor cost was calculated based on the labor spent in working regular hours while overtime cost was the extra cost needed to manufacture products needed in the specific period.

2.2.7 Retail Price of Finished Goods and Unit Wholesale Manufacturing Cost

Retail price of finished goods is the price charged to the consumer for the final product. In some cases, retail price of finished goods is assumed to be fixed throughout the year (Li., 2007). Others consider variation in retail price. Some assume it to be varying for the entire time horizon, but fixed in a period (Cao et al., 2008; Yang and Wee, 2002). Koo et al. (2008) considered a mean price so as to account for fluctuations. On the other hand, Unit Wholesale Manufacturing cost is the cost that the manufacturer charges for manufacturing the product. In general cases, a fixed manufacturing cost is assumed. In setting the retail price and wholesale manufacturing price, Ma and Meng (2008) assume that the manufacturer and retailer cooperate and share information. They assume that the retail price is a function of time, while the unit wholesale price remains constant throughout the year.

In this thesis, retail price was found to be a constant based on market research from the case study company. Hence, a fixed value of retail price per unit sold of product was considered in the overall cumulative variant profit.

2.3 Time Related Parameters

2.3.1 Lead time

Liao and Shyu (1991) define lead time as the length of time between the time when an order for an item is placed and when it is actually available for satisfying customer demands. In each echelon of the supply chain, the entity being served is considered as the customer. Hence, in a multi-echelon supply chain consisting of suppliers, manufacturers and distribution centers, there is a lead time that is associated with each stage. In literature, lead time is considered to be zero, constant, very large and rarely varying. Ma and Meng (2008), Zhou and Min (2007) and Nachiappan and Jawahar (2007) either ignore the lead time or assume it to be zero. Lu (1995), Reiner and Treka (2004) and Koo et al. (2008) consider constant lead time for the replenishment of the products in the models they develop.

Gallego and van Ryzin (1994) proposed a single period model for a price-sensitive stochastic demand scenario with the objective of maximizing expected revenues. One of the properties of this model was very large lead time compared to the length of the selling period. This model fits the fashion industry where there is high level of perishability of the goods.

According to Little's Law, (Hopp and Spearman, 1996), a reduction in lead time also reduces the work in process. Cachon and Fisher (2000) suggest that in some supply chain settings, the reduction in lead time or batch size can have a greater impact on supply chain performance than information sharing. Chan and Chan (2005) considered average order lead time as one of the performance measures in simulation modeling for comparative evaluation of supply chain management strategies. Average order lead time analysis was performed by calculating the time between order date and delivery date. In fact, in their model, the average order lead-time was the most critical of the four performance measures considered (inventory level, average order lead time, transportation cost and resource utilization).

Hence, it becomes necessary to consider lead time in supply chain strategy investigations. In this thesis, for each of the different stages of the echelon, the lead time was assumed to follow a distribution that was selected based on historical data.

2.3.2 Time Horizon

Time horizon refers to the time frame for which a study is conducted or a model is built. In literature, there are references to one period and multi-period time horizons (Bhattacharjee and Ramesh, 2001). Bhattacharje and Ramesh (2001) derive efficient pricing policies for maximizing the net profit of a monopolistic retailer from a single product over a multi-period time horizon. Chen (2001) and Balkhi and Benkherouf (1996) divide the time horizon into different periods, not necessarily of equal length. Eksioglu et al. (2002) developed a model where the demand in a particular time period is satisfied from exactly one facility alone. Elmaraghy and Majety (2008) considered a time period of one year for their integrated supply chain design.

This study considered a time horizon of 52 periods. Each period was considered equal in length, and equal to seven days. Hence, in total, this study had a time horizon of three hundred and sixty four days.

2.4 Quantity Related Parameters

2.4.1 Demand

Demand for a particular product can be modeled as being deterministic or uncertain. Deterministic demand can be modeled as stationary or time-varying demand. Unknown demand can follow a known demand distribution or an unknown distribution.

Wee (1993) uses a constant deterministic demand rate in developing a production lot sizing model for deteriorating items. Hong et al. (1990) consider demand as linear when examining the optimal replenishment policy. Hariga and Benkherouf (1993) consider exponential time-varying demand. Bhattacharjee and Ramesh (2001) developed two algorithms to solve a multi-period pricing and ordering problem for a monopolistic retailer, dealing with a product having fixed life perishability, with deterministic demand. The demand is deterministic with a downward sloping demand curve. Having a regular downward sloping demand curve made it possible to plan out wastage.

Chen (2001) and Merzouk et al. (2001) considered time-varying demand in their models. Lazear (1986) studied phenomenon of markups and markdowns during a products inventory cycle in the context of a simple two-period model with a stationery unit cost and uncertain demand. Gallego and van Ryzin (1994) proposed a single-period model for a price sensitive stochastic demand scenario with the objective of maximizing expected revenues. Cachon (2001) studied competitive and cooperative selection of inventory policies in two-echelon supply chains with one supplier and many retailers facing stochastic demands.

Although in most real cases demand is stochastic in nature, modeling demand as deterministic reduces unnecessary computation complexity without major losses in accuracy. In this thesis, demand was considered to be deterministic and seasonal. Demand was considered to be more during certain peak seasons, and minimal in other seasons. The case study company was selected mainly because of this trend in demand.

2.4.2 Inventory Level

Mondschein and Bitran (1996) define inventory level as the dollar value of the products in inventory at the selling price. Most inventory management models consider a constant initial inventory level. Nahmias (1982) presented a review of ordering policies for perishable inventories. Raafat (1991) compiled a detailed review on inventory management of deteriorating items modeled mathematically. In developing a single-vendor and multiple-buyer production-inventory policy for a deteriorating item, Yang and Wee (2002) set maximum inventory level of buyers as well as vendors.

Chan and Chan (2005) consider inventory levels as one of the four performance measures for evaluating supply chain management strategies by building simulation models. Their inference is that inventory level is a key decision associated with supply chain performance.

In this thesis, each supply chain strategy has a different inventory level policy. Some strategies aim at reducing inventory levels, while others do not since they consider the demand to be much more than the capacity that can be supported by the production facility, and hence it would be in their best interest to have sufficient inventory always at hand. The production plan of the manufacturer determines the inventory level that will be maintained in the distribution centers.

2.4.3 Production Capacity

Production capacity in the past has been considered to be either unconstrained or limited. Florian and Klein (1971) were among the first to consider a multi-period single commodity production planning problem with production capacity constraints. Federgruen and Zipkin (1986) developed an inventory model with limited production capacity and uncertain demands. Baker et al. (1978) proposed an algorithm for the dynamic lot-size problem with time-varying production capacity constraints. He and Pindyck (1989) developed a model with flexible production capacity for a product with stochastic demand. In most optimization models, there is a maximum production capacity constraint beyond which production cannot occur. El Maraghy and Majety (2008) set a production capacity constraint in their multi-criteria optimization model for integrated supply chain design.

A constraint on the production capacity will help in testing the robustness of a supply chain strategy. For this reason, this thesis considers constraints on production capacity. The extent of the constraint was based on the values provided by the case study company.

2.5 Other Parameters

2.5.1 Deterioration Rate

Whitin (1957) was among the first to consider an inventory model for fashion goods deteriorating at the end of a prescribed storage period. Ghare and Scharder (1963) followed this with an Economic Order Quantity (EOQ) model with exponential decay and deterministic demand. Raafat (1991) then provided a detailed review of inventory management, with the idea that mathematical modeling requires simplification of assumptions such that analysis of the system is feasible. Hariga (1993) studied inventory models with linear demand rate of deteriorating items. Raafat et al. (1991) calculated the exact average cost equation for an inventory model with exponentially deteriorating items, from which it is possible to obtain the optimal value of other characteristics of the inventory model by using computer search techniques like Fibonacci or Hooke and Jeeves' search methods.

Covert and Philip (1973) developed a basic EOQ model for items with Weibull distribution deterioration. Elsayed and Terasi (1983) developed two economic order quantity models for inventory items with the deterioration rate given by a two-parameter Weibull distribution with shortages allowed. Yang and Wee (2002) developed a production-inventory system model of a deteriorating item, taking into account the views of both the vendor and the multi-buyer. They considered factors of deterioration and integration of vendor and buyers simultaneously. Dave (1979) developed an order-level inventory model continuous in units and discrete in time with deterioration assumed to be a constant fraction of the on-hand inventory.

Vrat and Padmanabhan (1995) presented three inventory models for deteriorating items with a selling rate that was dependant on amount of stock present. The first two models considered situations without backlogging and with complete backlogging respectively. The third model considered the backlogging rate to be dependent on the amount of demand backlogged. Chung et al. (2000) developed necessary and sufficient existence and uniqueness of optimal solutions to the first and second model. Zhou and Min (2007) developed necessary and sufficient existence and uniqueness of optimal solutions to a model similar to the third one proposed by Vrat and Padmanabhan (1995).

Balkhi and Benkherouf (1996) developed optimal replenishment policies for inventory systems with constant deterioration rate, varying demand rate and production rate over a finite planning horizon. They assumed deterioration occurs only when item is in stock and that deteriorated items are not repaired or replaced in the planning horizon. Chen (2001) points out that Balkhi and Benkherouf (1996) had erroneous results for the existence and uniqueness for the first partial derivative systems. With the help of an extra condition between replenishment rate and demand rate, they corrected the results. Benkherouf and Balkhi (1997) developed solutions to the inventory replenishment problem with increasing time-varying demand and non-decreasing deterioration rate.

Deterioration rate can be considered for both the raw material as well as for the finished goods. Deterioration rate depends on the type of the product. For this thesis, it was decided to consider a product whose raw material deteriorated at a high rate, while the finished product did not face any immediate deterioration. In the case study company, the raw material had a shelf life of 36 hours before it was considered fully deteriorated and unfit for consumption. The finished product on the other hand, had a shelf life of two years and did not face any immediate deterioration.

2.5.2 Resource Utilization

Resource utilization is defined as the percentage of time a resource is busy executing tasks with respect to the total simulation time. Enns and Suwanruji (2003) developed a test bed to compare different planning and control strategies for small production systems and supply chains. They found the resource utilization of the resources for the different strategies employed to be comparable to each other. Chan (2002) compared five different supply chain strategies developed using simulation with the objective of selecting a supply chain model having optimal performance in the four measurements - inventory level, order lead time, resource utilization, and transportation cost. It was found that based on the strategy, the resource utilization varied from 10.56% to 44.88%. Casssone (2005) used machine utilization as one of the production process performance metrics in estimating the values of a company based on operational performance metrics. The model developed in this work is a rate model, and hence resource utilization will not be of much importance in evaluating the efficiency of the overall system or the strategy being tested.

2.5 Summary

The parameters that constrain supply chain profits can be considered as being constant or varying throughout the period in consideration. The factors that will influence the supply chain are those that will vary seasonally and follow trends in prices across the year. These factors were labor cost, order cut costs, raw material costs and inventory holding cost. Since these bring about variations in the profitability of the supply chain, it is necessary to include these as the most crucial supply chain redesign parameters. We consider the selling price as being constant throughout the year. This is because the manufacturers of the product in consideration are the market dominators, and the sale lost to competitors is less than 10%. Holding cost is considered to be varying for each period in consideration. Transportation cost has been modeled as an inherent cost in the system. Shortage cost is present whenever there is a shortage, and varies on the quantity of shortages that are present. Ordering cost and production cost are considered as part of other fixed costs.

A parameter that hasn't been dealt with in depth in the past is the labor cost, and this is a crucial cost for the product in consideration. Labor cost was considered to have two components: a fixed cost as well as an overtime cost. Overtime cost was present for the extra days that workers were called for to meet the targets in the period. There is a constraint on the production capacity of the manufacturing facility, and this is considered as one of the most crucial aspects of redesign as many papers do not impose a practical constraint on manufacturing capabilities. The main performance measures are going to be cumulative variant profit, lost sales and inventory at hand. The objective would be to have maximum cumulative variant profit, least lost sales and an acceptable level of inventory at hand.

A summary of the parameters considered in literature are compared in Tables 1 through 8.

Table 1. Comparison of Cost Parameters across Papers 1-5

S #	Title	Unit Wholesale Price (Manuf.)	Retail Price of Finished Goods (Retailer)	Ordering Cost	Recovery Cost	Backorder Cost	Setup Production Cost at facility	Opportunity Cost	Per Unit Production Cost	Per Unit Holding Cost	Per Unit Shortage Cost in Period	Revenue in Period	Penalty Cost	Purchase Cost in Period	Per Unit Inventory cost	Holding Cost in Period	Transportation Costs
1	Huo, J., & Lu, L. (2008). Study On Profit Distribution in Upstream Supply Chain with Manufacturer Dominating. 2008 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2008, 2008.	x	x				x								x	`	x
2	Zhou, M .Y. & Min, M. (2007). An Inventory Model for Perishable Items under Stock-Dependent Demand Rate with Constraints of Customer-Waiting Time and Budget. Proceedings - ICSSSM'06: 2006 International Conference on Service Systems and Service Management, 1, 228-233.	x	x	x				x		x	x						
3	Liu, G., & Zhang, F. (2008). Research on supply chain coordination with the consideration of pricing and transportation cost. Proceedings of the IEEE International Conference on Automation and Logistics, ICAL 2008, 164-168.	x	x	x					x	x							x
4	Cao, X., Qin, Y., & Lu, R. (2008). Managing Rebate and Penalty Contract in Perishable Product's Supply Chain Under Disruptions. Proceedings of the IEEE International Conference on Automation and Logistics, ICAL 2008, 1, 186-190.	x	x					x	x				x				
5	Koo, L. Y., Srinivasan, R., Adhitya, A., & Karimi, A. I. (2008). Decision Support for Integrated Refinery Supply Chains. Part 2. Design and Operation. Computers and Chemical Engineering, 32(11), 2787-2800.	x	x					x		x	x	x	x	x			

Table 2. Comparison of Cost Parameters across Papers 6-10

S #	Title	Unit Wholesale Price (Manuf.)	Retail Price of Finished Goods (Retailer)	Ordering Cost	Recovery Cost	Backorder Cost	Setup Production Cost at facility	Opportunity Cost	Per Unit Production Cost	Per Unit Holding Cost	Per Unit Shortage Cost in Period	Revenue in Period	Penalty Cost	Purchase Cost in Period	Per Unit Inventory cost	Holding Cost in Period	Transportation Costs
6	Cao, X., Lu, R., & Yao, Z. (2007). A Study on Coordination in Three-stage Perishable Products Supply Chain Based on False Failure Return "IEEE International Conference on Grey Systems and Intelligent Services, GSIS 2007. Proceedings of 2007 IEEE International Conference on Grey Systems and Intelligent Services, 1, 1222-1226.	x	x						x								
7	Wee, H. M., & Jiang, J. C. (2007). A Note on a Single-Vendor and Multiple-Buyers Production-Inventory Policy for a Deteriorating Item. European Journal of Operational Research, 180(3), 1130-1134.	x		x			x		x	x	x					x	
8	Lu, L. (1995). A One Vendor Multi Buyer Integrated Inventory Model. European Journal of Operational Research, 81(2), 312-23.	x		x			x		x	x	x						
9	Bhattacharjee, S., & Ramesh, R. (2001). Multi-Period Profit Maximizing Model for Retail Supply Chain Management: An Integration of Demand and Supply-Side Mechanisms. European Journal of Operational Research, 122 (3), 584-641.	x		x						x	x					x	
10	Ma, Q., & Meng, L. (2008). Simulation Study about Perishable Products Inventory System with Resalable Product Return. Proceedings of the International Conference on Information Management, Innovation Management and Industrial Engineering 2, 1, 214-17.		x		x	x				x							

Table 3. Comparison of Cost Parameters across Papers 11-15

S #	Title	Unit Wholesale Price (Manuf.)	Retail Price of Finished Goods (Retailer)	Ordering Cost	Recovery Cost	Backorder Cost	Setup Production Cost at facility	Opportunity Cost	Per Unit Production Cost	Per Unit Holding Cost	Per Unit Shortage Cost in Period	Revenue in Period	Penalty Cost	Purchase Cost in Period	Per Unit Inventory cost	Holding Cost in Period	Transportation Costs
11	Balkhi, Z. T., & Benkherouf, L. (1996). On The Optimal Replenishment Schedule For an Inventory System with Deteriorating Items and Time-Varying Demand and Production Rates. Computers and Industrial Engineering, 30(4), 823-9.			x					x	x							
12	Chen, P. (2001). The Impact of Time-Varying Demand and Production Rates on Determining Inventory Policy. Mathematical Methods of Operations Research, 54, 395-405.			x					x	x	x					x	
13	Nachiappan, S. P., & Jawahar, N. (2007). A Genetic Algorithm for Optimal Operating Parameters of VMI System in A Two-Echelon Supply Chain. European Journal of Operational Research, 182(3), 1433-1452.						x		x	x							x
14	Eksioglu, S. D., Romejin, H. E. & Pardalos P. M. (2006). Cross-facility production and transportation planning problem with perishable inventory. Computers and Operations Research, v 33, n 11, p 3231-3251						x		x						x		x
15	Seliaman, M. E., Ahmad, A. R., & Saif, A. (2008). "Production and inventory decisions in a multi-stage supply chain with transportation cost." Proceedings of the International Conference on Information and Communication Technologies from Theory to Applications, ICTTA'08, 6.						x									x	x

Table 4. Comparison of Cost Parameters across Papers 16-21

S #	Title	Unit Wholesale Price (Manuf.)	Retail Price of Finished Goods (Retailer)	Ordering Cost	Recovery Cost	Backorder Cost	Setup Production Cost at facility	Opportunity Cost	Per Unit Production Cost	Per Unit Holding Cost	Per Unit Shortage Cost in Period	Revenue in Period	Penalty Cost	Purchase Cost in Period	Per Unit Inventory cost	Holding Cost in Period	Transportation Costs
16	Elmaraghy, H.A., and Majety, R. (2008). Integrated Supply Chain Design Using Multi-Criteria Optimization. International Journal of Advanced Manufacturing Technology, v 37, n 3-4, 371-399.																x
17	Nahmias, S., Perry, D., & Stadje, W. (2004). Perishable Inventory Systems with Variable Input and Demand Rates. Mathematical Methods of Operations Research, 60, 155-162.																
18	Reiner, G., & Trcka, M. (2004). Customized Supply Chain Design: Problems and Alternatives for a Production Company in the Food Industry. A Simulation Based Analysis. International Journal of Production Economics, 89(2), 217-229.																
19	Chan, F. T., & Chan, H. K. (2005). Simulation Modeling for Comparative Evaluation of Supply Chain Management Strategies. The International Journal of Advanced Manufacturing Technology, 25(9-10), 998-1006.																x
20	Merzouk, S. E., Grunder, O. & El Bagdouri, M (2001). "Optimization of holding and transportation costs in a simple linear supply chain." Proceedings - ICSSSM'06: 2006 International Conference on Service Systems and Service Management, 1, 583-588.															x	x
21	Mohandas, R. and Okudan, G. (2010) Maximizing Cumulative Variant Profit through Evaluation of Supply Chain Strategies.	x	x	x			x		x	x	x	x	x	x	x	x	

Table 5. Comparison of Non Cost Parameters across Papers 1-5

S #	Title	Numer of Periods	Lead Time	Time Period	Delivery Time	Maximum Waiting Time	Maximum inventory Holding Capacity	Deterioration Rate	Production Capacity	Resource Utilization	Inventory Level	Number of types of products	Number of Goods Produced	Reorder Point	Quantity of Ordered Goods	Production Rate	Order Quantity	Demand
1	Huo, J., & Lu, L. (2008). Study On Profit Distribution in Upstream Supply Chain with Manufacturer Dominating. 2008 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2008, 2008.						X										X	
2	Zhou, M .Y. & Min, M. (2007). An Inventory Model for Perishable Items under Stock-Dependent Demand Rate with Constraints of Customer-Waiting Time and Budget. Proceedings - ICSSSM'06: 2006 International Conference on Service Systems and Service Management, 1, 228-233.			X		x		X			X				X			
3	Liu, G., & Zhang, F. (2008). Research on supply chain coordination with the consideration of pricing and transportation cost. Proceedings of the IEEE International Conference on Automation and Logistics, ICAL 2008, 164-168.																X	X
4	Cao, X., Qin, Y., & Lu, R. (2008). Managing Rebate and Penalty Contract in Perishable Product's Supply Chain Under Disruptions. Proceedings of the IEEE International Conference on Automation and Logistics, ICAL 2008, 1, 186-190.																X	X
5	Koo, L. Y., Srinivasan, R., Adhitya, A., & Karimi, A. I. (2008). Decision Support for Integrated Refinery Supply Chains. Part 2. Design and Operation. Computers and Chemical Engineering, 32(11), 2787-2800.	X	X			X												X

Table 6. Comparison of Non Cost Parameters across Papers 6-10

S #	Title	Numer of Periods	Lead Time	Time Period	Delivery Time	Maximum Waiting Time	Maximum inventory Holding Capacity	Deterioration Rate	Production Capacity	Resource Utilization	Inventory Level	Number of types of products	Number of Goods Produced	Reorder Point	Quantity of Ordered Goods	Production Rate	Order Quantity	Demand
6	Cao, X., Lu, R., & Yao, Z. (2007). A Study on Coordination in Three-stage Perishable Products Supply Chain Based on False Failure Return "IEEE International Conference on Grey Systems and Intelligent Services, GSIS 2007. Proceedings of 2007 IEEE International Conference on Grey Systems and Intelligent Services, 1, 1222-1226.																x	
7	Wee, H. M., & Jiang, J. C. (2007). A Note on a Single-Vendor and Multiple-Buyers Production-Inventory Policy for a Deteriorating Item. European Journal of Operational Research, 180(3), 1130-1134.			x	x			x			x					x		x
8	Lu, L. (1995). A One Vendor Multi Buyer Integrated Inventory Model. European Journal of Operational Research, 81(2), 312-23.		x									x				x		x
9	Bhattacharjee, S., & Ramesh, R. (2001). Multi-Period Profit Maximizing Model for Retail Supply Chain Management: An Integration of Demand and Supply-Side Mechanisms. European Journal of Operational Research, 122 (3), 584-641.	x		x											x			x
10	Ma, Q., & Meng, L. (2008). Simulation Study about Perishable Products Inventory System with Resalable Product Return. Proceedings of the International Conference on Information Management, Innovation Management and Industrial Engineering 2, 1, 214-17.																	x

Table 7. Comparison of Non Cost Parameters across Papers 11-15

S #	Title	Numer of Periods	Lead Time	Time Period	Delivery Time	Maximum Waiting Time	Maximum inventory Holding Capacity	Deterioration Rate	Production Capacity	Resource Utilization	Inventory Level	Number of types of products	Number of Goods Produced	Reorder Point	Quantity of Ordered Goods	Production Rate	Order Quantity	Demand
11	Balkhi, Z. T., & Benkherouf, L. (1996). On The Optimal Replenishment Schedule For an Inventory System with Deteriorating Items and Time-Varying Demand and Production Rates. Computers and Industrial Engineering, 30(4), 823-9.	x						x			x							x
12	Chen, P. (2001). The Impact of Time-Varying Demand and Production Rates on Determining Inventory Policy. Mathematical Methods of Operations Research, 54, 395-405.			x				x			x							x
13	Nachiappan, S. P., & Jawahar, N. (2007). A Genetic Algorithm for Optimal Operating Parameters of VMI System in A Two-Echelon Supply Chain. European Journal of Operational Research, 182(3), 1433-1452.																	
14	Eksioglu, S. D., Romejin, H. E. & Pardalos P. M. (2006). Cross-facility production and transportation planning problem with perishable inventory. Computers and Operations Research, v 33, n 11, p 3231-3251										x		x					x
15	Seliaman, M. E., Ahmad, A. R., & Saif, A. (2008). "Production and inventory decisions in a multi-stage supply chain with transportation cost." Proceedings of the International Conference on Information and Communication Technologies from Theory to Applications, ICTTA'08, 6.															x		x

Table 8. Comparison of Non Cost Parameters across Papers 16-21

S #	Title	Numer of Periods	Lead Time	Time Period	Delivery Time	Maximum Waiting Time	Maximum inventory Holding Capacity	Deterioration Rate	Production Capacity	Resource Utilization	Inventory Level	Number of types of products	Number of Goods Produced	Reorder Point	Quantity of Ordered Goods	Production Rate	Order Quantity	Demand
16	Elmaraghy, H.A., and Majety, R. (2008). Integrated Supply Chain Design Using Multi-Criteria Optimization. International Journal of Advanced Manufacturing Technology, v 37, n 3-4, 371-399.			X			X		X		X							X
17	Nahmias, S., Perry, D., & Stadje, W. (2004). Perishable Inventory Systems with Variable Input and Demand Rates. Mathematical Methods of Operations Research, 60, 155-162.																	x
18	Reiner, G., & Trcka, M. (2004). Customized Supply Chain Design: Problems and Alternatives for a Production Company in the Food Industry. A Simulation Based Analysis. International Journal of Production Economics, 89(2), 217-229.													X			X	X
19	Chan, F. T., & Chan, H. K. (2005). Simulation Modeling for Comparative Evaluation of Supply Chain Management Strategies. The International Journal of Advanced Manufacturing Technology, 25(9-10), 998-1006.		X							X	X						X	X
20	Merzouk, S. E., Grunder, O. & El Bagdouri, M (2001). "Optimization of holding and transportation costs in a simple linear supply chain." Proceedings - ICSSSM'06: 2006 International Conference on Service Systems and Service Management, 1, 583-588.		X														X	X
21	Mohandas, R. and Okudan, G. (2010) Maximizing Cumulative Variant Profit through Evaluation of Supply Chain Strategies.	X	X	X			X		X	X	X	X	X	X	X	X	X	X

Chapter 3

Methodology

3.1 A Simulation Approach

Optimizing a supply chain has long been dealt with quantitatively. Most analytical models have many constraints that have to be satisfied before results can be utilized in practical scenarios. Such models also take only few objectives into account such as optimizing inventory and holding costs, but ignore other important factors such as transportation cost and information technology costs. If many parameters are considered, then there are bound to be many assumptions made and heuristics developed so as to simplify the system. The problem with this is that the exact model is never represented, and heuristics are only accurate to a certain percentage depending on the problem under study. An alternative to relying only on quantitative methods is to use discrete event simulation. Zee and Vorst (2005) suggest that simulation is often regarded as the proper means for supporting decision making because of its inherent modeling flexibility. According to Chang and Makatsoris (2001): "Discrete-event simulation allows the evaluation of operating performance prior to the implementation of a system since: (a) it enables companies to perform powerful what-if analyses leading them to better planning decisions; (b) it permits the comparison of various operational alternatives without interrupting the real system and (c) it permits time compression so that timely policy decisions can be made."

Many scholars have used simulation to solve supply chain problems. Swaminathan et al. (1998) developed customized supply chain models by remodeling supply chain parameters such as demand, lead-time, transportation time and costs. Archibald et al. (1999) used a simulation model for distribution and collaborative planning of inventory in a multi-plant hypothetical food processing organization. The simulation model measured return on investment, inventory turns and stock out delays. Reiner and Trcka (2003) studied product specific supply chain in the food industry. Vorst et al. (2000) modeled and simulated a three stage supply chain and considered eight different performance parameters. Three of these were cost based: (a) holding cost (b) processing cost (c) cost of product write-offs and necessary price reduction, and five were service based: (a) number of stock-outs per hour (b) delivery reliability of producer (c) average remaining product freshness (d) utilization of transport careers, and (e) product assortment. Their conclusion was that by increasing ordering and delivery frequencies, decreasing producer's lead time and implementing new information systems, the overall supply chain can be improved. Further, it was also observed that many of the problems were unique, and thus, it was observed that each supply chain is different and redesign would be specific to an industry and product.

Automod has been used as the simulation tool. Automod presents many advantages over other simulation packages. It allows reusing model objects, unlimited model size with a high performance simulation engine and also packs best-in-class statistical analysis features (LeBaron and Jacobsen, 2007). The Automod code for the simulation model is developed and explained in Appendix B.

3.2 Selection of Model Parameters

From literature survey, certain parameters were found to have a significant contribution towards deciding the favorability of a supply chain strategy. Yet, none of these parameters were able to tie each other together in order to obtain a single dependent variable that could be used in estimating the favorability of a supply chain strategy.

This research work proposes a new dependent variable called Overall Cumulative Variant Profit that ties in the contribution of all the significant factors that decide the favorability of a supply chain strategy. Overall cumulative variant profit aims at being a single measure that can be used in the process of evaluating a supply chain strategy.

The parameters on which the simulation model is built help in calculating the overall cumulative variant profit. Variables that have been used in this study are of two types: those that are obtained from the simulation, and those that are used to calculate the overall cumulative variant profit. Variables that are obtained from the simulation are referred to as indirect variables since they do not affect the cumulative variant profit directly. These indirect variables include inventory levels in each period, number of overtimes scheduled, demand met, and demand unmet for the three products in each period.

3.2.1 Definition of Overall Cumulative Variant Profit (CVP)

Overall cumulative variant profit is defined as the summation of all variable profits from all products that are associated with a supply chain. Overall cumulative variant profit depends on varying cost factors as well as fixed cost factors. Varying cost factors are those that are seasonal and fluctuate due to seasonality in raw material cost, labor cost, inventory holding cost and order cut cost. Fixed cost factors are those that remain constant in the time horizon for which the supply chain strategy is tested. Overall cumulative variant profit encompasses all products in a supply chain and considers individual as well as collective contribution of products towards the success of a supply chain strategy.

$$Overall\ CVP = \sum_{x=1}^{N} CVP_x - \sum_{i=1}^{n} \{(OT_i * K_i) + (L_i * TR_i)\} \qquad (3.1)$$

Where,

x - *Current Product ranging from product "x" = 1 to product "x" = N*

n	-	*Current period*
i	-	*Period ranging from i = 1 to i= 52*
CVP_x	-	*Cumulative variant profit for product "x"*
OT_i	-	*Number of overtimes scheduled for period "i"*
K_i	-	*Cost of overtime in period "i"*
L_i	-	*Unit raw material truck load cost in period "i"*
TR_i	-	*Number of trucks needed in period "i"*
N	-	*Total number of products in the supply chain*

For each product in the supply chain, individual cumulative variant profit has to be calculated using Equation 3.2.

$$\boldsymbol{CVP_x} = \sum_{i=1}^{n}(SP_{xi} * N_{xi}) - \{ (C_{1xi} * I_{xi}) + OC_{xi} + (C_{2xi} + C_{3xi}) * N_{xi}\} \qquad (3.2)$$

Where,

x	-	*Product 1, 2, 3*
n	-	*Current period*
i	-	*Period ranging from i = 1 to i= 52*
SP_{xi}	-	*Unit selling price in period "i" for product "x"*
N_{xi}	-	*Total quantity of product "x" sold in period "i"*
C_{1xi}	-	*Unit holding cost of product "x" in period "i"*
C_{2xi}	-	*Regular labor cost of product "x" in period "i"*
C_{3xi}	-	*Other fixed costs of product "x" in period "i"*
I_{xi}	-	*Ending Quantity of Inventory of product "x" sold in period "i"*
OC_{xi}	-	*Order cut cost of product "x" in period "i"*

The variables on which overall cumulative variant profit depend on were selected based on their significant contribution towards the success of a supply chain strategy from literature survey summarized in Chapter 2. The objective of the simulation model is to provide parameters that will directly or indirectly aid in calculating the overall cumulative variant profit. The parameters that influence the overall cumulative variant profit are discussed as direct variables in section 3.2.3.

3.2.2 Indirect Variables

Indirect variables are the variables that are obtained from the simulation which help to calculate the variables that directly influence the favorability of the supply chain strategy. In the simulation model, each indirect variable is calculated in every period. The indirect variables used in this simulation model are:

a. quantity of finished goods that are packaged at the production facility in every period,
b. the number of overtimes scheduled in each period so that the production plan is met,
c. the demand that is not met in each period for the different products,
d. the quantity of the different products that are sold in each period, and
e. the quantity of each finished product stored at the distribution center at the end of every period.

The quantity of finished goods that are packaged at the production facility every week helps to determine the labor cost as well as the other fixed costs in every period. For each packaged good, there is a labor cost as well as other fixed cost associated with it. The number of overtimes scheduled in a period determines the cost of the overtimes, since to schedule each overtime means that a fixed cost is associated with it. Demand that is not met in a period helps in calculating the order cut costs since for each order that is not met, a shortage cost to the customer must be paid to maintain good customer relation. The quantity of different products sold in each period is the actual sales made in the period. This helps calculate the total selling price of the goods in the period. The quantity of each finished product stored at the distribution center in every period helps calculate the inventory holding cost since inventory holding cost is based on the ending inventory at the distribution centers.

Each of these quantities is obtained for each product in the supply chain. Since there are three different products in the supply chain, the simulation model helps calculate these factors for these three products.

3.2.3 Direct Variables

Direct variables are those that are used to calculate the cumulative variant profit. They are classified as independent, dependent and fixed variables. Fixed variables in this simulation model are the variables that are independent of the time horizon. Investment cost that is associated with buying new equipment is considered as a fixed variable. Independent variables are the variables that vary with the time period and quantity of goods sold. They cause a lot of variation on the cumulative variant profit, and are the most crucial factors that have to be examined when calculating the cumulative variant profit. The dependent variable is the variable that depends on the independent variables in the study. In this case, the only dependent variable is cumulative variant profit.

3.2.3.1 Independent Variables

Independent variables are the variables on which cumulative variant profit is modeled. From Equation 3.1 and 3.2, we find that the independent variables are as follows:

a. **Selling Price:** Selling price was considered to be constant for each product in all the periods considered. This was based on data provided from the organization used in the case study. Selling price is charged per unit of item sold, and hence depends on quantities of items that were sold in each period for each product.

b. **Unit Holding Cost:** In each period, the holding costs of the different products are different. Each product has a holding cost associated with each unit of product that is stored as inventory in the distribution center. An item is charged with holding cost only if it remains in the distribution center for more than one period. Total holding cost is calculated by multiplying the unit holding cost with the quantity of items left in inventory at the end of every period. In this thesis, holding cost was considered to have two components: (1) a fixed component which dealt with capital cost, and (2) a variable component which consisted of inventory service cost, storage cost and inventory risk cost. Capital cost was considered fixed since it would not vary in the period unless there was investment in terms of buying new equipment. If the supply chain strategy proposed required that there should be investment in new equipment, then based on the depreciation, a percentage would be deducted from the overall cumulative variant profit. The variable components were accounted for by a parameter called inventory holding cost which was the cost of storage space based on the quantity of finished product in storage in the period as well as the cost of storing the product in the specified period.

c. **Regular Labor Cost:** Regular labor cost is calculated based on the quantities of products manufactured in the period. For each item that is manufactured, there is a regular labor cost associated with it in each period.

d. **Other Fixed Costs:** Other fixed costs include all costs that are fixed in a period and apply if any part of the supply chain is functioning. It is charged per unit of item manufactured, and the unit value of other fixed cost is based on data provided by the case study organization. In this model, it includes costs such as:

i. Capital cost

ii. Transportation cost

iii. Ordering cost

iv. Non manufacturing facility labor costs

v. Other ingredient costs

e. **Order Cut Costs:** Order cut costs are due to the result of unmet orders in a period. Each period has a specific order cut cost associated with it, and order cut costs vary depending on the quantity of each product whose order was not met. In the proposed model, shortage costs were calculated per unit item of unmet demand. Hence, it was called order cut costs. That is, the shortage cost is calculated based on the total quantity of items whose demand was not met in a period. In this way, customer preference is not considered, but it is assumed that for each unmet demand, there is a monetary loss.

f. **Overtime Costs:** If the manufacturing unit is not able to manufacture the periods' production schedule, it has to schedule overtime. Overtime cost is associated with each overtime shift that is scheduled. For each overtime shift that is scheduled, there is a fixed cost associated with it.

g. **Variable Raw Material Cost:** Since the major raw material has a short shelf life, it is required to consider this cost as being variable. Due to its seasonal nature, each period has a unit raw material cost which was obtained from historical data. Raw material cost is charged per truck load and depends on the number of truckloads of raw materials that were used in a period.

3.4 Simulation Model

In modeling the supply chain using discrete event simulation, it was observed that a rate model would be the most appropriate. In its simplest essence, a rate model consists of an input variable that decreases over a certain period of time and an output variable that increases for the same period of time. A rate model has been the backbone for the simulation model at the different stages of the manufacturing facility as well as the packaging facility. The simulation model consists of four stages:

a. Raw material stage
b. Manufacturing facility stage
c. Packaging facility stage
d. Distribution center stage

3.4.1 Raw Material Stage

The raw material stage receives all the ingredients that are required to manufacture the product. Variability in the most crucial raw material ingredient that affects the cumulative variant profit is required to be modeled. The input to this stage is the number of trucks of raw ingredients that are arriving each week. The number of trucks that are expected to arrive on a per week basis is based on the production plan for the period in consideration. Each truckload is equivalent to 50,000 lbs of raw material. There can be variability in the number of truckloads that are used in a period, and if there is excess raw material, it gets added to the inventory. Since there is storage space for close to six truckloads of raw material at any given time, infinite storage capacity is assumed. The important output that we get from this stage towards calculating the cumulative variant profit is the number of truckloads of raw material that has been used in each week. Since the raw material prices vary monthly, it becomes necessary to identify to what extent savings can be made in the months the raw materials cost more.

3.4.2 Manufacturing Facility Stage

The manufacturing facility converts the raw ingredients into the finished and consumable goods. The inputs to this stage include the output from the raw material stage. Also, the total quantity of finished product necessary by the end of each week is given as an input. Here the raw materials get converted to the finished product through a series of seven stages. Since modeling all the seven stages would not contribute significantly to the entire model of the supply chain simulation, only crucial steps that are bottlenecks in the manufacturing facility are modeled. Modeling the manufacturing stage was achieved by implementing a rate model where the input and output rates are known. Downtime is modeled with the help of actual data when the stage which has the biggest bottleneck has gone down into breakdown. From this stage the main parameter that contributes to cumulative variant profit is the number of overtime shifts that are scheduled. If there is insufficient quantity of finished product, the packaging activity cannot commence. The output from this stage that becomes the main input to the next stage is the quantity of finished product available in pounds. There is assumed to be no lead time between the manufacturing facility and the packaging facility.

3.4.3 Packaging Facility Stage

This stage represents where the product is packaged into three different sized cans and packets. They also have the same normal and overtime schedule as the manufacturing facility. The input to this stage is the quantity of finished product that is ready for packaging. Packaging stage does not depend on any other parameter. Packaging can only begin once enough buffer of finished product is available. There are two different packaging lines that can each package one product size at a given time. Of these two packaging lines, one is dedicated to a single packaging size while the other can be switched between two sizes depending on the order quantity for the week. Since packaging equipment speeds are comparatively faster, they rarely are a cause for downtime, and it is assumed they never breakdown. The output from this stage is the number of packed product of each size in cans and packets. This is used as input to the distribution center. There is a lead time of two days for the trucks to reach the distribution center. This limitation is relaxed in the simulation model by assuming that the lead time is zero. This is because if product is expected to be delivered immediately, it can be done with the help of an urgent delivery which would result in higher transportation cost. The complications that would arise due to this were too high to incorporate this in the model.

3.4.4 Distribution Center Stage

The distribution center stage is where the product gets shipped out to the retail stores. It is where the inventory is stored until the orders for the product come through from the retail stores. Although there are five different distribution centers, all the orders are pooled together, and are delivered based on the period requirements. Input to this stage from the packaging facility is the number of packaged ready products. The number of packaged products helps to determine the quantity of inventory being held at the end of every period which helps in determining the inventory holding cost. Also, since it is at the distribution center where the periodic demand is known, it is in this stage where sales as well as order cuts are calculated. If orders are not met, then there is a shortage cost associated with each order cut. It is also assumed that these orders shall be met in future.

3.5 Assumptions

The assumptions that have been made in the different stages of the simulation are discussed in sections 3.5.1 to 3.5.4. These assumptions were crucial in developing the simulation model as well as defining the entities used in the system. Appendix A has the complete list of entities used in the simulation model.

3.5.1 Raw Material Stage

a. Raw materials that have large variable costs associated across the year are modeled in the simulation. From the case study, the major raw material with seasonal cost is the raw onion. Other raw materials are included as part of other fixed costs. These include raw materials such as cost of cooking flour, cooking oil and spices. This is calculated per can manufactured.
b. There is a lead time of 14 days for raw materials with variable cost to be delivered. Based on the production plan of the month, the number of trucks arriving each day takes into consideration this 14 day lead time. For other raw materials, lead time is assumed to be zero since they are always available and there has never been an instance of them running out.
c. Each truck load corresponds to 50,000 lbs of raw material.
d. It is assumed that there is enough storage space available to store all incoming raw material.

3.5.2 Manufacturing Facility Stage

a. There is a maximum production capacity of 88,000 lbs of finished product every 24 hours. This requires 150,000 lbs of raw ingredients. The rate of production is fixed but reduces due to downtime and raw material availability.

b. The manufacturing facility consists of eight steps that finally lead to the finished product. Since modeling all the eight steps was beyond the scope of this project, it was decided to set the input per minute to the first stage as well as the output per minute from the last stage. Actual data over a six month period was recorded and based on the averages obtained from these, the input and output rates were calculated. The input to the system was 104.17 lbs of raw material per minute, while the output was 61.11 lbs of finished product per minute.

c. Production targets for each day are read from an excel sheet, along with the number of trucks of raw materials that are arriving.

d. Downtime was modeled based on data from an excel sheet when the main bottleneck of the manufacturing facility was down. Data for this was obtained for the period for which the model is being simulated.

e. In the manufacturing facility stage, manufacturing is conducted on a continuous basis to meet the production targets. The production levels achieved are also constantly monitored. At the end of the 3rd day of each week, the achieved production is compared versus that week's target, and on the basis of what proportion of the target has been met, the decision of whether to schedule overtime or not is made.

f. If there is an estimated shortage of less than 50,000 lbs of finished product, then there is no overtime scheduled. If the shortages are lesser than 110,000, then only one day of overtime is scheduled. If the shortages are more than 110,000, then two days of overtime are scheduled. These values are determined as a function of the present week's production level achieved.

3.5.3 Packaging Facility

a. There are two packaging lines that can run independently. Of these, one is used to package two products (A and B), while the other can only package one product (C) at a time.

b. Product A has the highest priority between the three since its demand is the highest. Product C can run independently of A and B. B is only produced if there is enough 'buffer' (i.e., ready processed material to be packaged) for it to be packaged. Also, since the company believes that if product type B and C were unavailable to the customer, they would switch-over to product type A; hence, A is given the highest priority.

c. Packaging can only start when there is a minimum quantity of finished unpackaged product available. The minimum quantity is 4000 lbs of product.. Since there is wastage of less than 5%, wastage has not been modeled into the system.

d. Since the packaging facility rarely has breakdowns, it has not been considered to have downtime.

e. Preventive maintenance costs are considered as fixed costs, and are scheduled only for the weekends. Changeover time from Product A to B is constant at 15 minutes.

3.5.4 Distribution Center

a. There is a lead time of 2 days for the product to be delivered. Since the distribution center ships out product to the retailers every week, this lead time of 2 days is not significant, because the entire product is ready to be shipped out by the start of the next week.

b. If demand in a period is not met, then it is assumed to be part of the demand for the next week.

3.6 Supply Chain Strategies

In order to be able to develop alternative strategies, it is necessary to build a base model which emulates the present supply chain characteristics. The base model is a representation of the actual model that is being utilized at present. The manufacturing and packaging facilities are shut down from the months of February through April because the demands for the products are comparatively lesser and the company wants to reduce overhead costs during those months. The model aims at building inventory from May to meet the huge demand in the months of October and November. Because of this, there is going to be a huge inventory holding cost. Since this base model is unable to meet the entire demand, it becomes necessary to evaluate alternatives. As such the following alternative strategies are proposed and tested.

3.6.1 Uniform Production Model

In most manufacturing facilities where the demand is constant, a uniform production model is considered. In the uniform production model, the entire predicted demand for the time horizon is divided equally for each period. For example, previous year's demand is added to the expected growth rate, and this is divided equally by the total number of periods to obtain the production schedule for each period. Each period will have the same number of shifts scheduled, and no overtime will be scheduled. The expected problems that arise in this model would be inability to meet demands in periods where the demand is extremely large. Also, there would be constant inventory being held especially in months where the demand is less. All these would act against the uniform production model, but it is included as a strategy so that it can be tested for its robustness in meeting demand and the level of variation it can cause to the performance measures such as cumulative variant profit and unmet sales. In the literature review that was conducted, most researchers did not consider uniform production models because it does not account for any variability, and hence of less research value.

3.6.2 Just-in-time (JIT) Production Model

To be able to reduce the inventory being held as well as being able to meet the entire demand in all periods, it becomes necessary to consider a just-in-time production model. The just-in-time production model has a production plan with an objective of meeting the complete demand without stopping production during any month. Production is such that the demand is just met, and hardly any inventory is held. The forecasts are based on previous year's demands and the manufacturing and packaging facilities run throughout the year. It is expected that the inventory built in this model will be less than the previous models, even though the operation costs would be higher. The constraint in being unable to meet demand in this scenario would be production capacity, and hence, it becomes necessary to evaluate production capabilities.

3.6.3 Increased Production Capacity for Base Model

The increased production capacity model was built with an intention of evaluating the greater percentage of demand that could be met while following the base model's production plan. This means that the manufacturing and packaging facilities are shut down from the months of February through May, but since there is increased production capacity, they should be able to meet the demand completely. The additional cost that would be associated in this stage would be the cost in building an additional packaging facility, and costs associated with operating this new facility. The additional operation cost, labor cost and other relevant costs have been included in the evaluation of the performance measures. Based on the data provided by the case study company, the cost of buying additional packaging equipment was obtained and expected to depreciate over an eight year period. This depreciation rate is the rate that is considered by the case study company for their analysis.

3.6.4 Increased Production Capacity for Just-in-time (JIT) Model

The objective of this model is to reap the benefits of both the just-in-time production model as well as the increased production capacity model. The production capacity is doubled, and the manufacturing and packaging facility work throughout the year following just-in-time production so that the demand is met. This model will have more overhead costs associated with it, but in effect, it is necessary to consider if this contribution will largely affect the cumulative variant profit.

Chapter 4

Results

The simulation model of each strategy was run for a period of 52 weeks with each week consisting of seven days. Hence, the simulation model depicted the supply chain for 364 days. The company that was used in the case study calculated their profit every quarter. The simulation models calculated the weekly cumulative variant profit, and at the end of fifty two periods, calculated overall cumulative variant profit. Although computation time was considerably larger than with a model built having the basic period consisting of weeks rather than days, the accuracy and flexibility of this system is higher. Appendix D gives the detailed data on each period for the different strategies.

The calculation of overall cumulative profit is described in section 4.1. This is followed by details and inferences from each strategy. Certain parameters such as order cut costs, total labor costs and total sales were discussed separately since they changed the dynamics of each strategy. This is followed by a comparison of the cumulative variant profit across all strategies. A mixed strategy is proposed where periods are grouped together to yield the maximum cumulative variant profit. A mixed strategy is more dynamic and involves switching between strategies so as to yield better cumulative variant profit. This chapter concludes with a summary and interpretation of results.

4.1 Calculation of Overall Cumulative Variant Profit

Overall cumulative variant profit was calculated using Equations 3.1 and 3.2. The input to the simulation model consisted of the production plan in each of the simulation strategies. The production plan specified the production quantities of each product in each period. Outputs from the simulation model provided values for the indirect variables discussed in section 3.2.2. These helped calculate the direct variables needed in calculating the overall cumulative variant profit. For each strategy the overall cumulative profit was calculated by period. In order to be able to represent the models more consistently, the periods have each been grouped into four. Appendix D gives the details of each strategy by period, while the rest of this chapter groups periods by four so as to make representation of results more understandable.

4.2 Base Model Strategy

The base model is the current strategy that is used by the company in the case study. There is no investment cost to use this strategy. The production plan, sales, order cut costs, inventory holding cost, regular labor cost and other fixed costs of the base model strategy are discussed below. Appendix A has the Automod code that was used to build the base model.

4.2.1 Production Plan

From Figure 3, it is seen that between periods 5 through16, there is no production at all, and the manufacturing facility shuts down. The objective is to build enough inventory in periods 1-4 so as to meet the demands of period 5-16. Demand in periods 5-16 is forecasted to be the least, and hence the only incurred cost would be inventory holding cost. Periods 21-28 and 37-34 are the periods where the production is at its maximum.

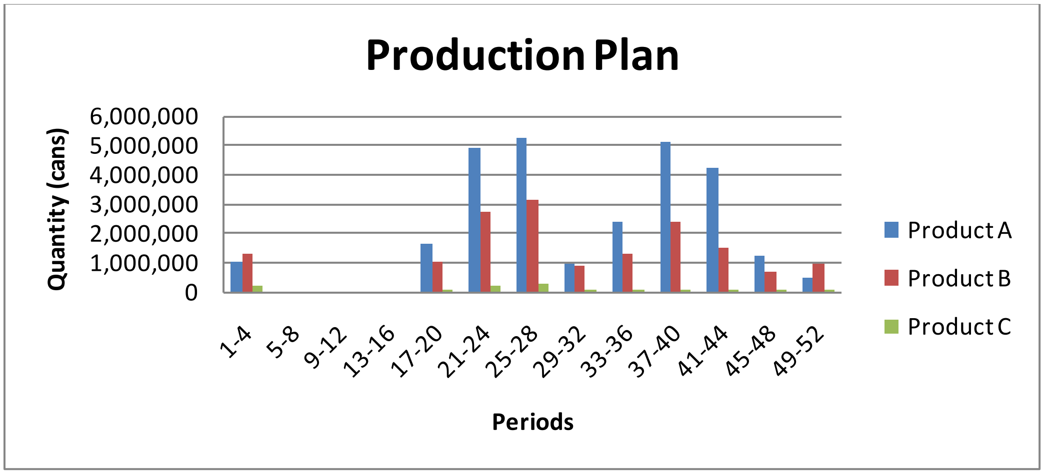

Figure 3. Production Plan for Base Model

Table 9 shows the values of the quantities of each product that are manufactured in the grouped periods. It can be seen that the maximum production capacity for the products A, B and C are in the range of five million, three million and two hundred ninety thousand units, respectively. This occurs in period 25-28 since the demands in this period and the following periods are expected to be the largest in volume. There is a reduction in production during periods 29-32 so as to reduce the inventory holding cost. But this is followed by a short period of increased production during periods 37-44.

Table 9. Production Plan for Base Model

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	1,013,952	1,326,036	226,120
5-8	0	0	0
9-12	0	0	0
13-16	0	0	0
17-20	1,634,640	1,017,536	101,588
21-24	4,890,520	2,736,084	232,880
25-28	5,226,192	3,120,284	290,208
29-32	933,840	886,072	45,932
33-36	2,405,020	1,336,172	46,336
37-40	5,098,184	2,398,620	34,640
41-44	4,213,724	1,480,488	35,436
45-48	1,249,108	687,016	30,748
49-52	459,624	967,092	15,412
Total	**27,124,804**	**15,955,400**	**1,059,300**

4.2.2Demand Met / Sales

From figure 4, it can be seen that the maximum sales is during periods 37-44. Sales for the rest of the months are considerably less, and it can be observed that the sales during periods 37-44 account for more than eighty percent of the sales of the whole year.

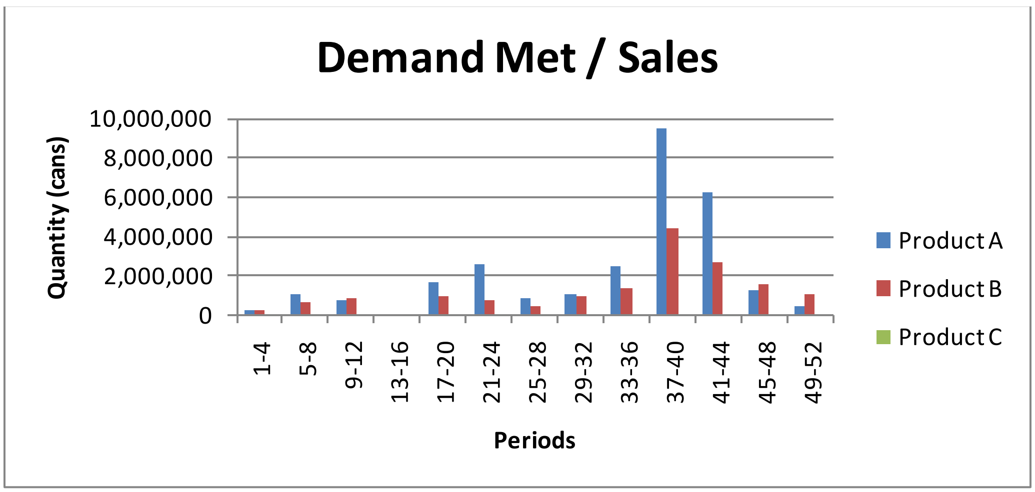

Figure 4. Demand Met for Base Model

Table 10 shows the values of sales in the grouped periods. There were no sales of products A and B during periods 13-16 while there was a substantial amount of sales for product C. The reason for no sales during the periods of 13-16 could have been because of stock outs that led to a complete depletion of inventory from the warehouse. Maximum sales were in periods 37-44 for items A and B. Product C, on the other hand, had sales that were consistent throughout the year except for periods 5-8 and 49-52 as seen in Table 10.

Table 10. Demand Met for Base Model

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,852
5-8	1,057,316	666,076	28,436
9-12	730,189	863,204	64,560
13-16	0	0	44,928
17-20	1,635,200	1,017,940	48,932
21-24	2,597,013	775,736	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	9,461,460	4,451,476	64,288
41-44	6,269,319	2,693,628	64,472
45-48	1,249,500	1,616,440	72,340
49-52	459,900	1,023,188	16,304
Total	**28,129,725**	**16,331,192**	**657,068**

4.2.3 Order Cut Costs

The product with the most order cuts was product A. Product C on the other hand did not face any order cuts because its demand in terms of volume was the least. Product B did have order cuts, but they were minimal and would not have affected the overall cumulative variant profit as much as product A would have. The periods with the most order cuts were period 13-20 and period 45-52.

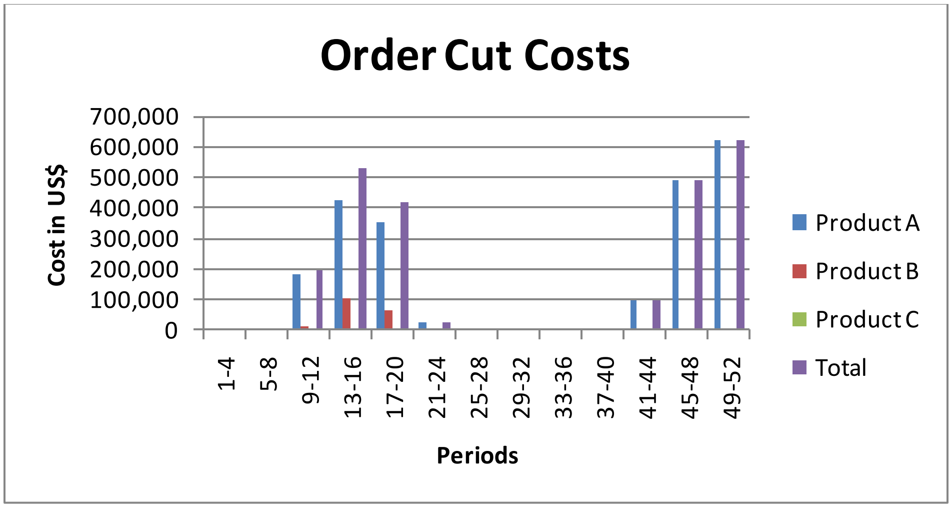

Figure 5. Order Cut Costs for Base Model

Table 11 shows the periods with the maximum order cut costs. For the period week 9 through 20, order cuts were due to both product A and product B totaling over 1.14 million USD. Periods 21-52 had order cuts only for product A that totaled 1.23 million USD. In total, 2.3 million USD was lost from the overall cumulative variant profit due to order cuts.

Table 11. Order Cut Costs for Base Model

Period	Product A (cans)	Product B (cans)	Total (cans)
9-12	180,455	13,212	193,667
13-16	426,350	102,868	529,217
17-20	354,495	66,899	421,393
21-24	25,871	0	25,871
41-44	96,564	0	96,564
45-48	490,622	0	490,622
49-52	620,629	0	620,629

4.2.4 Inventory Holding Cost

Since product A had the largest volume, it was the product that resulted with maximum holding cost. Periods 25-40 had the largest holding cost with comparable contribution from both product A and B.

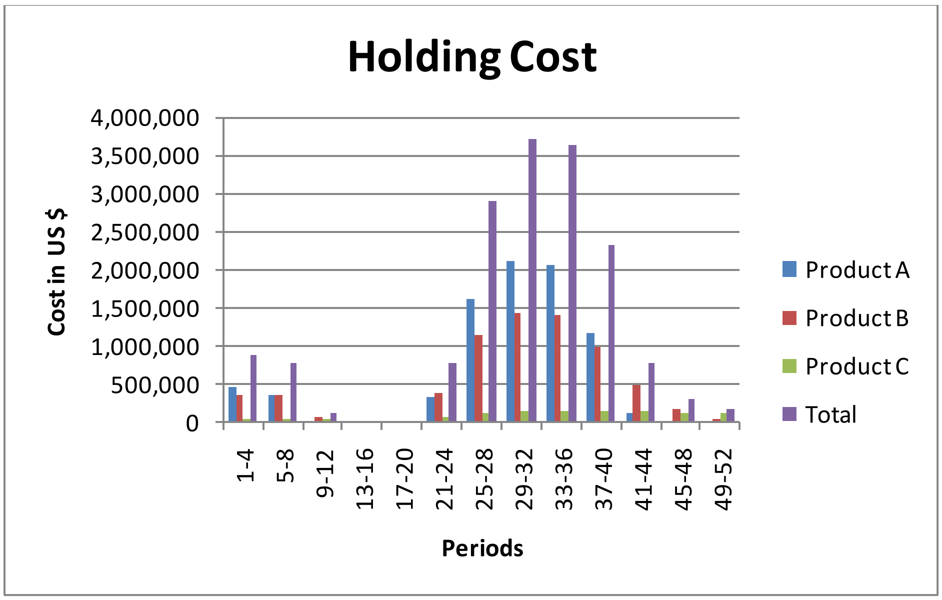

Figure 6. Inventory Holding Cost for Base Model

In Figure 6, it is seen that a total of 16.4 million USD was spent on inventory holding cost. On average per four periods, there was 1.2 million dollars in inventory. The periods with the maximum quantity of products in inventory was periods 25-40. In these periods alone, the inventory holding cost was 12.6 million USD. This is close to 76% of the holding cost across the fifty two periods. The inventory holding cost in the rest of the periods is substantially less, and does not contribute significantly to overall cumulative variant profit.

Table 12. Inventory Holding Cost for Base Model

Period	Product A (cans)	Product B (cans)	Product C (cans)	Total (cans)
1-4	477,312	365,856	35,126	878,294
5-8	360,342	356,154	50,559	767,055
9-12	6,844	71,876	34,326	113,046
13-16	0	0	17,686	17,686
17-20	0	0	22,875	22,875
21-24	325,629	375,783	64,921	766,332
25-28	1,615,213	1,153,828	135,301	2,904,343
29-32	2,115,430	1,442,684	163,292	3,721,405
33-36	2,070,473	1,411,116	161,934	3,643,523
37-40	1,181,221	991,450	155,727	2,328,399
41-44	121,700	502,762	146,443	770,904
45-48	0	171,692	134,687	306,379
49-52	0	49,112	129,553	178,665

4.2.5 Regular Labor Cost

Since there was no production during the periods 5-16, there was no labor cost in these months. The maximum money that was spent on labor was in periods 21-28 and 37-44.

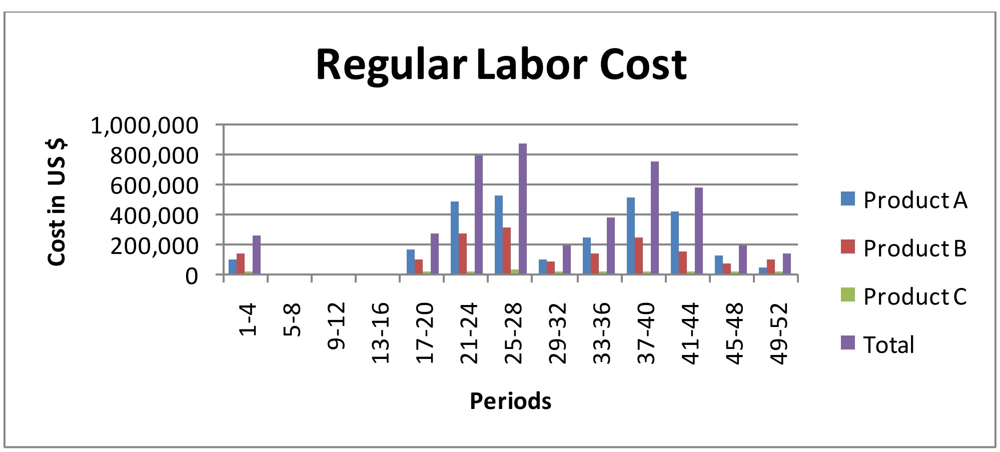

Figure 7. Regular Labor Cost for Base Model

Table 13. Regular Labor Cost for Base Model

Period	Product A (cans)	Product B (cans)	Product C (cans)	Total (cans)
1-4	101,360	132,748	22,608	256,716
17-20	163,450	101,794	10,138	275,382
21-24	489,020	273,658	23,270	785,948
25-28	522,550	312,158	29,002	863,710
29-32	93,380	88,704	4,579	186,663
33-36	240,450	133,672	4,608	378,730
37-40	509,810	239,932	3,456	753,198
41-44	421,330	148,148	3,542	573,020
45-48	124,880	68,838	3,053	196,771
49-52	45,920	96,712	1,526	144,158

In total, 4.4 million USD was spent on regular labor cost. This is substantially less when we consider the overall cumulative variant profit. Also half of this is during the periods 21-28 and 37-40.

4.2.6 Overtime Costs

Overtime was present only during select periods in which the production plan was consistently large. The total amount of money spent on overtime cost was 364,000 USD.

Table 14. Overtime Costs for Base Model

Period	Overtime Cost (US $)
21-24	104,000
25-28	104,000
37-40	104,000
41-44	52,000

4.2.7 Overall CVP

In the base model strategy, there were periods that yielded losses. These periods were 1-4, 13-16 and 25-28. In fact, period 25-28 had losses of up to 3 million USD. In total, the losses were 3.8 million USD. The highest cumulative variant profit was made in periods 37-44.

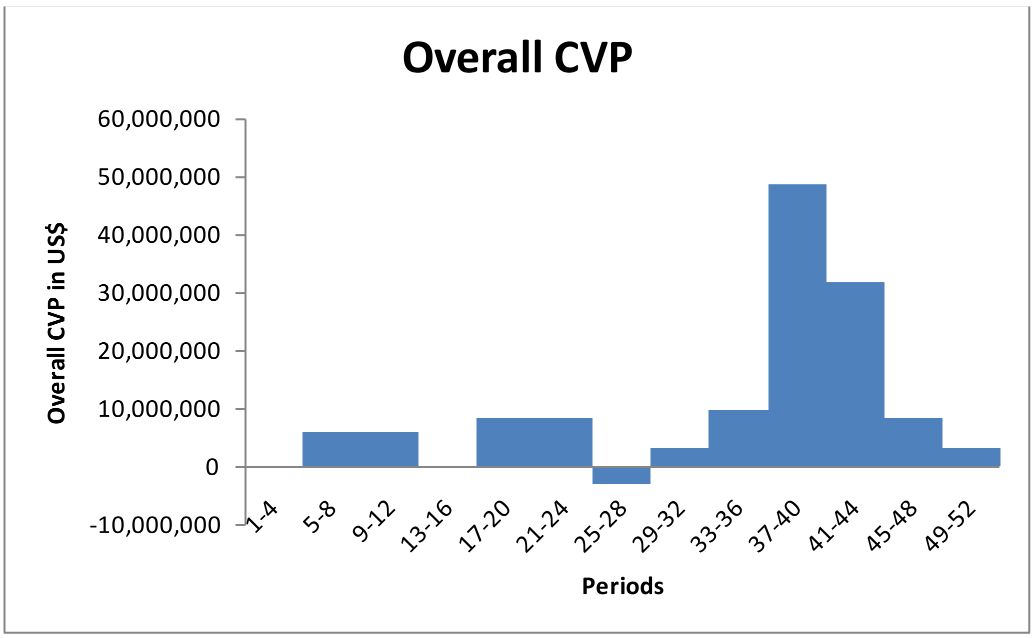

Figure 8. Overall CVP for Base Model

Periods 37-44 made the maximum cumulative variant profit, and it was seen that this was close to 62.16% of the entire cumulative variant profit. Certain periods resulted in losses and the cumulative variant loss was -3,830,674. These were periods 1-4, 13-16 and 25-28. This is a significant loss and the production plan should be modified so that this loss is eliminated through implementation of another strategy.

Table 15. Overall CVP for Base Model

Period	Overall CVP (in USD)
1-4	-430,203
5-8	6,081,307
9-12	5,785,262
13-16	-192,421
17-20	8,278,485
21-24	8,431,541
25-28	-3,208,050
29-32	3,099,770
33-36	9,747,853
37-40	48,658,684
41-44	31,879,650
45-48	8,333,711
49-52	3,086,775

In Figure 8, it can be observed that there is no fixed pattern in the overall cumulative variant profit. The model has a production plan that is inconsistent, and there are no visible trends in the overall cumulative variant profit. In short, the strategy is highly unpredictable and inconsistent. The overall cumulative variant profit across all periods was found to be 129,552,363 USD.

4.3 Uniform Production Model

The uniform production strategy is one of the proposed strategies where there is uniform production across all periods irrespective of demand. The inventory holding cost associated with this would be the largest. The trends from this model are very predictable since the production plan is fixed and won't adapt to changing sales. There will be issues on holding finished goods inventory as well as raw ingredients inventory.

4.3.1 Production Plan

Since the production plan for each period is fixed, each period will produce the same amount of each individual product. The rates for these production requirements were obtained as being the average outcome of scheduling ten shifts in a period. They were based off actual data that suggested these would be the average values for production for ten shifts. Table 16 shows the splits and consistency within the periods.

Table 16. Production Plan for Uniform Production Model

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	2,403,370	1,256,246	50,544
5-8	2,403,370	1,256,246	50,544
9-12	2,403,370	1,256,246	50,544
13-16	2,403,370	1,256,246	50,544
17-20	2,403,370	1,256,246	50,544
21-24	2,403,370	1,256,246	50,544
25-28	2,403,370	1,256,246	50,544
29-32	2,403,370	1,256,246	50,544
33-36	2,403,370	1,256,246	50,544
37-40	2,403,370	1,256,246	50,544
41-44	2,403,370	1,256,246	50,544
45-48	2,403,370	1,256,246	50,544
49-52	2,403,370	1,256,246	50,544
Total	**31,243,810**	**16,331,198**	**657,072**

4.3.2 Demand Met / Sales

Demand met was the largest in periods 37-44. The remaining periods had demand met in each period as less than 2.6 million units of product A and 1.5 million units of product B.

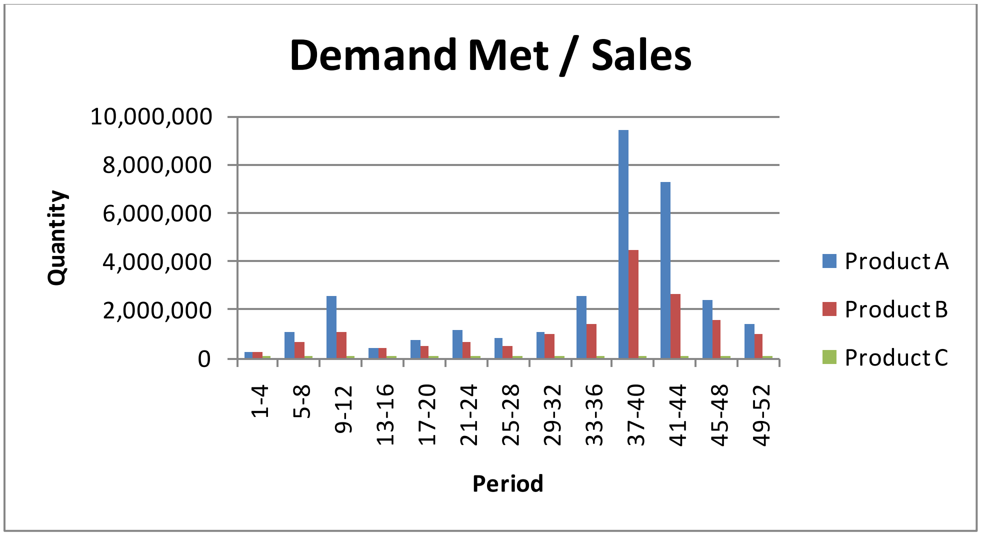

Figure 9. Demand Met/ Sales for Uniform Production Model

As can be followed in Table 17, the sales for product A, B and C in period 37-40 were 9.46 million, 4.45 million and 64,288 units, respectively. In total, 31.24 units of product A were sold, 16.3 million units of product B were sold and 657,068 units of product C were sold. Comparing with the base model, it is evident that there were more sales using this strategy for product A alone, but sales remained the same for products B and C.

Table 17. Demand Met/ Sales for Uniform Production Model

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,760
5-8	1,057,316	666,076	28,528
9-12	2,577,864	1,127,440	64,560
13-16	455,776	400,164	44,928
17-20	787,316	490,088	48,932
21-24	1,142,496	639,188	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	9,461,460	4,451,476	64,288
41-44	7,289,919	2,693,628	53,688
45-48	2,403,800	1,616,440	50,688
49-52	1,398,037	1,023,188	48,740
Total	**31,243,812**	**16,331,192**	**657,068**

4.3.3 Order Cut Costs

Table 18 shows the order cut costs. It is seen that there were no order cuts for product B and the order cuts for product C were minimal. Product A had order cut costs that were significant compared to the other two products. The total order cut costs were 190,936 USD.

Table 18. Order Cut Costs for Uniform Production Model

Period	**Product A (cans)**	**Product B (cans)**	**Product C (cans)**	**Total (cans)**
41-44	18,830	0	1,123	19,953
45-48	142,214	0	4,863	147,078
49-52	21,619	0	2,287	23,905

This is not substantial in comparison to the overall cumulative variant profit. The only ill-effect of this would be negative customer satisfaction. Measures will have to be taken so as to appease the customers. Also, the order cuts were in periods 41-52 which are the periods right after those with largest demand volumes across all the periods. The most significant contribution would be to take measures to see if order cuts can be minimized in periods 45-48.

4.3.4 Inventory Holding Cost

The holding cost per product is given for all the periods in Figure 10. It is observed that the holding cost increases linearly every period until the peak periods and then tends to decrease due to sales. It should be noted that holding cost for product A and product B are higher than that of product C.

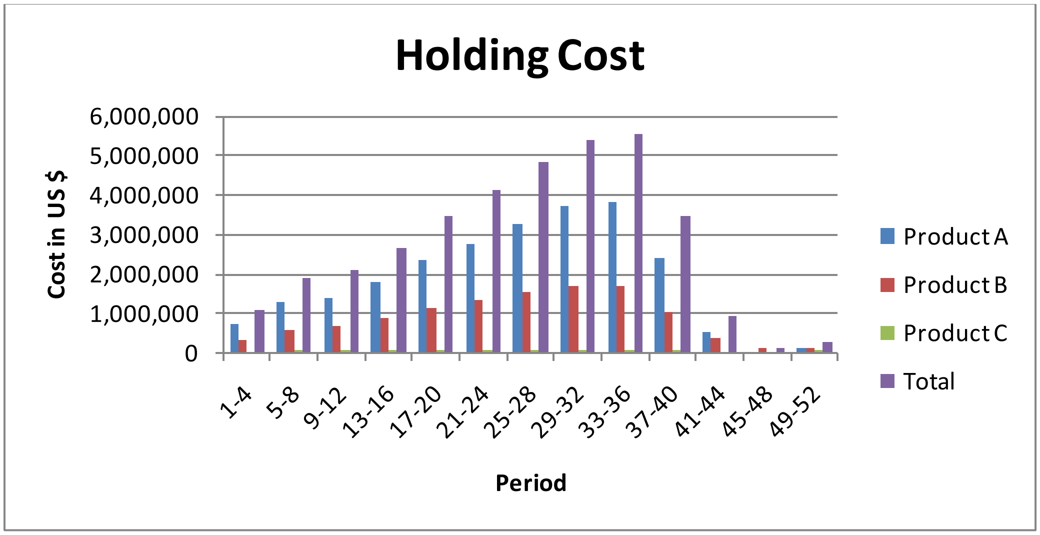

Figure 10. Inventory Holding Cost for Uniform Production Model

The inventory holding cost in this model would be the most significant failure of this model. It can be seen that the holding cost keeps building every period until the peak season. Holding cost in periods 25-36 is the highest.

Table 19. Inventory Holding Cost for Uniform Production Model

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
1-4	755,212	351,688	2	1,106,902
5-8	1,285,602	584,814	4,421	1,874,837
9-12	1,412,368	681,521	4,317	2,098,206
13-16	1,781,085	868,320	3,804	2,653,209
17-20	2,338,144	1,124,408	4,847	3,467,399
21-24	2,784,383	1,339,885	4,314	4,128,582
25-28	3,252,429	1,567,349	4,895	4,824,673
29-32	3,707,818	1,706,332	5,054	5,419,203
33-36	3,838,897	1,703,100	5,112	5,547,109
37-40	2,410,477	1,045,289	2,592	3,458,358
41-44	541,142	374,511	0	915,653
45-48	0	130,112	0	130,112
49-52	126,332	133,627	156	260,115

From Table 19, the total inventory holding cost was 35.88 million USD. The peak periods with the maximum cost were from periods 21-36. On average, 2.76 million USD was spent every four periods on inventory holding cost.

4.3.5 Regular Labor Cost

Since the production plan was to uniformly produce across the year irrespective of the demand, the regular labor cost would remain consistent across all periods. In total, 4.82 million USD was spent across all periods on regular labor cost. For any four periods, USD 240,380 was spent on regular labor cost for product A, while USD 125,664 was spent on product B and USD 5069 for product C.

4.3.6 Overtime Cost

There were no overtimes scheduled in this strategy, and hence no money was spent on overtime costs. The savings in this aspect was significantly less since the base strategy spent only 364,000 USD, across all periods in terms of overtime costs.

4.3.7 Overall CVP

There were significant profits in periods 37-44. But unfortunately, many periods had huge losses. Periods such as 1-4, 13-20 and 25-28 resulted in losses that totaled 5.43 million USD which is a significant loss.

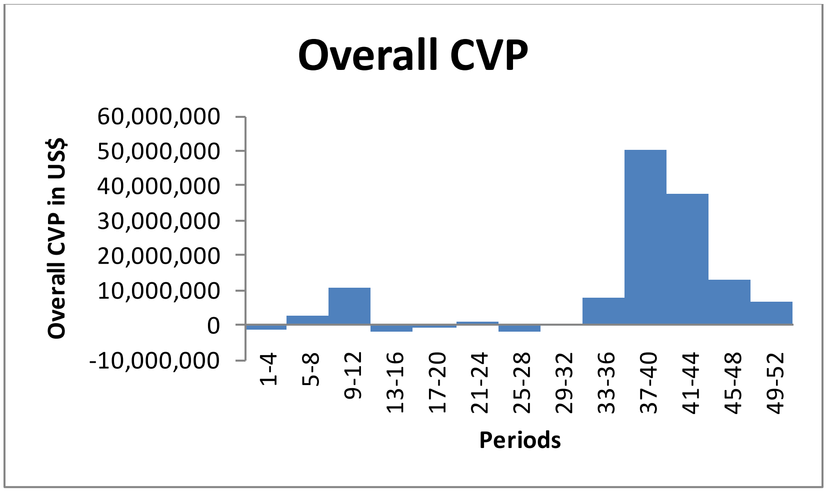

Figure 11. Overall CVP for Uniform Production Model

In fact, it is only during the periods of 33-52 that the company makes any profit. This means that sufficient capital will be necessary to sustain the supply chain until then.. It would be difficult to follow this strategy from a practical perspective.

Table 20. Overall CVP for Uniform Production Model

Period	**Overall CVP (USD)**
1-4	-1,366,881
5-8	2,498,870
9-12	10,844,574
13-16	-1,636,109
17-20	-638,975
21-24	823,561
25-28	-1,784,697
29-32	212,758
33-36	7,916,335
37-40	50,139,431
41-44	37,936,401
45-48	12,962,280
49-52	6,739,921
Total	**124,647,469**

From the Table 20, it can be seen that the uniform production model makes an overall cumulative variant profit of 124.65 million USD. This is lesser than that of the base model. The main drawback of this model was its huge inventory holding cost. This strategy resulted in 35.88 million USD being spent on inventory holding cost across the whole year. This strategy can be used in scenarios where the overtime cost is huge and the objective would be to have the least overtime cost. Also, when there is a need to have minimum order cut costs, this scenario would be useful. If the penalty for an order cut was much more significant than the one set in this case study, then this strategy can be a potentially successful strategy. In scenarios where the holding cost is less, this strategy would result in higher profits.

4.4 Just-in-Time (JIT) Model

The just-in-time strategy developed for this case study has an objective of meeting the demand as per the forecast, with constant check on trying to reduce the inventory holding cost. Its limitation would be the capacity constraints which could be solved by equipment purchase. This is considered as another strategy.

4.4.1 Production Plan

The production plan is similar to a make-to-order scenario where production is mainly to meet the needs of the customer, with an objective of minimizing the inventory holding cost. However, since it is known well in advance that the demands during the peak months cannot be met by the present production capacity a small quantity of inventory is maintained throughout the year so that any surges in demand can be dealt with. The production plan aimed at making the forecasted amount with maximum production during the periods of 37-44.

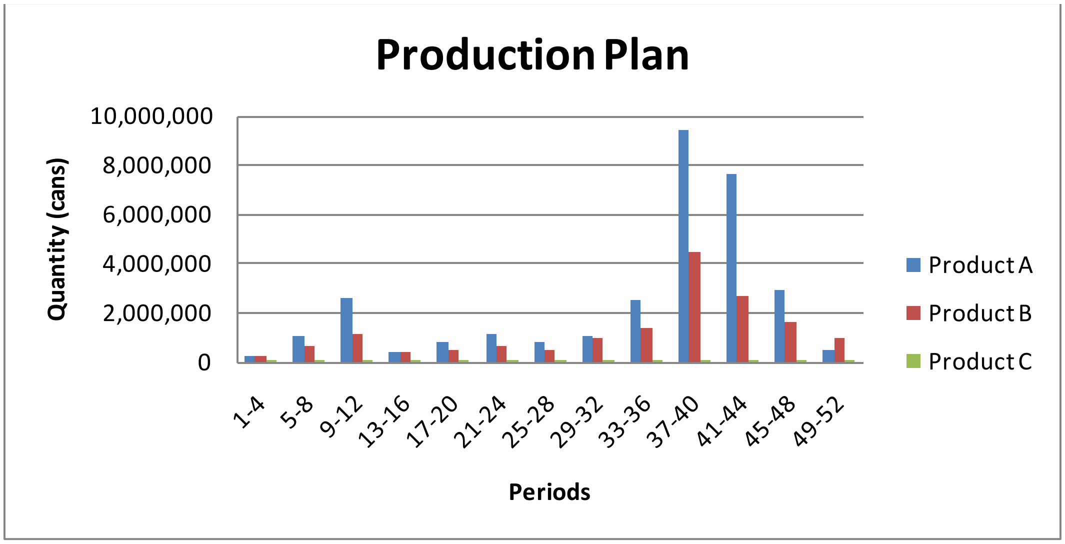

Figure 12. Production Plan of JIT Model

As can be followed in Table 21, the maximum production was during the periods 37-40 when 9.46 million units of product A, 4.45 million units of product B and 64,288 units of product C were manufactured. The total number of products A, B and C made across all the periods were 31.24 million, 16.33 million and 657,078 units respectively.

Table 21. Production Plan for JIT Model

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,852
5-8	1,057,316	666,076	28,436
9-12	2,577,864	1,127,440	64,560
13-16	455,776	400,164	44,928
17-20	787,316	490,088	48,932
21-24	1,142,496	639,188	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	9,461,460	4,451,476	64,288
41-44	7,666,520	2,693,628	64,472
45-48	2,938,952	1,616,440	72,340
49-52	486,284	1,023,188	16,304
Total	**31,243,812**	**16,331,192**	**657,068**

4.4.2 Demand Met / Sales

The sales were the highest in periods 33-44. There were also more sales of product A than B and C combined. The remaining periods had sales that were comparatively less, and was less than half of the sales made during the peak periods.

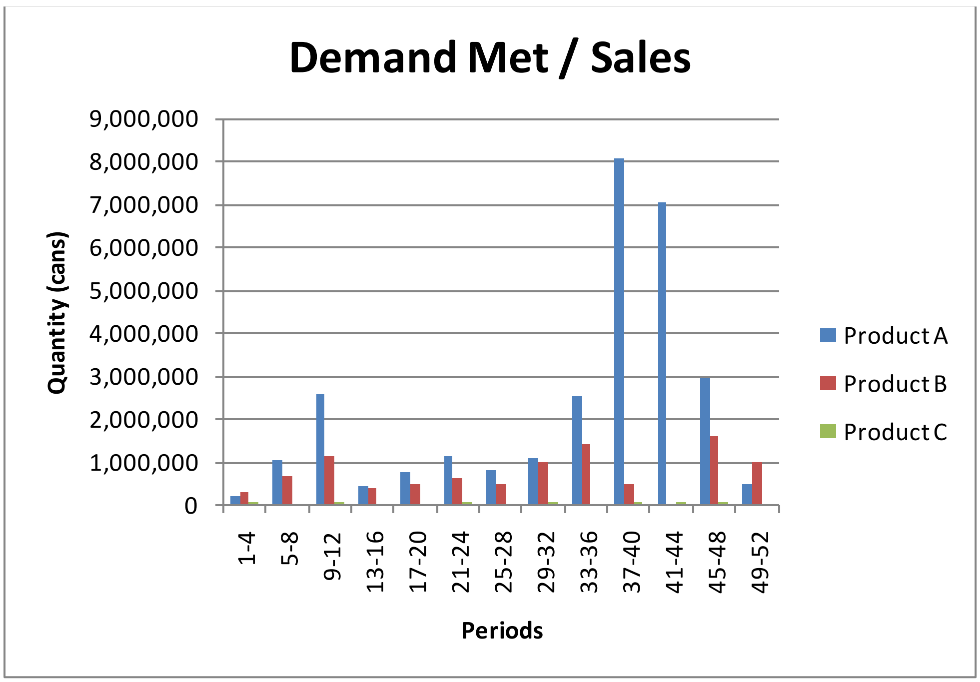

Figure 13. Demand/Sales for JIT Model

During periods 37-40, the sales peaked at 8.06 million units for product A, while it peaked to 1.62 million units for product B during periods 45-48. Product C had maximum sales also during periods 45-48 at 72,340 units. It was also seen that during periods 41-44, product B was stocked out and hence there was no sales. All the demands would have resulted in order cut costs.

Table 22. Demand Met for JIT Model

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,852
5-8	1,057,316	666,076	28,436
9-12	2,577,864	1,127,440	64,560
13-16	455,776	400,164	44,928
17-20	787,316	490,088	48,932
21-24	1,142,496	639,188	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	8,059,304	507,780	64,288
41-44	7,056,000	0	64,472
45-48	2,939,300	1,617,000	72,340
49-52	486,500	1,024,100	16,304
Total	**29,231,700**	**9,695,340**	**657,068**

4.4.3 Order Cut Costs

There were significant order cut costs during the peak season, and this totaled 5.52 million USD. The major product that contributed to this was product B, and this was because preference in resource utilization in the model was given to product A since its demand was higher. It is not good to have losses as large as this in terms of order cuts, and the most feasible option would be to have inventory of product B during the peak months.

Table 23. Order Cut Costs for JIT Model

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
37-40	120,119	454,879	0	574,997
41-44	356,746	1,125,443	0	1,482,189
45-48	402,492	1,327,395	0	1,729,887
49-52	402,439	1,327,239	0	1,729,677

4.4.4 Inventory Holding Cost

Table 24 shows the inventory holding cost for each product. Since the objective of the JIT strategy was to keep a minimal amount of inventory throughout the year, it was seen that a total of 4.3 million USD was spent on inventory holding cost. This is substantially much less than the other models and results in larger inventory turnover and the supply chain will have enough liquid cash if it needs to use in different projects.

Table 24. Inventory Holding Cost for JIT Model

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
1-4	320,092	160,112	48	480,252
5-8	320,190	160,328	78	480,596
9-12	320,284	160,693	135	481,112
13-16	320,437	160,906	221	481,564
17-20	320,548	161,169	262	481,979
21-24	320,691	161,600	271	482,562
25-28	320,773	162,068	321	483,163
29-32	320,854	162,389	353	483,596
33-36	321,033	162,484	401	483,918
37-40	32,155	0	472	32,627
41-44	0	0	507	507
45-48	0	0	559	559
49-52	0	0	610	610

The inventory holding cost is constant for periods 1-36 which are the non peak months. When comparing with the order cut costs, if inventory was built such that there were no order cut costs in the peak periods, then the model would be more profitable.

4.4.5 Regular Labor Cost

The regular labor cost peaks in periods where the demand is the highest (periods 37-44)

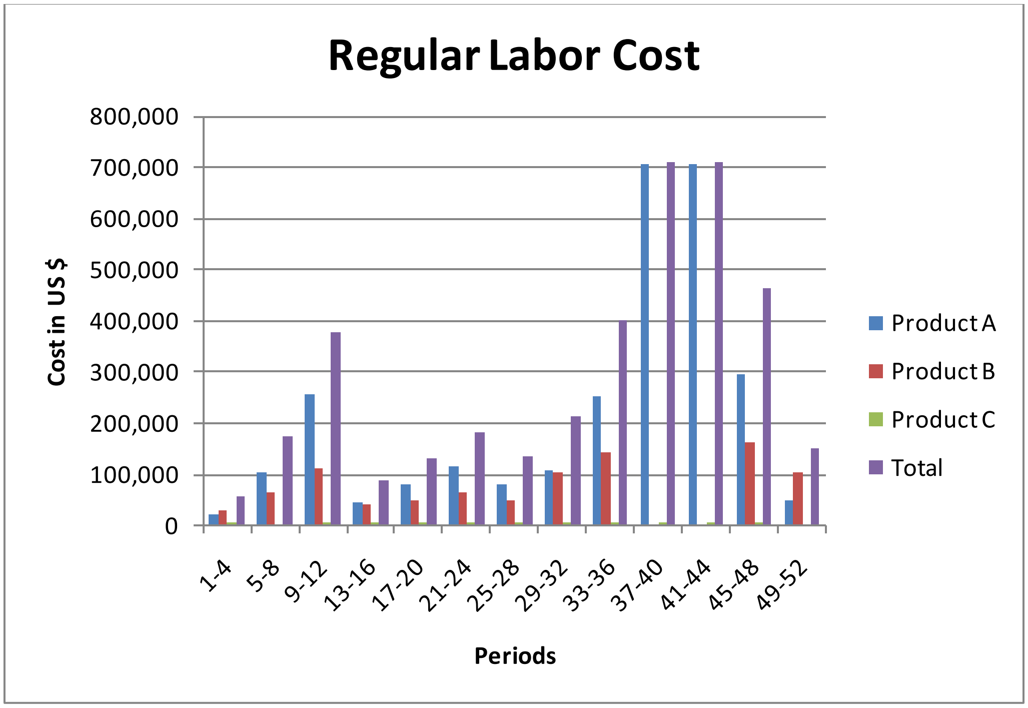

Figure 14. Regular Labor Cost for JIT Model

From the Table 25, it can be seen that during the peak periods, 712,000 USD on average was spent on labor. The total spent on labor was 3.81 million USD. This is much less than the uniform production strategy and the base model.

Table 25. Regular Labor Cost for JIT Model

Period	Product A	Product B	Product C	Total
1-4	22,820	29,876	5,098	57,794
5-8	105,770	66,682	2,851	175,303
9-12	257,810	112,882	6,480	377,172
13-16	45,640	40,040	4,522	90,202
17-20	78,750	49,126	4,896	132,772
21-24	114,310	64,064	5,443	183,817
25-28	82,040	49,126	4,579	135,745
29-32	107,730	102,256	5,299	215,285
33-36	254,520	141,372	4,925	400,817
37-40	705,583	0	6,451	712,034
41-44	705,600	0	6,451	712,051
45-48	293,930	161,700	7,258	462,888
49-52	48,650	102,410	1,642	152,702

4.4.6Overtime Cost

Overtime cost was not a significant factor since only a total of 147,000 USD was spent on overtime cost across all periods. Most of the periods did not have any overtime scheduled, and it is only during the peak periods that overtime is ever scheduled. Hence, this strategy minimizes the cost of overtime.

Table 26. Overtime Cost for JIT Model

Period	Overtime Cost
37-40	104,000
41-44	104,000
45-48	39,000

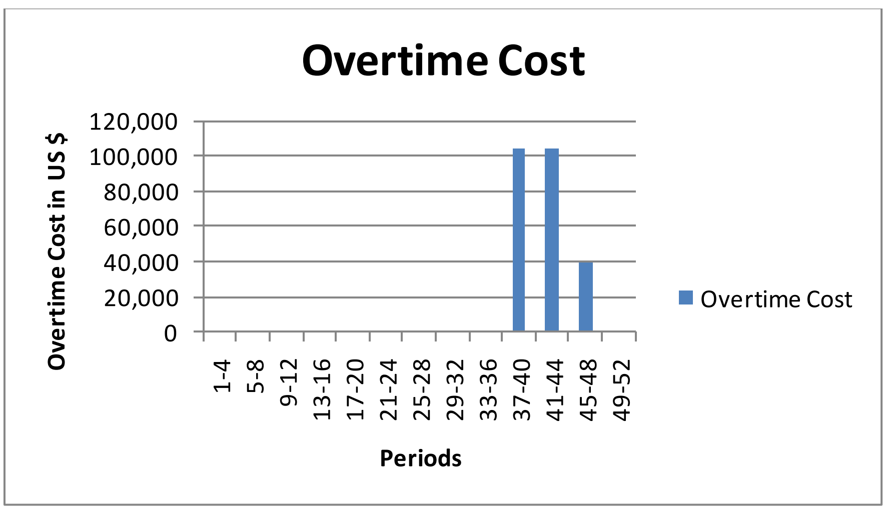

Figure 15. Overtime Cost for JIT Model

4.4.7 Overall CVP

The overall cumulative variant profit never goes negative. It peaks during the periods 37-44. The remaining months do have a cumulative variant profit, but it is less since the sales during those months is less. Table 27 gives the overall cumulative variant profit by period. It is seen that the cumulative variant profit is more consistent here, and there is never a period where the cumulative variant profit surges to huge quantities such as in periods 37-40 of the uniform production strategy where it peaks to 50 million USD.

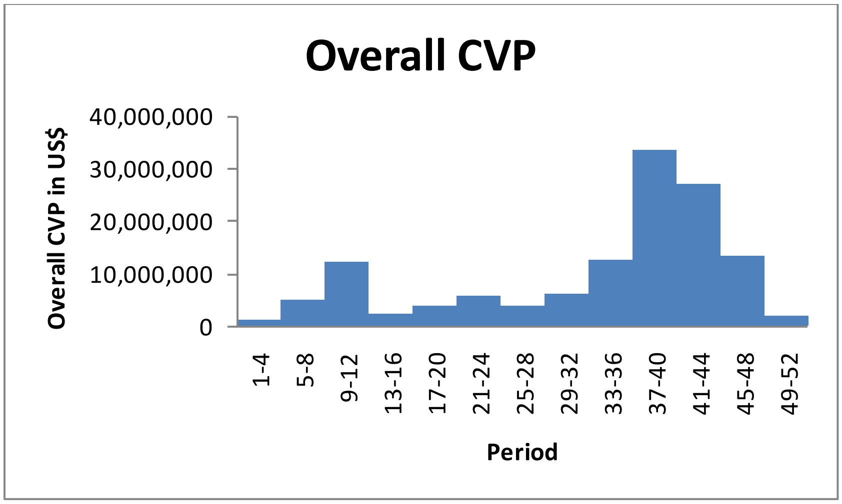

Figure 16. Overall CVP of JIT Model

Table 27. Overall CVP of JIT Model

Period	Overall CVP (in USD)
1-4	1,321,734
5-8	5,190,067
9-12	12,388,215
13-16	2,407,147
17-20	3,930,978
21-24	5,696,448
25-28	4,071,450
29-32	6,142,612
33-36	12,778,229
37-40	33,763,209
41-44	26,936,416
45-48	13,502,779
49-52	2,232,829

This strategy is more consistent and predictable. There is never a period in which the cumulative variant profit goes negative. Its potential lies in its low inventory holding costs and labor costs. Its major drawback was the huge cost that resulted due to order cuts. This reduced the overall cumulative variant profit by 5.52 million USD which was significant considering the other strategies.

4.5 Base Model with Doubled Capacity

One of the major drawbacks of the base model is its limited capacity. If the capacity was increased by buying additional packaging equipment at the manufacturing facility, it was proposed that there would be lesser order cut costs and the strategy would be able to yield better overall cumulative variant profit. It should be noted that to increase the capacity, there should be investment in buying equipment. Based on the depreciation of the item, a cost should be subtracted from the overall cumulative variant profit of the model. Details of this depreciation cost are discussed below under the overall cumulative variant profit section.

4.5.1 Production Plan

The production plan is the same as the production plan for the base model. There is no production during the periods 5-16, and then there is consistent production during the peak periods.

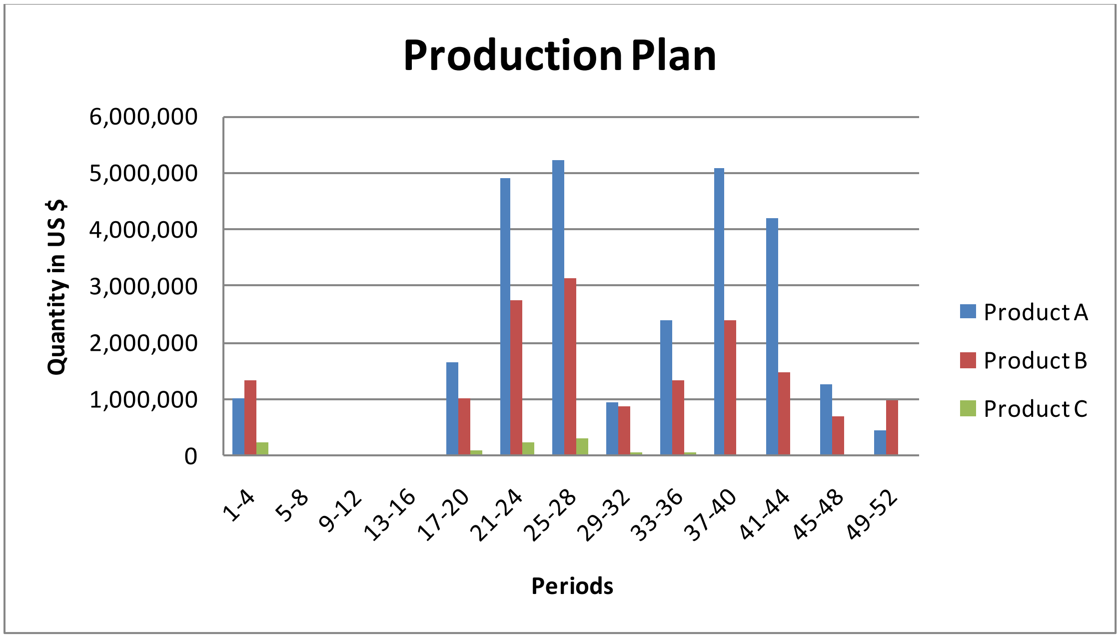

Figure 17. Production Plan for Base Model with Doubled Capacity

It can be seen that the maximum production capacity for the products A, B and C are in the range of five million, three million and two hundred ninety thousand units, respectively. This occurs in periods 25-28 since the demands in this period and the following periods are expected to be the largest in volume. One of the characteristics of the base model is that during periods 5-16 there is no production. Inventory that is built prior to these periods should be enough to meet demands during the periods of shut down. It is expected that order cuts should not result due to capacity constraints. There is a reduction in production during periods 29-32 so as to reduce the inventory holding cost. But this is followed by a short period of increased production during periods 37-44.

Table 28. Production Plan for Base Model with Doubled Capacity

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	1,013,952	1,326,036	226,120
5-8	0	0	0
9-12	0	0	0
13-16	0	0	0
17-20	1,634,640	1,017,536	101,588
21-24	4,890,520	2,736,084	232,880
25-28	5,226,192	3,120,284	290,208
29-32	933,840	886,072	45,932
33-36	2,405,020	1,336,172	46,336
37-40	5,098,184	2,398,620	34,640
41-44	4,213,724	1,480,488	35,436
45-48	1,249,108	687,016	30,748
49-52	459,624	967,092	15,412
Total	**27,124,804**	**15,955,400**	**1,059,300**

4.5.2 Demand Met / Sales

The sales of the base model with doubled capacity should be better than that of the base model without any capacity increase. By comparing figures 4 and 18, it was seen that the sales in both models is very similar.

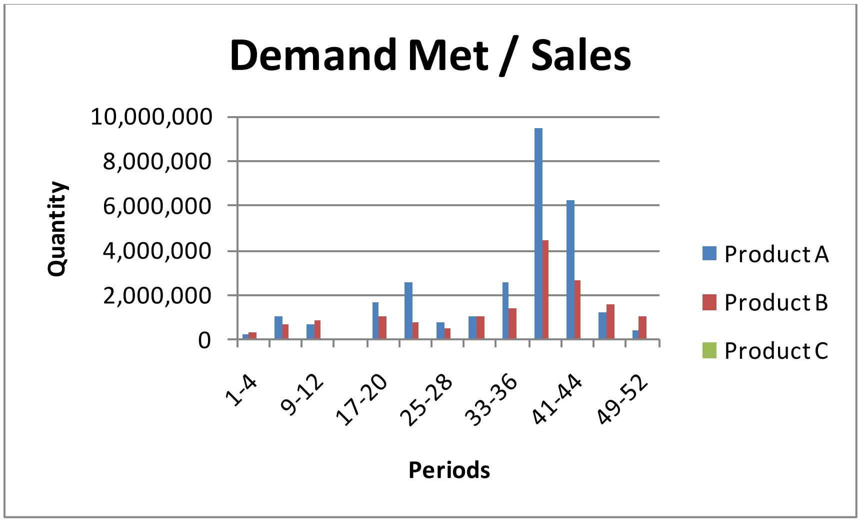

Figure 18. Demand Met for Base Model with Doubled Capacity

By comparing table 9 and table 30, it was observed that the gain in sales from the base model strategy to the base model strategy with increased capacity was a mere 6,825 USD. This is not significant, and occurs in periods 9-16. There is also a slight increase in sales during periods 45-52.

Table 29. Demand Met for Base Model with Doubled Capacity

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,852
5-8	1,057,316	666,076	28,436
9-12	732,814	863,204	64,560
13-16	1,400	0	44,928
17-20	1,635,200	1,019,480	48,932
21-24	2,594,038	774,196	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	9,461,460	4,451,476	64,288
41-44	6,273,694	2,693,628	64,472
45-48	1,250,200	1,616,440	72,340
49-52	460,600	1,023,188	16,304
Total	**28,136,550**	**16,331,192**	**657,068**

4.5.3 Order Cut Costs

It was expected that the order cut costs would be reduced but there was only a marginal reduction in order cut costs. Order cut costs remained significantly high in periods 13-20 and 49-52. Order cuts in periods 13-20 were due to lack of sufficient stock of products A, B and C being manufactured before the shut down. This was also the case in periods 41-52. Increased capacity would aid only in months where production is unable to keep up with demand. Hence, these order cuts could have even been prevented in the base model had sufficient stock been built instead of deciding to lower the production volumes.

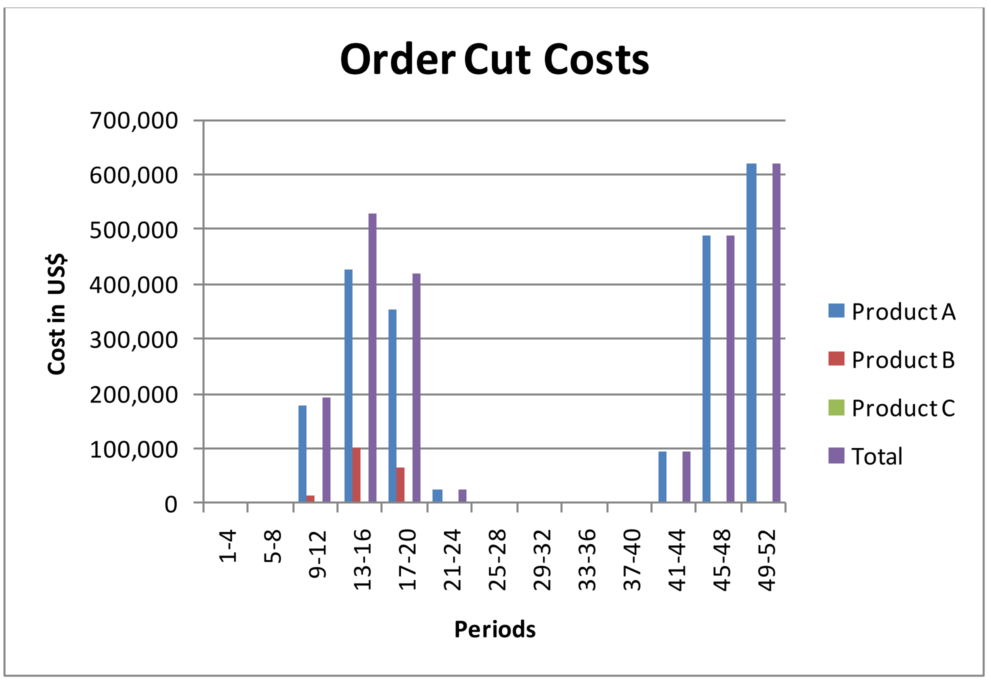

Figure 19. Order Cut Cost for Base Model with Doubled Capacity

By comparing table 27 and table 30, it was seen that the savings in order cut costs was only 4,306 USD, which is significantly less. There were still order cuts which resulted in a total cost of 2.377 million USD.

Table 30. Order Cut Costs for Base Model with Doubled Capacity

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
9-12	180,140	13,212	0	193,352
13-16	425,807	102,868	0	528,675
17-20	353,900	66,706	0	420,606
21-24	25,713	0	0	25,713
41-44	96,126	0	0	96,126
45-48	489,659	0	0	489,659
49-52	619,526	0	0	619,526

4.5.4 Inventory Holding Cost

When comparing the inventory holding cost, the holding cost in the base model strategy and the base model with increased capacity was similar. The periods with the maximum and minimum inventory holding cost remained the same.

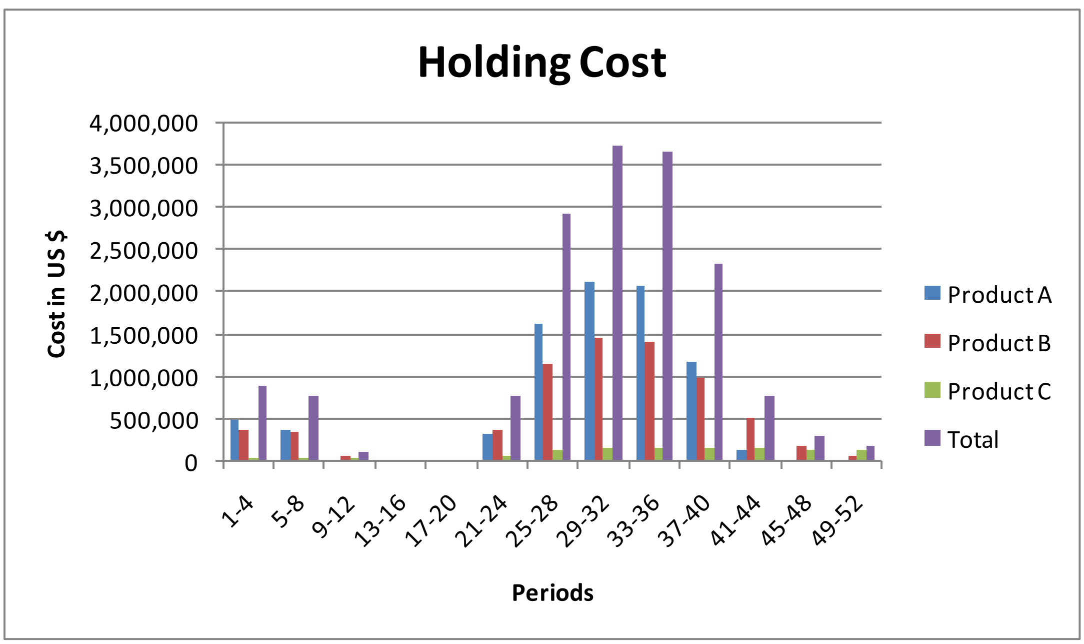

Figure 20. Inventory Holding Cost for Base Model with Doubled Capacity

When comparing Tables 31 and 33, there was more holding cost associated with product A and C in this strategy than in the base model without increased capacity. Product B, on the other hand, had lesser inventory holding cost using this model. In total 25,000 USD was spent extra in this model in terms of inventory holding cost than the base model.

Table 31. Inventory Holding Cost for Base Model with Doubled Capacity

Period	Product A	Product B	Product C	Total
1-4	477,508	365,856	35,149	878,513
5-8	360,762	356,154	50,639	767,556
9-12	6,984	71,876	34,499	113,359
13-16	0	0	17,951	17,951
17-20	0	0	23,232	23,232
21-24	326,469	376,584	65,370	768,423
25-28	1,616,389	1,155,122	135,785	2,907,296
29-32	2,116,746	1,444,162	163,776	3,724,684
33-36	2,071,873	1,412,595	162,476	3,646,943
37-40	1,182,621	992,929	156,361	2,331,911
41-44	122,400	504,240	147,111	773,751
45-48	0	173,479	135,412	308,891
49-52	0	51,083	130,314	181,396

4.5.5 Regular Labor Cost

The regular labor cost associated with this model was also similar to the base model. In fact when comparing the two models it was seen that the regular labor cost in this model was slightly higher than the base model without increased capacity by 2,692 USD. This was due to the periods where extra production had to be scheduled so as to keep up with demand since production capacity was increased.

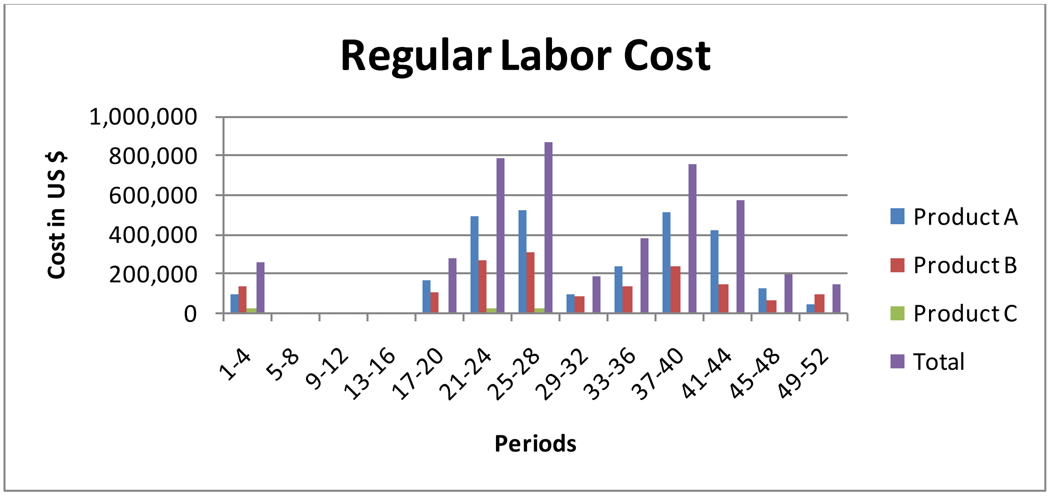

Figure 21. Regular Labor Cost for Base Model with Doubled Capacity

The extra production capacity results in more regular labor cost, but it will also result in lesser overtime cost than the base model without capacity increase.

Table 32. Regular Labor Cost for Base Model with Doubled Capacity

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
1-4	101,500	132,748	22,637	256,885
5-8	140	0	58	198
9-12	140	0	58	198
13-16	140	0	58	198
17-20	163,520	101,948	10,195	275,663
21-24	489,160	273,812	23,328	786,300
25-28	522,620	312,312	29,030	863,962
29-32	93,520	88,704	4,608	186,832
33-36	240,520	133,672	4,666	378,858
37-40	509,880	239,932	3,514	753,326
41-44	421,400	148,148	3,571	573,119
45-48	125,020	68,992	3,110	197,122
49-52	46,060	96,712	1,555	144,327

4.5.6 Overtime Cost

The only periods with overtime costs were periods 21-24 and periods 25-28, and the total overtime cost was found to be 91,000 USD. The overtime cost for the base model strategy without increased capacity is 364,000 USD. This is a significant difference with the base model, and hence the major contribution to improving the overall cumulative variant profit would be reduction in the overtime costs.

4.5.7 Overall CVP

Overall cumulative variant profit was found to be 129,820,936 USD. This is more than the overall cumulative variant profit of the base model without any increase in capacity. It should be noted that to double the packaging capacity, there will be additional cost since new equipment must be bought. Each equipment has a yearly depreciation cost that is associated with it, and hence this percentage depreciation cost must be subtracted from the overall cumulative variant profit of the strategies that aim to double capacity. For doubling the packaging capacity for the case study company, it was seen that the additional cost would be seven million US dollars. Since the equipment is expected to depreciate over a period of eight years, the final Overall Cumulative Variant Profit becomes 128,945,935 USD.

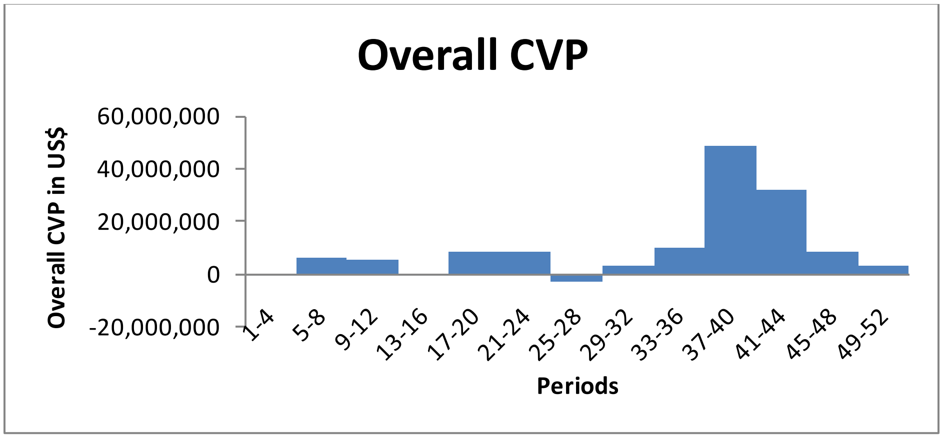

Figure 22. Overall CVP for Base Model with Doubled Capacity

There were periods that registered a loss and these periods resulted in the overall cumulative variant profit reducing by 3.78 million USD. These were periods 1-4, 13-16 and 25-28. The main drawback of this model is that although capacity is increased, the timing of the production is too late to meet demands adequately. There were order cuts in periods 9-20 as well as from 41-44 because of this. Having no production in periods 5-16 can be successful when adequate inventory is built. Hence, increasing the production capacity of the base model will not yield in higher overall cumulative profit unless sufficient stock is built in periods prior to shut down as well as where production volumes is planned to reduce. The major issue with the base model is in the decision of timing of when to produce.

Table 33. Overall CVP for Base Model with Doubled Capacity

Period	Overall CVP (USD)
1-4	-431,410
5-8	6,079,650
9-12	5,796,419
13-16	-186,734
17-20	8,281,118
21-24	8,474,749
25-28	-3,160,483
29-32	3,095,504
33-36	9,743,687
37-40	48,758,426
41-44	31,949,181
45-48	8,333,387
49-52	3,087,442

4.6 JIT Model with Doubled Capacity

The JIT model with doubled capacity was suggested since it would make the supply chain more dynamic, and produce only during the periods when the demand is the highest.

4.6.1 Production Plan

The production plan is similar to the production plan of the JIT model. An average value of inventory is maintained until the peak season where production is increased so that demand is met with an objective of not having any order cut costs.

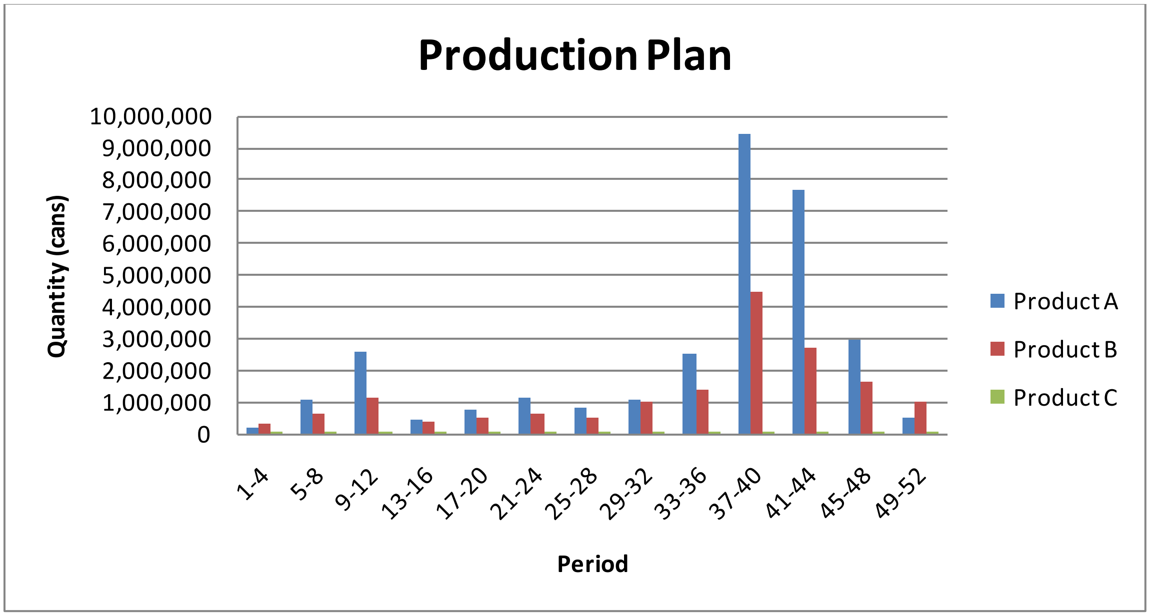

Figure 23. Production Plan for JIT Model with Doubled Capacity

From Table 34, it should be noted that the peak periods where production is the highest is during periods 37-44.

Table 34. Production Plan for JIT Model with Doubled Capacity

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,852
5-8	1,057,316	666,076	28,436
9-12	2,577,864	1,127,440	64,560
13-16	455,776	400,164	44,928
17-20	787,316	490,088	48,932
21-24	1,142,496	639,188	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	9,461,460	4,451,476	64,288
41-44	7,666,520	2,693,628	64,472
45-48	2,938,952	1,616,440	72,340
49-52	486,284	1,023,188	16,304
Total	**31,243,812**	**16,331,192**	**657,068**

4.6.2 Demand Met / Sales

Figure 24 shows the demand that was met in all the periods. As expected, the demand is higher during the peak periods 37-44. In other periods, the figures were comparatively less.

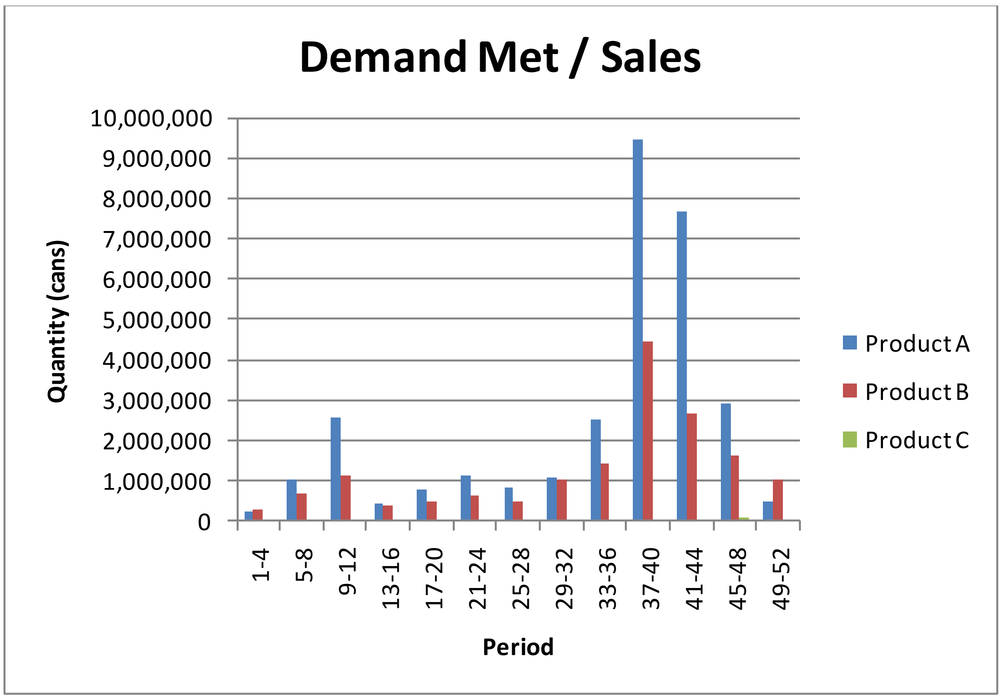

Figure 24. Demand Met for JIT Model with doubled capacity

The demand that was met in all the periods is higher than the demand in the other models. From Table 35, it can be seen that a total of 31.24 million units of product A were sold which is much more than the 29.23 million units sold in the JIT model. Similar to this, 16.33 million units of product B were sold against 9.70 million units of product B in JIT model. This increase in sales was an indication that the overall cumulative variant profit for this system is expected to be larger than the other strategies.

Table 35. Demand Met for JIT Model with Doubled Capacity

Period	Product A (cans)	Product B (cans)	Product C (cans)
1-4	228,020	298,200	50,852
5-8	1,057,316	666,076	28,436
9-12	2,577,864	1,127,440	64,560
13-16	455,776	400,164	44,928
17-20	787,316	490,088	48,932
21-24	1,142,496	639,188	54,404
25-28	820,352	489,788	45,556
29-32	1,076,928	1,021,840	52,972
33-36	2,544,528	1,413,676	49,024
37-40	9,461,460	4,451,476	64,288
41-44	7,666,520	2,693,628	64,472
45-48	2,938,952	1,616,440	72,340
49-52	486,284	1,023,188	16,304
Total	**31,243,812**	**16,331,192**	**657,068**

4.6.3 Order Cut Costs

It was found that there were no order cuts, and hence there was no effect on the cumulative variant profit. It should be noted that one of the drawbacks of the JIT model was the huge number of order cuts worth 5.52 million USD that affected the overall cumulative variant profit. This problem is solved by increasing the production capacity in the JIT model. No order cuts mean that all the demand was met, and hence from the perspective of order cuts, this is the most feasible model. No order cut costs, apart from implying sufficient production capacity, also means efficient coordination in the supply chain. It is one of the major objectives of any supply chain to have minimum order cuts since it would mean better customer satisfaction.

4.6.4 Inventory Holding Cost

Inventory holding cost for the model was expected to be higher since the production capacity increased, and hence there was more inventory kept at hand even if the inventory turnover was much larger. The total inventory holding cost in this model was found to be 6.32 million USD which was higher than the JIT model by 1.95 million USD. Also, it was observed that the average inventory kept was 486,016 USD. This is significantly less, which means that the supply chain will have more cash flow in the system.

Table 36. Inventory Holding Cost for JIT Model with Doubled Capacity

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
1-4	320,148	160,112	128	480,388
5-8	320,386	160,636	251	481,273
9-12	320,704	161,494	400	482,598
13-16	320,941	161,892	579	483,411
17-20	321,192	162,462	653	484,308
21-24	321,559	163,078	720	485,357
25-28	321,725	163,855	863	486,443
29-32	321,946	164,360	929	487,235
33-36	322,209	164,456	1,034	487,698
37-40	322,517	164,902	1,140	488,559
41-44	322,910	165,440	1,175	489,526
45-48	323,273	165,717	1,227	490,218
49-52	323,582	166,275	1,336	491,193

4.6.5 Regular Labor Cost

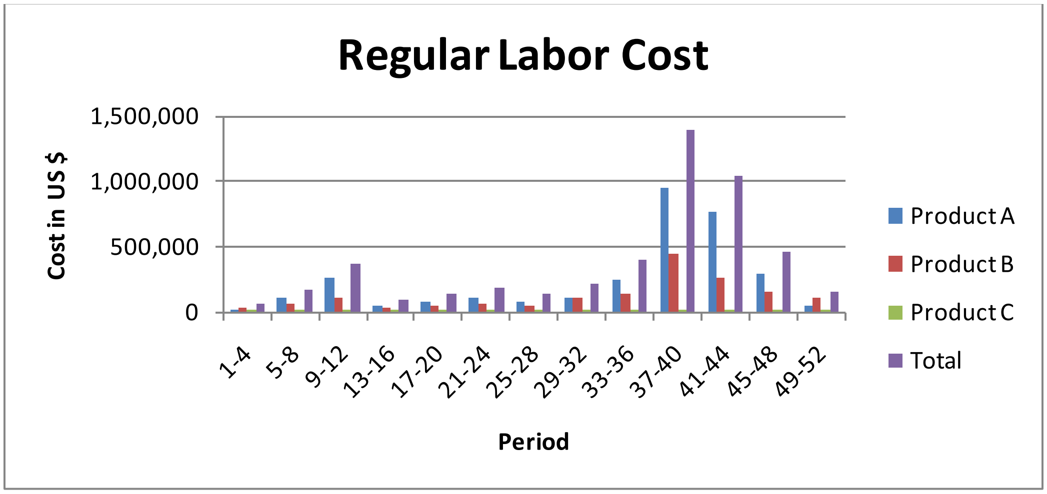

Figure 25. Regular Labor Cost for JIT Model with Doubled Capacity

In total, 4.83 million USD was spent on regular labor cost in the 52 periods. This is significantly more than the JIT model, but it is mainly because a higher number of products were manufactured in the facility over the 52 periods.

Table 37. Regular Labor Cost for JIT Model with Doubled Capacity

Period	Product A (USD)	Product B (USD)	Product C (USD)	Total (USD)
1-4	22,820	29,876	5,126	57,822
5-8	105,840	66,836	2,880	175,556
9-12	257,880	113,036	6,509	377,425
13-16	45,640	40,040	4,550	90,230
17-20	78,820	49,280	4,896	132,996
21-24	114,380	64,064	5,472	183,916
25-28	82,040	49,280	4,608	135,928
29-32	107,800	102,256	5,299	215,355
33-36	254,520	141,372	4,954	400,846
37-40	946,260	445,368	6,451	1,398,079
41-44	766,780	269,500	6,451	1,042,731
45-48	294,000	161,700	7,258	462,958
49-52	48,720	102,564	1,670	152,954

4.6.6 Overtime Cost

The overtime cost associated with this strategy was found to be 156,000 USD for the entire year. This occurred in the periods 37-44. These were the periods with the highest sales, which meant that production was at its maximum. Hence, there is not a significant amount of money spent on overtime.

4.6.7 Overall CVP

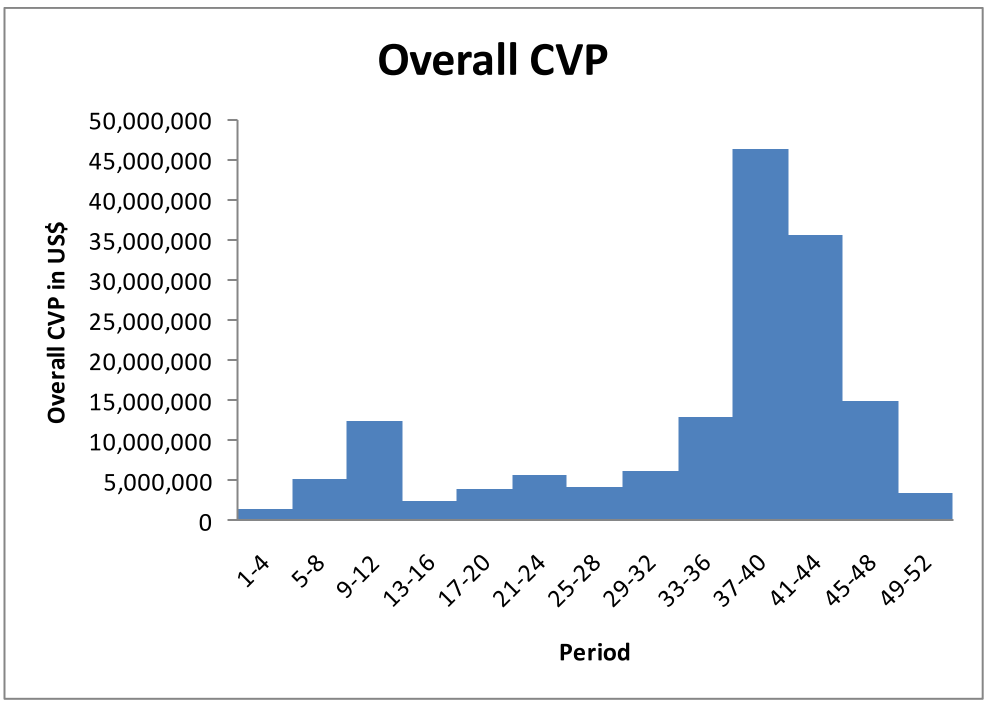

Figure 26. Overall CVP for JIT Model with Doubled Capacity

There was no period where the overall cumulative variant profit was negative. It should also be noted that in order to double capacity, there will be an investment cost associated while implementing this strategy. Each equipment has a yearly depreciation cost that is associated with it, and hence this percentage depreciation cost must be subtracted from the overall cumulative variant profit of the strategies that aim to double capacity. For doubling the packaging capacity for the case study company, it was seen that the additional cost would be seven million US dollars. Since the equipment is expected to depreciate over a period of eight years, the final Overall Cumulative Variant Profit was reduced to 153,218,553 USD from 154,093,553 USD.

Table 38. Overall CVP for JIT Model with Doubled Capacity

Period	Overall CVP (USD)
1-4	1,321,429
5-8	5,187,911
9-12	12,385,250
13-16	2,405,132
17-20	3,927,338
21-24	5,693,074
25-28	4,067,100
29-32	6,138,563
33-36	12,774,280
37-40	46,303,574
41-44	35,644,187
45-48	14,778,565
49-52	3,467,152

Comparing the overall cumulative variant profit across all models, it was observed that the JIT model with doubled capacity would yield the highest overall cumulative variant profit.

4.7 Comparison of Certain Parameters Across All Strategies

4.7.1 Total Demand Met

Table 39 shows the demand met using the different strategies. Both uniform production model and the JIT model with doubled capacity had the maximum sales and met most of the demand. Other strategies failed in meeting demand, and this resulted in reducing their overall cumulative variant profit. One major drawback of the JIT model is that it met only slightly over half of the demands met by the other strategies for product B. All demands for product C were met in all strategies.

Table 39. Comparison of Demand Met Across All Strategies

Total Demand Met (Sales)	Base Model	Uniform Production Model	JIT Model	Base Model with Doubled Capacity	JIT Model with Doubled Capacity
Product A	28,129,725	31,243,812	29,231,700	28,136,550	31,243,812
Product B	16,331,192	16,331,192	9,695,340	16,331,192	16,331,192
Product C	657,068	657,068	657,068	657,068	657,068

4.7.2 Other Parameters

Each strategy has its own merits and demerits. Some parameters behave differently in each strategy, if we understood the relation between the parameters and the strategy, then it is possible to apply the correct strategy to the different models. Table 40 shows certain parameters and their respective values for the various strategies.

Table 40. Comparison of Parameters Across All Strategies

Type of Strategy	Base Model	Uniform Production Model	JIT Model	Base Model with Doubled Capacity	JIT Model with Doubled Capacity
Order Cut Cost (USD)	2,377,962	190,944	5,516,750	2,373,657	0
Inventory Holding Cost (USD)	16,418,908	35,884,359	4,373,046	16,443,907	6,318,208
Other fixed Cost (USD)	21,732,876	23,988,494	19,224,626	21,746,397	24,163,991
Regular Labor Cost (USD)	4,414,296	4,824,466	3,808,581	4,416,987	4,826,797
Overtime Labor Cost (USD)	364,000	0	247,000	91,000	156,000
Total Labor Cost (USD)	4,778,296	4,824,466	4,055,581	4,507,987	4,982,797
Overall CVP (USD)	129,552,363	124,647,469	130,362,112	128,945,935	153,218,553

In order to compare any parameter across the different strategies, it was necessary to do a t-test to determine if the difference between the means is statistically significant or not. For all the tests, a confidence interval of 95% with $\alpha = 0.05$ was taken. The number of samples was considered as 52 representing the 52 different periods. If $p > \alpha$, it would mean that we would fail to reject the null hypothesis and say that the difference in means is statistically insignificant. If $p < \alpha$, it would imply that the null hypothesis is rejected, and we can conclude that the difference in means is statistically significant. It should be noted that being statistically insignificant does not imply practically insignificant for all cases.

Table 41. P-Value for Order Cut Costs

P-Value	Base Model	Uniform Production Model	JIT Model	Base Model with Doubled Capacity	JIT Model with Doubled Capacity
Base Model	-	0.000	0.817	0.499	-
Uniform Production Model	0.000	-	0.000	0.000	0.000
JIT Model	0.817	0.000	-	0.000	0.000
Base Model with Doubled Capacity	0.499	0.000	0.020	-	0.323
JIT Model with Doubled Capacity	-	0.000	-	-	-

From Table 41, the different p-values can be noted when comparing the different strategies against each other for order cut costs. It was observed that there is a statistical significance between the base model and the uniform production model as well as the JIT model since their respective p-value is lesser than $\alpha = 0.05$. But order cut costs between the base model and the base model with doubled capacity was not significant since both models had similar production schedules that resulted in similar order cut costs. Since the JIT model with doubled capacity had no order cut costs, there is no need to compare it with the other systems because it is by far the best option in terms of order cut costs.

Order cut costs are found to be the least in the JIT model with doubled capacity and the uniform production model. If investment cost is an issue, and the inventory holding cost is not a major factor unlike the case study company, then the uniform production model works to yield a good cumulative variant profit. If customer satisfaction is the primary objective of the company, then having the least order cuts would be the most crucial factor. The base model does have an acceptable value of overall cumulative variant profit, but there is a significant loss in terms of order cut costs. Doubling the capacity of the base model only reduces the order cut costs slightly without bringing a significant change to the order cut costs. Surprisingly, it is the JIT model that has the most order cut costs. Although its overall cumulative variant profit is the best among the strategies without any investment cost, a loss of 5.52 million USD in order cuts would mean dissatisfied customers who may not return in future periods. This would be unacceptable and would be a hasty decision to take. No order cut costs in the JIT model with doubled capacity means that this strategy had the most satisfied customers. It also means that in future periods, the customer orders may increase solely on customer satisfaction. Hence, with respect to order cut costs, the best strategy to opt for would be the JIT model with doubled capacity.

Table 42. P-Values for Inventory Holding Cost

P-Value	Base Model	Uniform Production Model	JIT Model	Base Model with Doubled Capacity	JIT Model with Doubled Capacity
Base Model	-	0.000	0.001	0.994	0.000
Uniform Production Model	0.000	-	0.000	0.000	0.000
JIT Model	0.001	0.000	-	0.000	0.000
Base Model with Doubled Capacity	0.994	0.000	0.000	-	0.000
JIT Model with Doubled Capacity	0.00	0.000	0.000	0.000	-

Table 42 shows the p-values for inventory holding cost across the different strategies. There is a statistical significance between the means in inventory holding cost across all the strategies except between the base model and the base model with doubled capacity. The statistical significance between the strategies implies that the inventory holding cost varies significantly across the strategies. Since the base model and the base model with doubled capacity has similar production plans, their difference in means of inventory holding cost is not statistically significant.

Inventory holding cost is a major cost factor that brings down the feasibility of the uniform production model. Warehouse space is expensive and having large investment in terms of finished product tied up in inventory adds to cost. In a scenario where the inventory holding cost is not an issue, then the uniform production model would still be a strategy to consider. The base model does not have acceptable inventory targets since the value does not significantly change even when the production capacity is increased. By comparing the JIT model and the JIT model with doubled capacity, it was observed that at times it would be better to have more inventory at hand, and a slight increase in the inventory levels might result in larger sales. Hence, finding the perfect level of acceptable inventory becomes crucial for maximizing profit. Having a real low inventory target may not be the best solution always.

Other fixed cost incorporates costs such as transportation cost, marketing and sales cost, advertising cost, product promotion cost and other employee salary costs. Since this is a fixed cost that depends on the quantity of products sold, it is bound to be higher if more products are sold. There would be no way to reduce this cost unless more units of products are sold and hence improving the overall cumulative variant profit. Regular labor cost also behaves in the same pattern, and the real benefit in having higher regular labor cost would be the savings in terms of reduced overtime cost.

Overtime cost was not a significant factor in deciding the overall cumulative variant profit, but if the per unit cost of labor went higher, then it would be worth considering ways to reduce it. The base model had a huge overtime cost, but doubling capacity meant a reduction in overtime cost. Hence, if the supply chain faces huge overtime costs, then increasing the capacity of the production units can help reduce overtime cost.

Overall cumulative variant profit is much higher for the JIT model with doubled capacity and shows an increment of over 20% from the other strategies. Hence, this is the best strategy to consider for this supply chain. Its major advantage was reduced overtime cost and having no order cut costs.

4.8 Variation of CVP Across Strategies

Table 43 shows the variation of overall cumulative variant profit across all strategies in each of the periods. Also, the total overall cumulative profit with and without equipment cost is also calculated. Since it is the base model with doubled capacity as well as the JIT model with doubled capacity that have equipment investment cost, there is a reduction in the actual overall cumulative profit.

Table 43. Variation of CVP Across All Strategies

Overall Cumulative Variant Profit (USD)					
Period	**Base Model**	**Uniform Production Model**	**JIT Model**	**Base Model with Doubled Capacity**	**JIT Model with Doubled Capacity**
1-4	-430,203	-1,366,881	1,321,734	-431,410	1,321,429
5-8	6,081,307	2,498,870	5,190,067	6,079,650	5,187,911
9-12	5,785,262	10,844,574	12,388,215	5,796,419	12,385,250
13-16	-192,421	-1,636,109	2,407,147	-186,734	2,405,132
17-20	8,278,485	-638,975	3,930,978	8,281,118	3,927,338
21-24	8,431,541	823,561	5,696,448	8,474,749	5,693,074
25-28	-3,208,050	-1,784,697	4,071,450	-3,160,483	4,067,100
29-32	3,099,770	212,758	6,142,612	3,095,504	6,138,563
33-36	9,747,853	7,916,335	12,778,229	9,743,687	12,774,280
37-40	48,658,684	50,139,431	33,763,209	48,758,426	46,303,574
41-44	31,879,650	37,936,401	26,936,416	31,949,181	35,644,187
45-48	8,333,711	12,962,280	13,502,779	8,333,387	14,778,565
49-52	3,086,775	6,739,921	2,232,829	3,087,442	3,467,152
Total	**129,552,363**	**124,647,469**	**130,362,112**	**129,820,935**	**154,093,553**
Total with Equipment cost	**129,552,363**	**124,647,469**	**130,362,112**	**128,945,935**	**153,218,553**

The base model had three groups of period with losses. These losses totaled 3,830,674 USD. The periods with the biggest profits were the periods where the sales were also the most. This meant that the inventory holding cost associated with these periods would have a lesser effect on the overall cumulative variant profit. The base model is a good strategy since without any investment cost the overall cumulative variant profit is 128,552,363 USD. In fact, even by having the manufacturing facility shut down for 11 periods, it was still able to maintain a favorable overall cumulative variant profit. The strategy was not able to meet the demands during the initial periods, right after the shut down since demand was higher than forecasted by the model and there was not enough stock built. This also resulted in order cut costs. Overtime had to be scheduled, and hence it would only result in additional costs. One way to improve on it would be to have more inventory at hand before going into shut down. But this would only mean higher inventory holding cost in those periods of shut down.

The uniform production model had four groups of periods with loses that totaled 5,426,662 USD. There were order cuts that were comparatively insignificant. The biggest drawback for this strategy was the huge inventory holding cost. This was well anticipated, but it was thought that the reduction in overtime and order cut costs would offset this inventory holding cost. This was not the case since the inventory holding cost was much greater than any value of overtime or order cut cost that could be offset. This strategy can be employed only when the order cut costs and the overtime costs are expected to be larger than the inventory holding cost.

The JIT model did not have any groups of periods with negative overall cumulative variant profit. It was able to maintain lower overtime costs with lower inventory holding cost, but it resulted in higher order cut costs. Hence, a JIT model with capacity constraints will result in favorable overall cumulative variant profit, but there will be huge order cuts that will make the strategy less favorable.

Increasing the capacity of the packaging lines would require additional equipment, and would result in capital expenditure. Unless the returns are larger than the investment on equipment, it would be unwise to opt for a capacity increase. This was the case with the base model having increased capacity. It only resulted in less profit than the base model without equipment expenditure. But the JIT model with increased capacity was able to reap a higher overall cumulative variant profit since investment in increasing capacity made it possible to reduce order cut costs to zero, and maintain low inventory holding cost and overtime costs at the same time.

4.9 Combining Strategies

From Table 43, it was seen that certain strategies work better in certain periods. An option for any supply chain is to realize that by being dynamic, and realizing the trends expected, switching between strategies might result in higher overall cumulative variant profit. The JIT model with increased capacity resulted in no order cuts which meant that all the demand in the periods were met at the lowest inventory holding cost. In a situation where the JIT model with increased capacity still had order cuts, then it would be feasible to consider switching between strategies in certain periods so that the overall cumulative variant profit is higher. Consider periods 5-8 when overall cumulative profit was the highest for the base model. The main reason for this could be attributed to the production facility being shut down, and all costs associated with running the production facility tending to zero. Hence, for those periods alone, using the base model could prove to reap the highest overall cumulative variant profit. Another example would be during periods 49-52 when the uniform production model has the highest overall cumulative variant profit. This is because the strategy does not anticipate sudden reduction in the demand, and hence succeeds in selling more products.

In conclusion, switching between strategies for different periods can be a feasible alternative when there is sudden variation or fluctuations such as in variation of raw material costs in different periods or extreme fluctuation in gas prices can all result in adopting different strategies based on the needs of the periods under consideration.

4.10 Summary

Table 43 summarizes the overall cumulative variant profit associated with each model with and without investment in equipment. It was seen that strategies such as the base model, uniform production model and JIT model can be employed for shorter periods when the objective of the supply chain shifts. The base model can be considered when shut down in certain periods is crucial. A uniform production model can be considered when inventory holding cost is not an issue. A JIT model without increased capacity can be considered when order cuts are not so crucial.

However, the best strategy to employ when inventory holding cost is expected to be the least with overtime costs minimum and no order cut costs is the JIT model with doubled capacity. Hence, it can be concluded that the JIT model with increased capacity strategy is the most robust in terms of minimum overtime costs, order cut costs and inventory holding costs.

Chapter 5

Conclusions and Future Research

5.1 Conclusions

This thesis proposes a method of comparing supply chain strategies by using a new variable called overall cumulative variant profit. It makes use of simulation models of the different supply chain strategies to obtain independent parameters that help in computing the overall cumulative variant profit.

Selection of independent parameters was done after an extensive literature survey on supply chains and supply chain strategies. It was found that there was no unifying single parameter that could be used to evaluate the productivity and the profits associated with implementing an alternative supply chain strategy. All parameters that were found in literature to contribute significantly to the efficiency of a supply chain strategy were selected, and overall cumulative variant profit was modeled based on these parameters.

The supply chain selected was identified to be a multi-echelon supply chain consisting of raw material suppliers, a single manufacturing unit, a packaging facility as well as five distribution centers. Demand was selected to be seasonal. A case study organization that deals with the manufacture and distribution of French fried onions was used, since it was able to meet the demand requirements as well as the echelons in the supply chain.

Different strategies were weighed against each other, and behaviors of the independent parameters were compared across all the strategies. Unique features of each strategy were outlined based on the simulation model.

It was found that the JIT model with increased capacity yielded the best overall cumulative variant profit. It was able to do so by maintaining low inventory holding costs, having no order cut costs and minimum overtime costs. It was also observed that the cumulative variant profit in different periods was higher in some strategies, while lower in others. Hence, by being able to combine strategies, higher yields of overall cumulative profit can be reaped. Since simulation can aid in effectively predicting the overall cumulative variant profit for that period, running a simulation to calculate the overall cumulative variant profit, and thereby selecting the strategy that yields the highest overall cumulative variant profit is a feasible solution.

5.2 Future Research

The simulation model considered only a specific type of supply chain where demand was seasonal. The same simulation model can be extended and applied to other supply chains where the demand behaves differently. With different characteristics of demand, various other supply chain strategies can be modeled and studied.

Additionally, the same model can be used where selling price of products vary periodically. This can be modeled either to follow a specific distribution, or it can be obtained from market research or historical data. An interesting parameter that can improve the accuracy of overall cumulative variant profit is transportation cost. Although it was included as part of other fixed costs, transportation can be included as a varying cost considering fluctuations in gas prices.

The supply chain considered only one manufacturing unit. Strategies might change when additional manufacturing units producing the same product are present. In that scenario, distance between the distribution centers and the manufacturing units can be modeled so that there is less expense on transportation.

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Appendix A

List of Entities

Process Name	Description	Number of Processes
P_DC	Process that simulates the distribution center functioning with weekly demands being met or shortages not being met stored into excel file	1
P_day	Process that is used to schedule overtime of 1 or 2 days	1
P_downtime	Used to Schedule the downtime based off an excel sheet	1
P_downtime_processing		
P_initialization	Load creation Module; determines the number of trucks arriving everyday. Assigns variables to values at start of day	1
P_loadsend	Process that clones a load either to P_machine2 or P_machineA1 depending on buffer available	1
P_machine2	Process representation for packaging of 24 Oz. bags. Packaging is done only if there is enough buffer	1
P_machineA1	Process representation for packaging of 6 Oz. Cans. Packaging is done only if there is enough buffer	1
P_machineA2	Process representation for packaging of 2.8 Oz. Cans. Packaging is done only if there is enough buffer	1
P_proc	Decides whether the R_process is up or down and puts current load on order list, or lets it continue	1
P_processing	Process that converts the input to output at specified machine rates	1
P_ready_package	clones 1 load every minute to the different packaging modules depending on amount of product that needs to be packaged	1
P_weekly_finished	Process to store statistics to excel sheet at the end of every week	1

Resource Name	Description	Number of Processes
R_machine3	Resource that represents the packaging of 72 24-Oz bags per minute	1
R_machineA1	Resource that represents the packaging of 175 6-Oz bags per minute	1
R_machineA2	Resource that represents the packaging of 385 2.8-Oz bags per minute	1
R_process	Resource that represents the manufacture of 61.1111 lbs of products per minute	1

Queue Name	Description	Queue Capacity
Q_machineA1	Queue used to collect statistics on the number of units that went through machineA1	infinite
Q_machineA2	Queue used to collect statistics on the number of units that went through machineA2	infinite

Order List Name	Description	Number of Processes
1 OL_list	Order List utilized to handle Manufacturing when the Resource status is Up/Down	

	Variable Name	Description	Type	Initial Value
1	V_DC_A_row_week	Variable utilized to increment the Row number to which Excel prints in the DC module.	Real	2
2	V_DC_B_row_week	Variable utilized to increment the Row number to which Excel prints in the DC module.	Real	2
3	V_DC_C_row_week	Variable utilized to increment the Row number to which Excel prints in the DC module.	Real	2
4	V_DC_demand_A	Represents the Sales per week at the Distribution Center for 6 Oz. cans	Real	0
5	V_DC_demand_B	Represents the Sales per week at the Distribution Center for 2.8 Oz. cans	Real	0
6	V_DC_demand_C	Represents the Sales per week at the Distribution Center for 24 Oz. cans	Real	0
7	V_OT	Variable which signifies the number of days of Overtime utilized in a period.	Real	0
8	V_buffer	Variable that represents the total raw onion buffer	Real	0
9	V_cycle	Variable that represents the number of manufacturing cycles of Raw material to processed product that have been completed each day.	Real	0
10	V_day	Represents the day of the week with 1 representing Monday	Integer	1
11	V_days_consumption	Represents the total amount of raw material that was consumed	Real	0
12	V_days_production	Represents the total amount of finished product that was produced	Real	0
13	V_demand_not_met_A	Represents the amount of unmet 6 Oz cans	Real	0
14	V_demand_not_met_B	Represents the amount of unmet 2.8 Oz cans	Real	0
15	V_demand_not_met_C	Represents the amount of unmet 24 Oz bags	Real	0
16	V_downtime	Used to know whether the system is down or not	Real	0
17	V_downtime_counter	Used to count the number of times the resource was taken down	Integer	0
18	V_downtime_row	Variable used to increment the Row number from which the downtime data is read from Excel.	Real	2
19	V_finished_A	Represents the number of finished and packaged 6 Oz. cans at the end of a period	Real	1000000
20	V_finished_B	Represents the number of finished and packaged 2.8 Oz. cans at the end of a period	Real	500000
21	V_finished_C	Represents the number of finished and packaged 24 Oz. cans at the end of a period	Real	500000
22	V_forecast	Variable that represents the forecast of production planning	Real	0
23	V_inventory_remaining_A	Represents the amount of inventory remaining at the distribution center of the number of finished and packaged 6 Oz. cans	Real	0
24	V_inventory_remaining_B	Represents the amount of inventory remaining at the distribution center of the number of finished and packaged 6 Oz. cans	Real	0
25	V_inventory_remaining_C	Represents the amount of inventory remaining at the distribution center of the number of finished and packaged 6 Oz. cans	Real	0
26	V_lbs	Represents the amount of raw material that has been used for manufacturing the product	Real	0
27	V_no_of_trucks	Variable that reads the number of trucks arriving every day	Real	0
28	V_output	Represents the amount of processed finished goods at the end of every minute that then has to be packaged	Real	0
29	V_pack_row_week	Variable utilized to increment the row number on Excel to which Automod prints to.	Real	2
30	V_packaged_bin	Variable to represent the total amount of processed material that is to be packaged into Products A, B and C.	Real	0
31	V_row	Variable utilized to increment the row number on Excel from which Automod reads Production Target data.	Integer	2
33	V_shortage	V_shortage is a variable utilized to decide whether Overtime will need to be scheduled to meet a periods production requirement or not.	Real	0
34	V_targetA	Represents the weekly targets for packaged product of 6 Oz cans	Real	0
35	V_targetB	Represents the weekly targets for packaged product of 2.8 Oz cans	Real	0
36	V_targetC	Represents the weekly targets for packaged product of 24 Oz cans	Real	0
37	V_verification_counter	Variable utilized to control the switching of packaging between Products A and B in Machine 1 of Packaging.	Real	0
38	V_week	Variable that represents the week number	Real	0
39	V_weekly_finished_A	Quantity of packaged finished product of 6 Oz cans per week	Real	0
40	V_weekly_finished_B	Quantity of packaged finished product of 2.8 Oz cans per week	Real	0
41	V_weekly_finished_C	Quantity of packaged finished product of 24 Oz cans per week	Real	0
42	V_weekly_production	Represents the total quantity of product that is manufactured at the end of every week	Real	0
43	V_weekly_target	Represents the weekly targets that are read from the excel file	Real	0
44	Vstr_demand_met_A	Variable utlized to print the Demand Met of A in each period to Excel	String	
45	Vstr_demand_met_B	Variable utlized to print the Demand Met of B in each period to Excel	String	
46	Vstr_demand_met_C	Variable utlized to print the Demand Met of C in each period to Excel	String	
47	Vstr_demand_unmet_A	Variable utlized to print the Unmet Demand of A in each period to Excel	String	
48	Vstr_demand_unmet_B	Variable utlized to print the Unmet Demand of B in each period to Excel	String	
49	Vstr_demand_unmet_C	Variable utlized to print the Unmet Demand of C in each period to Excel	String	
50	Vstr_inv_rem_A	Variable utlized to print the Inventory Remaining at the end of each period of A to Excel	String	
51	Vstr_inv_rem_B	Variable utlized to print the Inventory Remaining at the end of each period of B to Excel	String	
52	Vstr_inv_rem_C	Variable utlized to print the Inventory Remaining at the end of each period of C to Excel	String	
53	Vstr_wk_finished_A	Variable utlized to print the Inventory Manufactured during each period of A to Excel	String	
54	Vstr_wk_finished_B	Variable utlized to print the Inventory Manufactured during each period of B to Excel	String	
55	Vstr_wk_finished_C	Variable utlized to print the Inventory Manufactured during each period of C to Excel	String	
56	VstrfinishedA	Variable utilized to print the Ending Inventory in a period of A to Excel	String	
57	VstrfinishedB	Variable utilized to print the Ending Inventory in a period of B to Excel	String	
58	VstrfinishedC	Variable utilized to print the Ending Inventory in a period of C to Excel	String	
59	Vstrot	Variable utilized to print the Overtimes scheduled to Excel	String	
60	Vstrperiod	Variable utilized to represent the periods from 1 to 52 whilst printing in Excel.	String	

Appendix B

AutoMod Code for Base Model

```
        begin model initialization function
            create 1 load of type L_initialsettings to P_initialization
            create 1 load of type L_day to P_day
            create 1 load of type L_ready_package to P_ready_package         //Packaging
            create 1 load of type L_weekly_finished to P_weekly_finished
            create 1 load of type L_DC to P_DC     //Distribution Center

            return true
        end

        //----------------------------------------------------------------------------------------
------------------
        //PROCESSING MODULE - Manufacturing facility
        //----------------------------------------------------------------------------------------
------------------

        /* This process sets initial values at the start of every day
        begin P_initialization arriving
            set V_no_of_trucks to XLGetA1("[production plan and sales data.xls]Production
Plan","C",V_row)   // Set Number of Trucks Arriving Per Week
            set V_buffer to (V_buffer + (50000*V_no_of_trucks))        // V_buffer is total raw onions
available
            if V_buffer > 150000 then set V_lbs to 150000            // To Limit the daily input feed
to 150000
            else set V_lbs to V_buffer                                // To Limit the daily input feed
to 150000

            create 1 load of type L_machine to P_proc

            wait for 24 hr
            set V_days_consumption to (V_cycle*104.16666)
            set V_days_production to (V_cycle*61.11111)
            set V_buffer to (V_buffer - V_days_consumption)
            set V_cycle to 0
            if V_day < 8 then increment V_weekly_production by V_days_production
            if V_day = 1 then
            begin
                                set V_DC_demand_A to XLGetA1("[production plan and sales
data.xls]Sales - Needed for DC","E",V_row)
                                set V_DC_demand_A to (V_DC_demand_A + V_demand_not_met_A)
                                set V_DC_demand_B to XLGetA1("[production plan and sales
data.xls]Sales - Needed for DC","F",V_row)
                                set V_DC_demand_B to (V_DC_demand_B + V_demand_not_met_B)
                                set V_DC_demand_C to XLGetA1("[production plan and sales
data.xls]Sales - Needed for DC","G",V_row)
                                set V_DC_demand_C to (V_DC_demand_C + V_demand_not_met_C)

                                set V_targetA to XLGetA1("[production plan and sales
data.xls]Production Plan","D",V_row)
                        set V_targetB to XLGetA1("[production plan and sales data.xls]Production
Plan","E",V_row)
                        set V_targetC to XLGetA1("[production plan and sales data.xls]Production
Plan","F",V_row)

                    set V_forecast to XLGetA1("[production plan and sales data.xls]Production
Plan","B",V_row)

                        set V_weekly_finished_A to 0
                        set V_weekly_finished_B to 0
                        set V_weekly_finished_C to 0
```

```
                                increment V_row by 1
                            end
            send to P_initialization
        end

        begin P_proc arriving                                       // Decides whether the R_process
is up or down and puts current load on order list, or lets it continue
            set A_arrival_time to ac
            if R_process status = 1 then clone to P_processing        // else hold load until resource
is free for new load
            else
                begin
                    wait to be ordered on OL_list
                    clone to P_processing                           // To make the load start at this
code - line when a load encounters continue statement
                end
            send to die
        end


        begin P_processing arriving                // Load created each day, cycle in this module,
update statistics and expire at days end

            if R_process status = 0 then        // Checks if cycled load should wait or proceed (else
hold load until resource is free for active load)
                begin
                    wait to be ordered on OL_list
                end
            if ((ac-A_arrival_time) <= 86399) then
                begin
                    if R_process status = 1 then
                        begin
                            if V_lbs > 0 then
                                begin
                                    decrement V_lbs by 104.16666            // Input Capacity per
minute
                                    use R_process for 1 min                     // Use Resource for 1
minute
                                    increment V_output by 61.11111            // Output Capacity per
minute
                                    increment V_packaged_bin by 61.1111
                                    increment V_cycle by 1
                                    //print "V_output:" V_output to message
                                    send to P_processing
                                end
                            send to die
                        end
                    send to P_processing
                end
            else                                                            // this loop executes at
the end of everyday
                begin
                    send to die
                end
        end

        begin P_downtime arriving
    set V_downtime to XLGetA1("[DATA FOR MODELLING DOWNTIME.xls]Sheet1","C",V_downtime_row)

    if V_downtime = 1 then clone 1 load to P_downtime_process

    inc V_downtime_counter by 1
    inc V_downtime_row by 1    //default value = 2

    if V_downtime_counter = 720 then
        begin
            set V_downtime_row to 2
```

```
            set V_downtime_counter to 0
        end

    wait for 60 min

    send to P_downtime
end

begin P_downtime_process arriving
    print "resource going down" to message
    take down R_process
    wait for 20 min
    bring up R_process
    order all load from OL_list to continue

 send to die
end

        begin P_day arriving                        // Process to schedule overtime
            wait for 24 hr                            // V_day set to 1 in GUI initially
            increment V_day by 1
            if V_day = 4 then                        // TO calculate and set the overtime for a week
at the end of 3rd Day
                begin
                    set V_weekly_target to (1.6667*V_weekly_production)
                    set V_shortage to (V_forecast - V_weekly_target)    // 5/3* V_weekly Production is
440K
                end
            if V_day = 6 then                        // Scheduling overtime at the end of the 5th day
                begin
                    if V_shortage < 50000 then        // No need for overtime, shutdown for 2 days
                        begin
                            take down R_process
                            wait for 48 hr
                            inc V_day by 2
                            bring up R_process
                            set V_weekly_production to 0
                            inc V_week by 1
                            set V_day to 1
                            print 0 to Vstrot
                                  print (V_row_week-1) to Vstrperiod //default value is 2
                                  call XLSetA1("[production plan and sales
data.xls]Statistics","A",V_row_week,Vstrperiod)
                                  call XLSetA1("[production plan and sales
data.xls]Statistics","B",V_row_week,Vstrot)

                                  inc V_row_week by 1

                        end
                    else if V_shortage <= 110000 then        // Saturday working, Sunday Not Working
                        begin
                            wait for 24 hr
                            inc V_day by 1

                            take down R_process
                            wait for 24 hr
                            inc V_day by 1
                            bring up R_process
                            set V_weekly_production to 0
                            inc V_week by 1
                            set V_day to 1
                            inc V_OT by 1
                            print V_OT to Vstrot
                                  print (V_row_week-1) to Vstrperiod //default value is 2
                                  call XLSetA1("[production plan and sales
data.xls]Statistics","A",V_row_week,Vstrperiod)
                                  call XLSetA1("[production plan and sales
data.xls]Statistics","B",V_row_week,Vstrot)
```

```
                                set V_OT to 0

                                inc V_row_week by 1


                          end
                      else if V_shortage > 110000 then    // Saturday and Sunday working
                          begin
                              wait for 48 hr
                              inc V_day by 2
                              set V_weekly_production to 0
                              inc V_week by 1
                              set V_day to 1
                              inc V_OT by 2
                              print V_OT to Vstrot
                                    print (V_row_week-1) to Vstrperiod //default value is 2
                                    call XLSetA1("[production plan and sales
data.xls]Statistics","A",V_row_week,Vstrperiod)
                                    call XLSetA1("[production plan and sales
data.xls]Statistics","B",V_row_week,Vstrot)
                                    set V_OT to 0
                                    inc V_row_week by 1
                          end
                  end
              send to P_day
          end

          //------------------------------------------------------------------------------------------------
------------------
          //PACKAGING MODULE
          //------------------------------------------------------------------------------------------------
------------------

          begin P_ready_package arriving
              wait for 1 min
              clone 1 load to P_loadsend
              send to P_ready_package
          end


          begin P_loadsend arriving
                   if V_packaged_bin > 65.25 and V_weekly_finished_B <=V_targetB then clone 1 load to
P_machineA1
                   if V_packaged_bin > 65.25 and V_weekly_finished_B >=V_targetB then clone 1 load to
P_machine2
          end

          begin P_machineA1 arriving // 6 oz. Product A Packaging

          if(V_packaged_bin > 65.25 ) then //175*0.375=65.25
                   begin
                     if V_weekly_finished_A <= V_targetA then
                            begin
                             move into Q_machineA1      //infinite capacity
                             use R_machineA1 for 1 min  //resource capacity = 1
                             inc V_weekly_finished_A by 175
                             inc V_finished_A by 175
                             dec V_packaged_bin by 65.25
                             if V_weekly_finished_C <= V_targetC and V_packaged_bin > 108 then clone 1
load to P_machine
                            end
                     else
                            begin
                                     inc V_verification_counter by 1
                                     send to P_machineA2
                            end
                   end
```

```
        send to die
        end

        begin P_machineA2 arriving  //2.8 oz. Product B Packaging
                if V_weekly_finished_C <= V_targetB then
                        begin
                                if(V_packaged_bin > 67.375 ) then //385*0.175=67.375
                                  begin
                                                if V_weekly_finished_B <= V_targetB then
                                                        begin
                                                                if V_verification_counter = 1
then wait for 15 min
                                                                move into Q_machineA2 //infinite
capacity
                                                                use R_machineA2 for 1 min
//resource capacity = 1
                                                                inc V_weekly_finished_B by 385
                                                                inc V_finished_B by 385
                                                                dec V_packaged_bin by 67.375
                                                                if V_weekly_finished_C <=
V_targetC and V_packaged_bin > 108 then clone 1 load to P_machine2
                                                        end
                                  end
                                end
                send to die
        end

        begin P_machine2 arriving  //24 oz. Product C Packaging

        if(V_packaged_bin > 108 ) then   //72*1.5=108
                begin
                         if V_weekly_finished_C <= V_targetC then
                                begin
                                        use R_machine3 for 1 min
                                        inc V_weekly_finished_C by 72
                                        inc V_finished_C by 72
                                        dec V_packaged_bin by 108
                                end
                end
                send to die
        end

        begin P_weekly_finished arriving  // At the end of the week, the statistic are stored into
excel
                wait for 7 day
                print (V_weekly_finished_A-175) to Vstr_wk_finished_A
                print V_weekly_finished_B to Vstr_wk_finished_B
                print (V_weekly_finished_C-72) to Vstr_wk_finished_C

                call XLSetA1("[production plan and sales
data.xls]Statistics","C",V_pack_row_week,Vstr_wk_finished_A)
                call XLSetA1("[production plan and sales
data.xls]Statistics","D",V_pack_row_week,Vstr_wk_finished_B)
                call XLSetA1("[production plan and sales
data.xls]Statistics","E",V_pack_row_week,Vstr_wk_finished_C)

            inc V_pack_row_week by 1

                send to P_weekly_finished
        end

        //------------------------------------------------------------------------------------------
------------------
        //DISTRIBUTION CENTER MODULE
        //------------------------------------------------------------------------------------------
------------------

        begin P_DC arriving
```

```
                wait for 7 day

                if V_finished_A >= V_DC_demand_A  then
               begin
                set V_inventory_remaining_A to V_finished_A - V_DC_demand_A

                    decrement V_finished_A by V_DC_demand_A
                    increment V_total_ship_A by V_DC_demand_A    //Maintains overall yearly shipment
values, reset each year.

                    print V_inventory_remaining_A to Vstr_inv_rem_A
                         print V_DC_demand_A to Vstr_demand_met_A
                                 print 0 to Vstr_demand_unmet_A
                    call XLSetA1("[production plan and sales
data.xls]Statistics","F",V_DC_A_row_week,Vstr_inv_rem_A)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","I",V_DC_A_row_week,Vstr_demand_met_A)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","J",V_DC_A_row_week,Vstr_demand_unmet_A)

                inc V_DC_A_row_week by 1

                    set V_demand_not_met_A to 0

                    if V_week < 5 then
                        begin
                            increment V_monthly_ship_A by V_DC_demand_A
                        end
                    else
                        begin
                            tabulate V_monthly_ship_A in T_monthly_ship_A    //Print monthly shipments
in Excel file
                            set V_monthly_ship_A to 0
                        end
               end
           else
               begin
                set V_demand_not_met_A to (V_DC_demand_A - V_finished_A)
                    set V_inventory_remaining to 0
                increment V_total_ship_A by V_finished_A    //Maintains overall yearly shipment
values, reset each year.
                print 0 to Vstr_inv_rem_A
                         print V_finished_A to Vstr_demand_met_A
                                 print V_demand_not_met_A to Vstr_demand_unmet_A
                    call XLSetA1("[production plan and sales
data.xls]Statistics","F",V_DC_A_row_week,Vstr_inv_rem_A)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","I",V_DC_A_row_week,Vstr_demand_met_A)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","J",V_DC_A_row_week,Vstr_demand_unmet_A)
                                 set V_finished_A to 0
                                 inc V_DC_A_row_week by 1

                    if V_week < 5 then
                        begin
                            increment V_monthly_ship_A by V_weekly_finished_A
                        end
                    else
                        begin
                            tabulate V_monthly_ship_A in T_monthly_ship_A
                            set V_monthly_ship_A to 0
                         end
               end

             //-------    B    --------
                if V_finished_B >= V_DC_demand_B  then
               begin
                set V_inventory_remaining_B to V_finished_B - V_DC_demand_B
```

```
                    decrement V_finished_B by V_DC_demand_B
                    increment V_total_ship_B by V_DC_demand_B    //Maintains overall yearly shipment
values, reset each year.
                    print V_inventory_remaining_B to Vstr_inv_rem_B
                         print V_DC_demand_B to Vstr_demand_met_B
                                 print 0 to Vstr_demand_unmet_B
                    call XLSetA1("[production plan and sales
data.xls]Statistics","G",V_DC_B_row_week,Vstr_inv_rem_B)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","K",V_DC_B_row_week,Vstr_demand_met_B)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","L",V_DC_B_row_week,Vstr_demand_unmet_B)

                 inc V_DC_B_row_week by 1

                    set V_demand_not_met_B to 0

                    if V_week < 5 then
                        begin
                            increment V_monthly_ship_B by V_DC_demand_B
                        end
                    else
                        begin
                            tabulate V_monthly_ship_B in T_monthly_ship_B    //Print monthly shipments
in Excel file
                            set V_monthly_ship_B to 0
                        end
                end
            else                  // The demand is not fulfilled
                begin
                    set V_demand_not_met_B to (V_DC_demand_B - V_finished_B)
                    set V_inventory_remaining to 0

                 increment V_total_ship_B by V_finished_B    //Maintains overall yearly shipment
values, reset each year.

                 print 0 to Vstr_inv_rem_B
                         print V_finished_B to Vstr_demand_met_B
                                 print V_demand_not_met_B to Vstr_demand_unmet_B
                    call XLSetA1("[production plan and sales
data.xls]Statistics","G",V_DC_B_row_week,Vstr_inv_rem_B)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","K",V_DC_B_row_week,Vstr_demand_met_B)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","L",V_DC_B_row_week,Vstr_demand_unmet_B)

                                 set V_finished_B to 0

                                 inc V_DC_B_row_week by 1

                    if V_week < 5 then
                        begin
                            increment V_monthly_ship_B by V_weekly_finished_B
                        end
                    else
                        begin
                            tabulate V_monthly_ship_B in T_monthly_ship_B
                            set V_monthly_ship_B to 0
                         end
                end
             //-------    C    --------

        if V_finished_C >= V_DC_demand_C  then                              // Demand is fulfilled
                begin
                 set V_inventory_remaining_C to V_finished_C - V_DC_demand_C
                    decrement V_finished_C by V_DC_demand_C
                    increment V_total_ship_C by V_DC_demand_C    //Maintains overall yearly shipment
values, reset each year.
```

```
                    print V_inventory_remaining_C to Vstr_inv_rem_C
                         print V_DC_demand_C to Vstr_demand_met_C
                                 print 0 to Vstr_demand_unmet_C
                    call XLSetA1("[production plan and sales
data.xls]Statistics","H",V_DC_C_row_week,Vstr_inv_rem_C)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","M",V_DC_C_row_week,Vstr_demand_met_C)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","N",V_DC_C_row_week,Vstr_demand_unmet_C)

                 inc V_DC_C_row_week by 1

                    set V_demand_not_met_C to 0

                    if V_week < 5 then
                        begin
                            increment V_monthly_ship_C by V_DC_demand_C
                        end
                    else
                        begin
                                                 tabulate V_monthly_ship_C in T_monthly_ship_C
//Print monthly shipments in Excel file
                            set V_monthly_ship_C to 0
                        end
                end
            else
                begin
                 set V_demand_not_met_C to (V_DC_demand_C - V_finished_C)
                    set V_inventory_remaining to 0
                    increment V_total_ship_C by V_finished_C    //Maintains overall yearly shipment
values, reset each year.

                 print 0 to Vstr_inv_rem_C
                         print V_finished_C to Vstr_demand_met_C
                                 print V_demand_not_met_C to Vstr_demand_unmet_C
                    call XLSetA1("[production plan and sales
data.xls]Statistics","H",V_DC_C_row_week,Vstr_inv_rem_C)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","M",V_DC_C_row_week,Vstr_demand_met_C)
                                 call XLSetA1("[production plan and sales
data.xls]Statistics","N",V_DC_C_row_week,Vstr_demand_unmet_C)

                                 set V_finished_C to 0

                                 inc V_DC_C_row_week by 1

                    if V_week < 5 then
                        begin
                            increment V_monthly_ship_C by V_weekly_finished_C
                        end
                    else
                        begin
                                                 tabulate V_monthly_ship_C in T_monthly_ship_C
                            set V_monthly_ship_C to 0
                         end
                end

                 send to P_DC

        end
```

Output Report for Base Model

*** AutoMod 12.2 ***

Model alpha

Statistics at Absolute Clock = 365:00:00:00.00, Relative Clock = 365:00:00:00.00

CPU time: Absolute: 30.812 sec, Relative: 30.812 sec

Statistics for Process System "alpha"

Process Statistics

Name	Total	Cur	Average	Capacity	Max	Min	Util	Av_Time	Av_Wait
P_initialization	**366**	1	1.00	--	1	0	--	**86163.93**	--
P_day	262	1	1.00	--	1	0	--	120366.41	--
P_downtime	**8761**	1	1.00	--	1	0	--	**3599.59**	--
P_ready_package	**525601**	1	1.00	--	1	0	--	**60.00**	--
P_DC	**53**	1	1.00	--	1	0	--	**595018.87**	--
P_proc	366	0	0.11	--	3	0	--	9304.92	--
P_processing	371711	1	1.00	--	3	0	--	85.01	--
P_loadsend	**525600**	0	0.00	--	1	0	--	0.00	--
P_machineA1	320351	0	0.29	--	1	0	--	29.04	--
P_machine2	343680	0	0.03	--	1	0	--	2.57	--

```
P_machineA2           165317     0     0.08        --     1      0     --      15.05
--
P_weekly_finished         53     1     1.00        --     1      0     -- 595018.87
--
P_downtime_process       806     0     0.03        --     1      0     --    1200.00
--


Resource Statistics
Name                   Total   Cur  Average Capacity   Max   Min   Util    Av_Time
Av_Wait     State
==================================================================================
==================
R_process             371222     1     0.71         1     1      0  0.706      60.00
0.00      Up   ----
R_machineA1           155034     0     0.29         1     1      0  0.295      60.00
0.00      Up   ----
R_machineA2            41464     0     0.08         1     1      0  0.079      60.00
0.00      Up   ----
R_machine3             14746     0     0.03         1     1      0  0.028      60.00
0.00      Up   ----


Random Number Streams
Name                 Total
============================
stream0              0
stream_R_process_1   0
stream_R_machineA1_1 0
stream_R_machineA2_1 0
stream_R_machine3_1  0
```

Appendix C

Result Files

Input Cost Parameters

Product A

Unit Selling Price	4.69
Unit Holding Cost	0.08
Unit Regular Labor Cost	0.1
Other Fixed Cost Per Can	0.4851
Unit Order Cut Cost	0.05
Per Shift Overtime Cost	13000

Product B

Unit Selling Price	2.5
Unit Holding Cost	0.08
Unit Regular Labor Cost	0.1
Other Fixed Cost Per Can	0.4851
Unit Order Cut Cost	0.05
Per Shift Overtime Cost	13000

Product C

Unit Selling Price	7.89
Unit Holding Cost	0.08
Unit Regular Labor Cost	0.1
Other Fixed Cost Per Can	0.4851
Unit Order Cut Cost	0.05
Per Shift Overtime Cost	13000

Base Model

Production Plan

Period	Production Plan (Total finished product required before Packaging)	Number of Product A (Cans)	Number of Product B (Cans)	Number of Product C (Cans)
1	237,867	253,488	331,509	56,530
2	237,867	253,488	331,509	56,530
3	237,867	253,488	331,509	56,530
4	237,867	253,488	331,509	56,530
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	235,860	408,660	254,384	25,397
18	235,860	408,660	254,384	25,397
19	235,860	408,660	254,384	25,397
20	235,860	408,660	254,384	25,397
21	665,519	1,222,630	684,021	58,220
22	665,519	1,222,630	684,021	58,220
23	665,519	1,222,630	684,021	58,220
24	665,519	1,222,630	684,021	58,220
25	735,295	1,306,548	780,071	72,552
26	735,295	1,306,548	780,071	72,552
27	735,295	1,306,548	780,071	72,552
28	735,295	1,306,548	780,071	72,552
29	143,537	233,460	221,518	11,483
30	143,537	233,460	221,518	11,483
31	143,537	233,460	221,518	11,483
32	143,537	233,460	221,518	11,483
33	301,304	601,255	334,043	11,584
34	301,304	601,255	334,043	11,584
35	301,304	601,255	334,043	11,584
36	301,304	601,255	334,043	11,584
37	595,884	1,274,546	599,655	8,660
38	595,884	1,274,546	599,655	8,660
39	595,884	1,274,546	599,655	8,660
40	595,884	1,274,546	599,655	8,660
41	473,097	1,053,431	370,122	8,859
42	473,097	1,053,431	370,122	8,859
43	473,097	1,053,431	370,122	8,859
44	473,097	1,053,431	370,122	8,859
45	158,691	312,277	171,754	7,687
46	158,691	312,277	171,754	7,687
47	158,691	312,277	171,754	7,687
48	158,691	312,277	171,754	7,687
49	91,179	114,906	241,773	3,853
50	91,179	114,906	241,773	3,853
51	91,179	114,906	241,773	3,853
52	91,179	114,906	241,773	3,853

Table 44. Simulation Output Statistics for Base Model for Period 1 - 26

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
1	0	253400	331870	56520	1196745	757320	43951	57005	0	74550	0	12713	0
2	0	253400	331870	56520	1393315	1014640	87830	57005	0	74550	0	12713	0
3	0	253400	331870	56520	1589885	1271960	131709	57005	0	74550	0	12713	0
4	0	253400	331870	56520	1786455	1529280	175588	57005	0	74550	0	12713	0
5	0	0	0	0	1522301	1362761	168551	264329	0	166519	0	7109	0
6	0	0	0	0	1258147	1196242	161514	264329	0	166519	0	7109	0
7	0	0	0	0	993993	1029723	154477	264329	0	166519	0	7109	0
8	0	0	0	0	729839	863204	147440	264329	0	166519	0	7109	0
9	0	0	0	0	85548	581344	131372	644466	0	281860	0	16140	0
10	0	0	0	0	0	299484	115304	85723	558743	281860	0	16140	0
11	0	0	0	0	0	17624	99236	0	1203034	281860	0	16140	0
12	0	0	0	0	0	0	83168	0	1847325	17624	264236	16140	0
13	0	0	0	0	0	0	72008	0	1961094	0	364277	11232	0
14	0	0	0	0	0	0	60848	0	2074863	0	464318	11232	0
15	0	0	0	0	0	0	49688	0	2188632	0	564359	11232	0
16	0	0	0	0	0	0	38528	0	2302401	0	664400	11232	0
17	0	408625	254485	25344	0	0	51711	408800	2090430	254485	532437	12233	0
18	0	408625	254485	25344	0	0	64894	408800	1878459	254485	400474	12233	0
19	0	408625	254485	25344	0	0	78077	408800	1666488	254485	268511	12233	0
20	0	408625	254485	25344	0	0	91260	408800	1454517	254485	136548	12233	0
21	2	1222550	684145	58176	0	387800	135907	1222725	517416	296345	0	13601	0
22	2	1222550	684145	58176	419685	912148	180554	803040	0	159797	0	13601	0
23	2	1222550	684145	58176	1356786	1436496	225201	285624	0	159797	0	13601	0
24	2	1222550	684145	58176	2293887	1960844	269848	285624	0	159797	0	13601	0
25	2	1306375	780395	72504	3395349	2618792	331035	205088	0	122447	0	11389	0
26	2	1306375	780395	72504	4496811	3276740	392222	205088	0	122447	0	11389	0

Table 45. Simulation Output Statistics for Base Model for Period 27 - 52

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
27	2	1306375	780395	72504	5598273	3934688	453409	205088	0	122447	0	11389	0
28	2	1306375	780395	72504	6699735	4592636	514596	205088	0	122447	0	11389	0
29	0	233450	221760	11448	6664128	4558936	512873	269232	0	255460	0	13243	0
30	0	233450	221760	11448	6628521	4525236	511150	269232	0	255460	0	13243	0
31	0	233450	221760	11448	6592914	4491536	509427	269232	0	255460	0	13243	0
32	0	233450	221760	11448	6557307	4457836	507704	269232	0	255460	0	13243	0
33	0	601125	334180	11520	6522475	4438597	507040	636132	0	353419	0	12256	0
34	0	601125	334180	11520	6487643	4419358	506376	636132	0	353419	0	12256	0
35	0	601125	334180	11520	6452811	4400119	505712	636132	0	353419	0	12256	0
36	0	601125	334180	11520	6417979	4380880	505048	636132	0	353419	0	12256	0
37	2	1274525	599830	8640	5327314	3867841	497688	2365365	0	1112869	0	16072	0
38	2	1274525	599830	8640	4236649	3354802	490328	2365365	0	1112869	0	16072	0
39	2	1274525	599830	8640	3145984	2841763	482968	2365365	0	1112869	0	16072	0
40	2	1274525	599830	8640	2055319	2328724	475608	2365365	0	1112869	0	16072	0
41	0	1053325	370370	8856	1192189	2025687	468418	1916630	0	673407	0	16118	0
42	2	1053325	370370	8856	329059	1722650	461228	1916630	0	673407	0	16118	0
43	0	1053325	370370	8856	0	1419613	454038	1382559	534071	673407	0	16118	0
44	2	1053325	370370	8856	0	1116576	446848	1053500	1397201	673407	0	16118	0
45	0	312200	172095	7632	0	884561	436467	312375	1819564	404110	0	18085	0
46	0	312200	172095	7632	0	652546	426086	312375	2241927	404110	0	18085	0
47	0	312200	172095	7632	0	420531	415705	312375	2664290	404110	0	18085	0
48	0	312200	172095	7632	0	188516	405324	312375	3086653	404110	0	18085	0
49	0	114800	241780	3816	0	174499	405136	114975	3093249	255797	0	4076	0
50	0	114800	241780	3816	0	160482	404948	114975	3099845	255797	0	4076	0
51	0	114800	241780	3816	0	146465	404760	114975	3106441	255797	0	4076	0
52	0	114800	241780	3816	0	132448	404572	114975	3113037	255797	0	4076	0

Table 46. Cumulative Profit for Item 1 for period 1 - 26

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
1	253400	1196745	57005	0	0	267353.45	95739.6	25340	122924.34	23349.51
2	253400	1393315	57005	0	0	267353.45	111465.2	25340	122924.34	7623.91
3	253400	1589885	57005	0	0	267353.45	127190.8	25340	122924.34	-8101.69
4	253400	1786455	57005	0	0	267353.45	142916.4	25340	122924.34	-23827.29
5	0	1522301	264329	0	0	1239703.01	121784.08	0	0	1117918.93
6	0	1258147	264329	0	0	1239703.01	100651.76	0	0	1139051.25
7	0	993993	264329	0	0	1239703.01	79519.44	0	0	1160183.57
8	0	729839	264329	0	0	1239703.01	58387.12	0	0	1181315.89
9	0	85548	644466	0	0	3022545.54	6843.84	0	0	3015701.7
10	0	0	85723	558743	27937.15	402040.87	0	0	0	374103.72
11	0	0	0	1203034	60151.7	0	0	0	0	-60151.7
12	0	0	0	1847325	92366.25	0	0	0	0	-92366.25
13	0	0	0	1961094	98054.7	0	0	0	0	-98054.7
14	0	0	0	2074863	103743.15	0	0	0	0	-103743.15
15	0	0	0	2188632	109431.6	0	0	0	0	-109431.6
16	0	0	0	2302401	115120.05	0	0	0	0	-115120.05
17	408625	0	408800	2090430	104521.5	1917272	0	40862.5	198223.9875	1573664.013
18	408625	0	408800	1878459	93922.95	1917272	0	40862.5	198223.9875	1584262.563
19	408625	0	408800	1666488	83324.4	1917272	0	40862.5	198223.9875	1594861.113
20	408625	0	408800	1454517	72725.85	1917272	0	40862.5	198223.9875	1605459.663
21	1222550	0	1222725	517416	25870.8	5734580.25	0	122255	593059.005	4993395.445
22	1222550	419685	803040	0	0	3766257.6	33574.8	122255	593059.005	3017368.795
23	1222550	1356786	285624	0	0	1339576.56	108542.88	122255	593059.005	515719.675
24	1222550	2293887	285624	0	0	1339576.56	183510.96	122255	593059.005	440751.595
25	1306375	3395349	205088	0	0	961862.72	271627.92	130637.5	633722.5125	-74125.2125
26	1306375	4496811	205088	0	0	961862.72	359744.88	130637.5	633722.5125	-162242.1725

Table 47. Cumulative Profit for Item 1 for period 27 - 52

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
27	1306375	5598273	205088	0	0	961862.72	447861.84	130637.5	633722.5125	-250359.1325
28	1306375	6699735	205088	0	0	961862.72	535978.8	130637.5	633722.5125	-338476.0925
29	233450	6664128	269232	0	0	1262698.08	533130.24	23345	113246.595	592976.245
30	233450	6628521	269232	0	0	1262698.08	530281.68	23345	113246.595	595824.805
31	233450	6592914	269232	0	0	1262698.08	527433.12	23345	113246.595	598673.365
32	233450	6557307	269232	0	0	1262698.08	524584.56	23345	113246.595	601521.925
33	601125	6522475	636132	0	0	2983459.08	521798	60112.5	291605.7375	2109942.843
34	601125	6487643	636132	0	0	2983459.08	519011.44	60112.5	291605.7375	2112729.403
35	601125	6452811	636132	0	0	2983459.08	516224.88	60112.5	291605.7375	2115515.963
36	601125	6417979	636132	0	0	2983459.08	513438.32	60112.5	291605.7375	2118302.523
37	1274525	5327314	2365365	0	0	11093561.85	426185.12	127452.5	618272.0775	9921652.153
38	1274525	4236649	2365365	0	0	11093561.85	338931.92	127452.5	618272.0775	10008905.35
39	1274525	3145984	2365365	0	0	11093561.85	251678.72	127452.5	618272.0775	10096158.55
40	1274525	2055319	2365365	0	0	11093561.85	164425.52	127452.5	618272.0775	10183411.75
41	1053325	1192189	1916630	0	0	8988994.7	95375.12	105332.5	510967.9575	8277319.123
42	1053325	329059	1916630	0	0	8988994.7	26324.72	105332.5	510967.9575	8346369.523
43	1053325	0	1382559	534071	26703.55	6484201.71	0	105332.5	510967.9575	5841197.703
44	1053325	0	1053500	1397201	69860.05	4940915	0	105332.5	510967.9575	4254754.493
45	312200	0	312375	1819564	90978.2	1465038.75	0	31220	151448.22	1191392.33
46	312200	0	312375	2241927	112096.35	1465038.75	0	31220	151448.22	1170274.18
47	312200	0	312375	2664290	133214.5	1465038.75	0	31220	151448.22	1149156.03
48	312200	0	312375	3086653	154332.65	1465038.75	0	31220	151448.22	1128037.88
49	114800	0	114975	3093249	154662.45	539232.75	0	11480	55689.48	317400.82
50	114800	0	114975	3099845	154992.25	539232.75	0	11480	55689.48	317071.02
51	114800	0	114975	3106441	155322.05	539232.75	0	11480	55689.48	316741.22
52	114800	0	114975	3113037	155651.85	539232.75	0	11480	55689.48	316411.42

Table 48. Cumulative Profit for Item 2 for period 1 - 26

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
1	331870	757320	74550	0	0	186375	60585.6	33187	160990.137	-68387.737
2	331870	1014640	74550	0	0	186375	81171.2	33187	160990.137	-88973.337
3	331870	1271960	74550	0	0	186375	101756.8	33187	160990.137	-109558.937
4	331870	1529280	74550	0	0	186375	122342.4	33187	160990.137	-130144.537
5	0	1362761	166519	0	0	416297.5	109020.88	0	0	307276.62
6	0	1196242	166519	0	0	416297.5	95699.36	0	0	320598.14
7	0	1029723	166519	0	0	416297.5	82377.84	0	0	333919.66
8	0	863204	166519	0	0	416297.5	69056.32	0	0	347241.18
9	0	581344	281860	0	0	704650	46507.52	0	0	658142.48
10	0	299484	281860	0	0	704650	23958.72	0	0	680691.28
11	0	17624	281860	0	0	704650	1409.92	0	0	703240.08
12	0	0	17624	264236	13211.8	44060	0	0	0	30848.2
13	0	0	0	364277	18213.85	0	0	0	0	-18213.85
14	0	0	0	464318	23215.9	0	0	0	0	-23215.9
15	0	0	0	564359	28217.95	0	0	0	0	-28217.95
16	0	0	0	664400	33220	0	0	0	0	-33220
17	254485	0	254485	532437	26621.85	636212.5	0	25448.5	123450.6735	460691.4765
18	254485	0	254485	400474	20023.7	636212.5	0	25448.5	123450.6735	467289.6265
19	254485	0	254485	268511	13425.55	636212.5	0	25448.5	123450.6735	473887.7765
20	254485	0	254485	136548	6827.4	636212.5	0	25448.5	123450.6735	480485.9265
21	684145	387800	296345	0	0	740862.5	31024	68414.5	331878.7395	309545.2605
22	684145	912148	159797	0	0	399492.5	72971.84	68414.5	331878.7395	-73772.5795
23	684145	1436496	159797	0	0	399492.5	114919.68	68414.5	331878.7395	-115720.4195
24	684145	1960844	159797	0	0	399492.5	156867.52	68414.5	331878.7395	-157668.2595
25	780395	2618792	122447	0	0	306117.5	209503.36	78039.5	378569.6145	-359994.9745
26	780395	3276740	122447	0	0	306117.5	262139.2	78039.5	378569.6145	-412630.8145

Table 49. Cumulative Profit for Item 2 for period 27 - 52

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
27	780395	3934688	122447	0	0	306117.5	314775.04	78039.5	378569.6145	-465266.6545
28	780395	4592636	122447	0	0	306117.5	367410.88	78039.5	378569.6145	-517902.4945
29	221760	4558936	255460	0	0	638650	364714.88	22176	107575.776	144183.344
30	221760	4525236	255460	0	0	638650	362018.88	22176	107575.776	146879.344
31	221760	4491536	255460	0	0	638650	359322.88	22176	107575.776	149575.344
32	221760	4457836	255460	0	0	638650	356626.88	22176	107575.776	152271.344
33	334180	4438597	353419	0	0	883547.5	355087.76	33418	162110.718	332931.022
34	334180	4419358	353419	0	0	883547.5	353548.64	33418	162110.718	334470.142
35	334180	4400119	353419	0	0	883547.5	352009.52	33418	162110.718	336009.262
36	334180	4380880	353419	0	0	883547.5	350470.4	33418	162110.718	337548.382
37	599830	3867841	1112869	0	0	2782172.5	309427.28	59983	290977.533	2121784.687
38	599830	3354802	1112869	0	0	2782172.5	268384.16	59983	290977.533	2162827.807
39	599830	2841763	1112869	0	0	2782172.5	227341.04	59983	290977.533	2203870.927
40	599830	2328724	1112869	0	0	2782172.5	186297.92	59983	290977.533	2244914.047
41	370370	2025687	673407	0	0	1683517.5	162054.96	37037	179666.487	1304759.053
42	370370	1722650	673407	0	0	1683517.5	137812	37037	179666.487	1329002.013
43	370370	1419613	673407	0	0	1683517.5	113569.04	37037	179666.487	1353244.973
44	370370	1116576	673407	0	0	1683517.5	89326.08	37037	179666.487	1377487.933
45	172095	884561	404110	0	0	1010275	70764.88	17209.5	83483.2845	838817.3355
46	172095	652546	404110	0	0	1010275	52203.68	17209.5	83483.2845	857378.5355
47	172095	420531	404110	0	0	1010275	33642.48	17209.5	83483.2845	875939.7355
48	172095	188516	404110	0	0	1010275	15081.28	17209.5	83483.2845	894500.9355
49	241780	174499	255797	0	0	639492.5	13959.92	24178	117287.478	484067.102
50	241780	160482	255797	0	0	639492.5	12838.56	24178	117287.478	485188.462
51	241780	146465	255797	0	0	639492.5	11717.2	24178	117287.478	486309.822
52	241780	132448	255797	0	0	639492.5	10595.84	24178	117287.478	487431.182

Table 50. Cumulative Profit for Item 3 for period 1 - 26

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
1	56520	43951	12713	0	0	100305.57	3516.08	5652	27417.852	63719.638
2	56520	87830	12713	0	0	100305.57	7026.4	5652	27417.852	60209.318
3	56520	131709	12713	0	0	100305.57	10536.72	5652	27417.852	56698.998
4	56520	175588	12713	0	0	100305.57	14047.04	5652	27417.852	53188.678
5	0	168551	7109	0	0	56090.01	13484.08	0	0	42605.93
6	0	161514	7109	0	0	56090.01	12921.12	0	0	43168.89
7	0	154477	7109	0	0	56090.01	12358.16	0	0	43731.85
8	0	147440	7109	0	0	56090.01	11795.2	0	0	44294.81
9	0	131372	16140	0	0	127344.6	10509.76	0	0	116834.84
10	0	115304	16140	0	0	127344.6	9224.32	0	0	118120.28
11	0	99236	16140	0	0	127344.6	7938.88	0	0	119405.72
12	0	83168	16140	0	0	127344.6	6653.44	0	0	120691.16
13	0	72008	11232	0	0	88620.48	5760.64	0	0	82859.84
14	0	60848	11232	0	0	88620.48	4867.84	0	0	83752.64
15	0	49688	11232	0	0	88620.48	3975.04	0	0	84645.44
16	0	38528	11232	0	0	88620.48	3082.24	0	0	85538.24
17	25344	51711	12233	0	0	96518.37	4136.88	2534.4	12294.3744	77552.7156
18	25344	64894	12233	0	0	96518.37	5191.52	2534.4	12294.3744	76498.0756
19	25344	78077	12233	0	0	96518.37	6246.16	2534.4	12294.3744	75443.4356
20	25344	91260	12233	0	0	96518.37	7300.8	2534.4	12294.3744	74388.7956
21	58176	135907	13601	0	0	107311.89	10872.56	5817.6	28221.1776	62400.5524
22	58176	180554	13601	0	0	107311.89	14444.32	5817.6	28221.1776	58828.7924
23	58176	225201	13601	0	0	107311.89	18016.08	5817.6	28221.1776	55257.0324
24	58176	269848	13601	0	0	107311.89	21587.84	5817.6	28221.1776	51685.2724
25	72504	331035	11389	0	0	89859.21	26482.8	7250.4	35171.6904	20954.3196
26	72504	392222	11389	0	0	89859.21	31377.76	7250.4	35171.6904	16059.3596

Table 51.Cumulative Profit for Item 3 for period 27 - 52

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
27	72504	453409	11389	0	0	89859.21	36272.72	7250.4	35171.6904	11164.3996
28	72504	514596	11389	0	0	89859.21	41167.68	7250.4	35171.6904	6269.4396
29	11448	512873	13243	0	0	104487.27	41029.84	1144.8	5553.4248	56759.2052
30	11448	511150	13243	0	0	104487.27	40892	1144.8	5553.4248	56897.0452
31	11448	509427	13243	0	0	104487.27	40754.16	1144.8	5553.4248	57034.8852
32	11448	507704	13243	0	0	104487.27	40616.32	1144.8	5553.4248	57172.7252
33	11520	507040	12256	0	0	96699.84	40563.2	1152	5588.352	49396.288
34	11520	506376	12256	0	0	96699.84	40510.08	1152	5588.352	49449.408
35	11520	505712	12256	0	0	96699.84	40456.96	1152	5588.352	49502.528
36	11520	505048	12256	0	0	96699.84	40403.84	1152	5588.352	49555.648
37	8640	497688	16072	0	0	126808.08	39815.04	864	4191.264	81937.776
38	8640	490328	16072	0	0	126808.08	39226.24	864	4191.264	82526.576
39	8640	482968	16072	0	0	126808.08	38637.44	864	4191.264	83115.376
40	8640	475608	16072	0	0	126808.08	38048.64	864	4191.264	83704.176
41	8856	468418	16118	0	0	127171.02	37473.44	885.6	4296.0456	84515.9344
42	8856	461228	16118	0	0	127171.02	36898.24	885.6	4296.0456	85091.1344
43	8856	454038	16118	0	0	127171.02	36323.04	885.6	4296.0456	85666.3344
44	8856	446848	16118	0	0	127171.02	35747.84	885.6	4296.0456	86241.5344
45	7632	436467	18085	0	0	142690.65	34917.36	763.2	3702.2832	103307.8068
46	7632	426086	18085	0	0	142690.65	34086.88	763.2	3702.2832	104138.2868
47	7632	415705	18085	0	0	142690.65	33256.4	763.2	3702.2832	104968.7668
48	7632	405324	18085	0	0	142690.65	32425.92	763.2	3702.2832	105799.2468
49	3816	405136	4076	0	0	32159.64	32410.88	381.6	1851.1416	-2483.9816
50	3816	404948	4076	0	0	32159.64	32395.84	381.6	1851.1416	-2468.9416
51	3816	404760	4076	0	0	32159.64	32380.8	381.6	1851.1416	-2453.9016
52	3816	404572	4076	0	0	32159.64	32365.76	381.6	1851.1416	-2438.8616

Table 52. Overall Cumulative Variant Profit for Base Model (Period 1 - 26)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
1	23349.51	-68387.737	63719.638	0	9500	66500	-47818.589
2	7623.91	-88973.337	60209.318	0	9500	66500	-87640.109
3	-8101.69	-109558.937	56698.998	0	9500	66500	-127461.629
4	-23827.29	-130144.537	53188.678	0	9500	66500	-167283.149
5	1117918.93	307276.62	42605.93	0	9500	0	1467801.48
6	1139051.25	320598.14	43168.89	0	9500	0	1502818.28
7	1160183.57	333919.66	43731.85	0	9500	0	1537835.08
8	1181315.89	347241.18	44294.81	0	9500	0	1572851.88
9	3015701.7	658142.48	116834.84	0	9500	0	3790679.02
10	374103.72	680691.28	118120.28	0	9500	0	1172915.28
11	-60151.7	703240.08	119405.72	0	9500	0	762494.1
12	-92366.25	30848.2	120691.16	0	9500	0	59173.11
13	-98054.7	-18213.85	82859.84	0	9500	0	-33408.71
14	-103743.15	-23215.9	83752.64	0	9500	0	-43206.41
15	-109431.6	-28217.95	84645.44	0	9500	0	-53004.11
16	-115120.05	-33220	85538.24	0	9500	0	-62801.81
17	1573664.013	460691.4765	77552.7156	0	9500	66500	2045408.205
18	1584262.563	467289.6265	76498.0756	0	9500	66500	2061550.265
19	1594861.113	473887.7765	75443.4356	0	9500	66500	2077692.325
20	1605459.663	480485.9265	74388.7956	0	9500	66500	2093834.385
21	4993395.445	309545.2605	62400.5524	26000	9500	180500	5158841.258
22	3017368.795	-73772.5795	58828.7924	26000	9500	180500	2795925.008
23	515719.675	-115720.4195	55257.0324	26000	6875	130625	298631.2879
24	440751.595	-157668.2595	51685.2724	26000	6875	130625	178143.6079
25	-74125.2125	-359994.9745	20954.3196	26000	6875	144375	-583540.8674
26	-162242.1725	-412630.8145	16059.3596	26000	6875	144375	-729188.6274

Table 53. Overall Cumulative Variant Profit for Base Model (Period 27 - 52)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
27	-250359.1325	-465266.6545	11164.3996	26000	6875	144375	-874836.3874
28	-338476.0925	-517902.4945	6269.4396	26000	6875	144375	-1020484.147
29	592976.245	144183.344	56759.2052	0	6875	27500	766418.7942
30	595824.805	146879.344	56897.0452	0	6875	27500	772101.1942
31	598673.365	149575.344	57034.8852	0	6875	27500	777783.5942
32	601521.925	152271.344	57172.7252	0	6875	27500	783465.9942
33	2109942.843	332931.022	49396.288	0	6875	61875	2430395.153
34	2112729.403	334470.142	49449.408	0	6875	61875	2434773.953
35	2115515.963	336009.262	49502.528	0	6875	61875	2439152.753
36	2118302.523	337548.382	49555.648	0	6875	61875	2443531.553
37	9921652.153	2121784.687	81937.776	26000	6875	116875	11982499.62
38	10008905.35	2162827.807	82526.576	26000	6875	116875	12111384.74
39	10096158.55	2203870.927	83115.376	26000	6875	116875	12240269.86
40	10183411.75	2244914.047	83704.176	26000	9500	161500	12324529.98
41	8277319.123	1304759.053	84515.9344	0	9500	123500	9543094.11
42	8346369.523	1329002.013	85091.1344	26000	9500	123500	9610962.67
43	5841197.703	1353244.973	85666.3344	0	9500	123500	7156609.01
44	4254754.493	1377487.933	86241.5344	26000	9500	123500	5568983.96
45	1191392.33	838817.3355	103307.8068	0	9500	47500	2086017.472
46	1170274.18	857378.5355	104138.2868	0	9500	47500	2084291.002
47	1149156.03	875939.7355	104968.7668	0	9500	47500	2082564.532
48	1128037.88	894500.9355	105799.2468	0	9500	47500	2080838.062
49	317400.82	484067.102	-2483.9816	0	9500	28500	770483.9404
50	317071.02	485188.462	-2468.9416	0	9500	28500	771290.5404
51	316741.22	486309.822	-2453.9016	0	9500	28500	772097.1404
52	316411.42	487431.182	-2438.8616	0	9500	28500	772903.7404

UNIFORM PRODUCTION MODEL

Table 54. Simulation Output Statistics for Uniform Production Model for Period 1 - 26

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
1	0	600950	314160	12672	1544120	739610	31	57005	0	74550	0	12713	0
2	0	600950	314160	12672	2088065	979220	0	57005	0	74550	0	12703	10
3	0	600950	314160	12672	2632010	1218830	0	57005	0	74550	0	12672	51
4	0	600950	314160	12672	3175955	1458440	0	57005	0	74550	0	12672	92
5	0	600950	314160	12672	3512576	1606081	5471	264329	0	166519	0	7201	0
6	0	600950	314160	12672	3849197	1753722	11034	264329	0	166519	0	7109	0
7	0	600950	314160	12672	4185818	1901363	16597	264329	0	166519	0	7109	0
8	0	600950	314160	12672	4522439	2049004	22160	264329	0	166519	0	7109	0
9	0	600950	314160	12672	4478923	2081304	18692	644466	0	281860	0	16140	0
10	0	600950	314160	12672	4435407	2113604	15224	644466	0	281860	0	16140	0
11	0	600950	314160	12672	4391891	2145904	11756	644466	0	281860	0	16140	0
12	0	600950	314160	12672	4348375	2178204	8288	644466	0	281860	0	16140	0
13	0	600950	314160	12672	4835381	2392323	9728	113944	0	100041	0	11232	0
14	0	600950	314160	12672	5322387	2606442	11168	113944	0	100041	0	11232	0
15	0	600950	314160	12672	5809393	2820561	12608	113944	0	100041	0	11232	0
16	0	600950	314160	12672	6296399	3034680	14048	113944	0	100041	0	11232	0
17	0	600950	314160	12672	6700520	3226318	14487	196829	0	122522	0	12233	0
18	0	600950	314160	12672	7104641	3417956	14926	196829	0	122522	0	12233	0
19	0	600950	314160	12672	7508762	3609594	15365	196829	0	122522	0	12233	0
20	0	600950	314160	12672	7912883	3801232	15804	196829	0	122522	0	12233	0
21	0	600950	314160	12672	8228209	3955595	14875	285624	0	159797	0	13601	0
22	0	600950	314160	12672	8543535	4109958	13946	285624	0	159797	0	13601	0
23	0	600950	314160	12672	8858861	4264321	13017	285624	0	159797	0	13601	0
24	0	600950	314160	12672	9174187	4418684	12088	285624	0	159797	0	13601	0
25	0	600950	314160	12672	9570049	4610397	13371	205088	0	122447	0	11389	0
26	0	600950	314160	12672	9965911	4802110	14654	205088	0	122447	0	11389	0

Table 55. Simulation Output Statistics for Uniform Production Model for Period 27 - 52

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
27	0	600950	314160	12672	10361773	4993823	15937	205088	0	122447	0	11389	0
28	0	600950	314160	12672	10757635	5185536	17220	205088	0	122447	0	11389	0
29	0	600950	314160	12672	11089353	5244236	16649	269232	0	255460	0	13243	0
30	0	600950	314160	12672	11421071	5302936	16078	269232	0	255460	0	13243	0
31	0	600950	314160	12672	11752789	5361636	15507	269232	0	255460	0	13243	0
32	0	600950	314160	12672	12084507	5420336	14936	269232	0	255460	0	13243	0
33	0	600950	314160	12672	12049325	5381077	15352	636132	0	353419	0	12256	0
34	0	600950	314160	12672	12014143	5341818	15768	636132	0	353419	0	12256	0
35	0	600950	314160	12672	11978961	5302559	16184	636132	0	353419	0	12256	0
36	0	600950	314160	12672	11943779	5263300	16600	636132	0	353419	0	12256	0
37	0	600950	314160	12672	10179364	4464591	13200	2365365	0	1112869	0	16072	0
38	0	600950	314160	12672	8414949	3665882	9800	2365365	0	1112869	0	16072	0
39	0	600950	314160	12672	6650534	2867173	6400	2365365	0	1112869	0	16072	0
40	0	600950	314160	12672	4886119	2068464	3000	2365365	0	1112869	0	16072	0
41	0	600950	314160	12672	3570439	1709217	0	1916630	0	673407	0	15672	446
42	0	600950	314160	12672	2254759	1349970	0	1916630	0	673407	0	12672	3892
43	0	600950	314160	12672	939079	990723	0	1916630	0	673407	0	12672	7338
44	0	600950	314160	12672	0	631476	0	1540029	376601	673407	0	12672	10784
45	0	600950	314160	12672	0	541526	0	600950	510389	404110	0	12672	16197
46	0	600950	314160	12672	0	451576	0	600950	644177	404110	0	12672	21610
47	0	600950	314160	12672	0	361626	0	600950	777965	404110	0	12672	27023
48	0	600950	314160	12672	0	271676	0	600950	911753	404110	0	12672	32436
49	0	600950	314160	12672	0	330039	0	600950	432374	255797	0	12672	23840
50	0	600950	314160	12672	47005	388402	0	553945	0	255797	0	12672	15244
51	0	600950	314160	12672	526384	446765	0	121571	0	255797	0	12672	6648
52	0	600950	314160	12672	1005763	505128	1948	121571	0	255797	0	10724	0

Table 56. Cumulative Profit for Item 1 for period 1 - 26 (Uniform Production Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
1	600950	1544120	57005	0	0	267353.45	123529.6	60095	291520.845	-207791.995
2	600950	2088065	57005	0	0	267353.45	167045.2	60095	291520.845	-251307.595
3	600950	2632010	57005	0	0	267353.45	210560.8	60095	291520.845	-294823.195
4	600950	3175955	57005	0	0	267353.45	254076.4	60095	291520.845	-338338.795
5	600950	3512576	264329	0	0	1239703.01	281006.08	60095	291520.845	607081.085
6	600950	3849197	264329	0	0	1239703.01	307935.76	60095	291520.845	580151.405
7	600950	4185818	264329	0	0	1239703.01	334865.44	60095	291520.845	553221.725
8	600950	4522439	264329	0	0	1239703.01	361795.12	60095	291520.845	526292.045
9	600950	4478923	644466	0	0	3022545.54	358313.84	60095	291520.845	2312615.855
10	600950	4435407	644466	0	0	3022545.54	354832.56	60095	291520.845	2316097.135
11	600950	4391891	644466	0	0	3022545.54	351351.28	60095	291520.845	2319578.415
12	600950	4348375	644466	0	0	3022545.54	347870	60095	291520.845	2323059.695
13	600950	4835381	113944	0	0	534397.36	386830.48	60095	291520.845	-204048.965
14	600950	5322387	113944	0	0	534397.36	425790.96	60095	291520.845	-243009.445
15	600950	5809393	113944	0	0	534397.36	464751.44	60095	291520.845	-281969.925
16	600950	6296399	113944	0	0	534397.36	503711.92	60095	291520.845	-320930.405
17	600950	6700520	196829	0	0	923128.01	536041.6	60095	291520.845	35470.565
18	600950	7104641	196829	0	0	923128.01	568371.28	60095	291520.845	3140.885
19	600950	7508762	196829	0	0	923128.01	600700.96	60095	291520.845	-29188.795
20	600950	7912883	196829	0	0	923128.01	633030.64	60095	291520.845	-61518.475
21	600950	8228209	285624	0	0	1339576.56	658256.72	60095	291520.845	329703.995
22	600950	8543535	285624	0	0	1339576.56	683482.8	60095	291520.845	304477.915
23	600950	8858861	285624	0	0	1339576.56	708708.88	60095	291520.845	279251.835
24	600950	9174187	285624	0	0	1339576.56	733934.96	60095	291520.845	254025.755
25	600950	9570049	205088	0	0	961862.72	765603.92	60095	291520.845	-155357.045
26	600950	9965911	205088	0	0	961862.72	797272.88	60095	291520.845	-187026.005

Table 57. Cumulative Profit for Item 1 for period 27 - 52 (Uniform Production Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
27	600950	10361773	205088	0	0	961862.72	828941.84	60095	291520.845	-218694.965
28	600950	10757635	205088	0	0	961862.72	860610.8	60095	291520.845	-250363.925
29	600950	11089353	269232	0	0	1262698.08	887148.24	60095	291520.845	23933.995
30	600950	11421071	269232	0	0	1262698.08	913685.68	60095	291520.845	-2603.445
31	600950	11752789	269232	0	0	1262698.08	940223.12	60095	291520.845	-29140.885
32	600950	12084507	269232	0	0	1262698.08	966760.56	60095	291520.845	-55678.325
33	600950	12049325	636132	0	0	2983459.08	963946	60095	291520.845	1667897.235
34	600950	12014143	636132	0	0	2983459.08	961131.44	60095	291520.845	1670711.795
35	600950	11978961	636132	0	0	2983459.08	958316.88	60095	291520.845	1673526.355
36	600950	11943779	636132	0	0	2983459.08	955502.32	60095	291520.845	1676340.915
37	600950	10179364	2365365	0	0	11093561.85	814349.12	60095	291520.845	9927596.885
38	600950	8414949	2365365	0	0	11093561.85	673195.92	60095	291520.845	10068750.09
39	600950	6650534	2365365	0	0	11093561.85	532042.72	60095	291520.845	10209903.29
40	600950	4886119	2365365	0	0	11093561.85	390889.52	60095	291520.845	10351056.49
41	600950	3570439	1916630	0	0	8988994.7	285635.12	60095	291520.845	8351743.735
42	600950	2254759	1916630	0	0	8988994.7	180380.72	60095	291520.845	8456998.135
43	600950	939079	1916630	0	0	8988994.7	75126.32	60095	291520.845	8562252.535
44	600950	0	1540029	376601	18830.05	7222736.01	0	60095	291520.845	6852290.115
45	600950	0	600950	510389	25519.45	2818455.5	0	60095	291520.845	2441320.205
46	600950	0	600950	644177	32208.85	2818455.5	0	60095	291520.845	2434630.805
47	600950	0	600950	777965	38898.25	2818455.5	0	60095	291520.845	2427941.405
48	600950	0	600950	911753	45587.65	2818455.5	0	60095	291520.845	2421252.005
49	600950	0	600950	432374	21618.7	2818455.5	0	60095	291520.845	2445220.955
50	600950	47005	553945	0	0	2598002.05	3760.4	60095	291520.845	2242625.805
51	600950	526384	121571	0	0	570167.99	42110.72	60095	291520.845	176441.425
52	600950	1005763	121571	0	0	570167.99	80461.04	60095	291520.845	138091.105

Table 58. Cumulative Profit for Item 2 for period 1 - 26 (Uniform Production Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
1	314160	739610	74550	0	0	186375	59168.8	31416	152399.016	-56608.816
2	314160	979220	74550	0	0	186375	78337.6	31416	152399.016	-75777.616
3	314160	1218830	74550	0	0	186375	97506.4	31416	152399.016	-94946.416
4	314160	1458440	74550	0	0	186375	116675.2	31416	152399.016	-114115.216
5	314160	1606081	166519	0	0	416297.5	128486.48	31416	152399.016	103996.004
6	314160	1753722	166519	0	0	416297.5	140297.76	31416	152399.016	92184.724
7	314160	1901363	166519	0	0	416297.5	152109.04	31416	152399.016	80373.444
8	314160	2049004	166519	0	0	416297.5	163920.32	31416	152399.016	68562.164
9	314160	2081304	281860	0	0	704650	166504.32	31416	152399.016	354330.664
10	314160	2113604	281860	0	0	704650	169088.32	31416	152399.016	351746.664
11	314160	2145904	281860	0	0	704650	171672.32	31416	152399.016	349162.664
12	314160	2178204	281860	0	0	704650	174256.32	31416	152399.016	346578.664
13	314160	2392323	100041	0	0	250102.5	191385.84	31416	152399.016	-125098.356
14	314160	2606442	100041	0	0	250102.5	208515.36	31416	152399.016	-142227.876
15	314160	2820561	100041	0	0	250102.5	225644.88	31416	152399.016	-159357.396
16	314160	3034680	100041	0	0	250102.5	242774.4	31416	152399.016	-176486.916
17	314160	3226318	122522	0	0	306305	258105.44	31416	152399.016	-135615.456
18	314160	3417956	122522	0	0	306305	273436.48	31416	152399.016	-150946.496
19	314160	3609594	122522	0	0	306305	288767.52	31416	152399.016	-166277.536
20	314160	3801232	122522	0	0	306305	304098.56	31416	152399.016	-181608.576
21	314160	3955595	159797	0	0	399492.5	316447.6	31416	152399.016	-100770.116
22	314160	4109958	159797	0	0	399492.5	328796.64	31416	152399.016	-113119.156
23	314160	4264321	159797	0	0	399492.5	341145.68	31416	152399.016	-125468.196
24	314160	4418684	159797	0	0	399492.5	353494.72	31416	152399.016	-137817.236
25	314160	4610397	122447	0	0	306117.5	368831.76	31416	152399.016	-246529.276
26	314160	4802110	122447	0	0	306117.5	384168.8	31416	152399.016	-261866.316

Table 59. Cumulative Profit for Item 2 for period 27 - 52 (Uniform Production Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
27	314160	4993823	122447	0	0	306117.5	399505.84	31416	152399.016	-277203.356
28	314160	5185536	122447	0	0	306117.5	414842.88	31416	152399.016	-292540.396
29	314160	5244236	255460	0	0	638650	419538.88	31416	152399.016	35296.104
30	314160	5302936	255460	0	0	638650	424234.88	31416	152399.016	30600.104
31	314160	5361636	255460	0	0	638650	428930.88	31416	152399.016	25904.104
32	314160	5420336	255460	0	0	638650	433626.88	31416	152399.016	21208.104
33	314160	5381077	353419	0	0	883547.5	430486.16	31416	152399.016	269246.324
34	314160	5341818	353419	0	0	883547.5	427345.44	31416	152399.016	272387.044
35	314160	5302559	353419	0	0	883547.5	424204.72	31416	152399.016	275527.764
36	314160	5263300	353419	0	0	883547.5	421064	31416	152399.016	278668.484
37	314160	4464591	1112869	0	0	2782172.5	357167.28	31416	152399.016	2241190.204
38	314160	3665882	1112869	0	0	2782172.5	293270.56	31416	152399.016	2305086.924
39	314160	2867173	1112869	0	0	2782172.5	229373.84	31416	152399.016	2368983.644
40	314160	2068464	1112869	0	0	2782172.5	165477.12	31416	152399.016	2432880.364
41	314160	1709217	673407	0	0	1683517.5	136737.36	31416	152399.016	1362965.124
42	314160	1349970	673407	0	0	1683517.5	107997.6	31416	152399.016	1391704.884
43	314160	990723	673407	0	0	1683517.5	79257.84	31416	152399.016	1420444.644
44	314160	631476	673407	0	0	1683517.5	50518.08	31416	152399.016	1449184.404
45	314160	541526	404110	0	0	1010275	43322.08	31416	152399.016	783137.904
46	314160	451576	404110	0	0	1010275	36126.08	31416	152399.016	790333.904
47	314160	361626	404110	0	0	1010275	28930.08	31416	152399.016	797529.904
48	314160	271676	404110	0	0	1010275	21734.08	31416	152399.016	804725.904
49	314160	330039	255797	0	0	639492.5	26403.12	31416	152399.016	429274.364
50	314160	388402	255797	0	0	639492.5	31072.16	31416	152399.016	424605.324
51	314160	446765	255797	0	0	639492.5	35741.2	31416	152399.016	419936.284
52	314160	505128	255797	0	0	639492.5	40410.24	31416	152399.016	415267.244

Table 60. Cumulative Profit for Item 3 for period 1 - 26 (Uniform Production Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
1	12672	31	12713	0	0	100305.57	2.48	1267.2	6147.1872	92888.7028
2	12672	0	12703	10	0.5	100226.67	0	1267.2	6147.1872	92811.7828
3	12672	0	12672	51	2.55	99982.08	0	1267.2	6147.1872	92565.1428
4	12672	0	12672	92	4.6	99982.08	0	1267.2	6147.1872	92563.0928
5	12672	5471	7201	0	0	56815.89	437.68	1267.2	6147.1872	48963.8228
6	12672	11034	7109	0	0	56090.01	882.72	1267.2	6147.1872	47792.9028
7	12672	16597	7109	0	0	56090.01	1327.76	1267.2	6147.1872	47347.8628
8	12672	22160	7109	0	0	56090.01	1772.8	1267.2	6147.1872	46902.8228
9	12672	18692	16140	0	0	127344.6	1495.36	1267.2	6147.1872	118434.8528
10	12672	15224	16140	0	0	127344.6	1217.92	1267.2	6147.1872	118712.2928
11	12672	11756	16140	0	0	127344.6	940.48	1267.2	6147.1872	118989.7328
12	12672	8288	16140	0	0	127344.6	663.04	1267.2	6147.1872	119267.1728
13	12672	9728	11232	0	0	88620.48	778.24	1267.2	6147.1872	80427.8528
14	12672	11168	11232	0	0	88620.48	893.44	1267.2	6147.1872	80312.6528
15	12672	12608	11232	0	0	88620.48	1008.64	1267.2	6147.1872	80197.4528
16	12672	14048	11232	0	0	88620.48	1123.84	1267.2	6147.1872	80082.2528
17	12672	14487	12233	0	0	96518.37	1158.96	1267.2	6147.1872	87945.0228
18	12672	14926	12233	0	0	96518.37	1194.08	1267.2	6147.1872	87909.9028
19	12672	15365	12233	0	0	96518.37	1229.2	1267.2	6147.1872	87874.7828
20	12672	15804	12233	0	0	96518.37	1264.32	1267.2	6147.1872	87839.6628
21	12672	14875	13601	0	0	107311.89	1190	1267.2	6147.1872	98707.5028
22	12672	13946	13601	0	0	107311.89	1115.68	1267.2	6147.1872	98781.8228
23	12672	13017	13601	0	0	107311.89	1041.36	1267.2	6147.1872	98856.1428
24	12672	12088	13601	0	0	107311.89	967.04	1267.2	6147.1872	98930.4628
25	12672	13371	11389	0	0	89859.21	1069.68	1267.2	6147.1872	81375.1428
26	12672	14654	11389	0	0	89859.21	1172.32	1267.2	6147.1872	81272.5028

Table 61. Cumulative Profit for Item 3 for period 27 - 52 (Uniform Production Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
27	12672	15937	11389	0	0	89859.21	1274.96	1267.2	6147.1872	81169.8628
28	12672	17220	11389	0	0	89859.21	1377.6	1267.2	6147.1872	81067.2228
29	12672	16649	13243	0	0	104487.27	1331.92	1267.2	6147.1872	95740.9628
30	12672	16078	13243	0	0	104487.27	1286.24	1267.2	6147.1872	95786.6428
31	12672	15507	13243	0	0	104487.27	1240.56	1267.2	6147.1872	95832.3228
32	12672	14936	13243	0	0	104487.27	1194.88	1267.2	6147.1872	95878.0028
33	12672	15352	12256	0	0	96699.84	1228.16	1267.2	6147.1872	88057.2928
34	12672	15768	12256	0	0	96699.84	1261.44	1267.2	6147.1872	88024.0128
35	12672	16184	12256	0	0	96699.84	1294.72	1267.2	6147.1872	87990.7328
36	12672	16600	12256	0	0	96699.84	1328	1267.2	6147.1872	87957.4528
37	12672	13200	16072	0	0	126808.08	1056	1267.2	6147.1872	118337.6928
38	12672	9800	16072	0	0	126808.08	784	1267.2	6147.1872	118609.6928
39	12672	6400	16072	0	0	126808.08	512	1267.2	6147.1872	118881.6928
40	12672	3000	16072	0	0	126808.08	240	1267.2	6147.1872	119153.6928
41	12672	0	15672	446	22.3	123652.08	0	1267.2	6147.1872	116215.3928
42	12672	0	12672	3892	194.6	99982.08	0	1267.2	6147.1872	92373.0928
43	12672	0	12672	7338	366.9	99982.08	0	1267.2	6147.1872	92200.7928
44	12672	0	12672	10784	539.2	99982.08	0	1267.2	6147.1872	92028.4928
45	12672	0	12672	16197	809.85	99982.08	0	1267.2	6147.1872	91757.8428
46	12672	0	12672	21610	1080.5	99982.08	0	1267.2	6147.1872	91487.1928
47	12672	0	12672	27023	1351.15	99982.08	0	1267.2	6147.1872	91216.5428
48	12672	0	12672	32436	1621.8	99982.08	0	1267.2	6147.1872	90945.8928
49	12672	0	12672	23840	1192	99982.08	0	1267.2	6147.1872	91375.6928
50	12672	0	12672	15244	762.2	99982.08	0	1267.2	6147.1872	91805.4928
51	12672	0	12672	6648	332.4	99982.08	0	1267.2	6147.1872	92235.2928
52	12672	1948	10724	0	0	84612.36	155.84	1267.2	6147.1872	77042.1328

Table 62. Overall CVP for Uniform Production Model (Period 1 - 26)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
1	-207791.995	-56608.816	92888.7028	0	9500	76000	-247512.1082
2	-251307.595	-75777.616	92811.7828	0	9500	76000	-310273.4282
3	-294823.195	-94946.416	92565.1428	0	9500	76000	-373204.4682
4	-338338.795	-114115.216	92563.0928	0	9500	76000	-435890.9182
5	607081.085	103996.004	48963.8228	0	9500	76000	684040.9118
6	580151.405	92184.724	47792.9028	0	9500	76000	644129.0318
7	553221.725	80373.444	47347.8628	0	9500	76000	604943.0318
8	526292.045	68562.164	46902.8228	0	9500	76000	565757.0318
9	2312615.855	354330.664	118434.8528	0	9500	76000	2709381.372
10	2316097.135	351746.664	118712.2928	0	9500	76000	2710556.092
11	2319578.415	349162.664	118989.7328	0	9500	76000	2711730.812
12	2323059.695	346578.664	119267.1728	0	9500	76000	2712905.532
13	-204048.965	-125098.356	80427.8528	0	9500	76000	-324719.4682
14	-243009.445	-142227.876	80312.6528	0	9500	76000	-380924.6682
15	-281969.925	-159357.396	80197.4528	0	9500	76000	-437129.8682
16	-320930.405	-176486.916	80082.2528	0	9500	76000	-493335.0682
17	35470.565	-135615.456	87945.0228	0	9500	76000	-88199.8682
18	3140.885	-150946.496	87909.9028	0	9500	76000	-135895.7082
19	-29188.795	-166277.536	87874.7828	0	9500	76000	-183591.5482
20	-61518.475	-181608.576	87839.6628	0	9500	76000	-231287.3882
21	329703.995	-100770.116	98707.5028	0	9500	76000	251641.3818
22	304477.915	-113119.156	98781.8228	0	9500	76000	214140.5818
23	279251.835	-125468.196	98856.1428	0	6875	55000	197639.7818
24	254025.755	-137817.236	98930.4628	0	6875	55000	160138.9818
25	-155357.045	-246529.276	81375.1428	0	6875	55000	-375511.1782
26	-187026.005	-261866.316	81272.5028	0	6875	55000	-422619.8182

Table 63. Overall CVP for Uniform Production Model (Period 27 - 52)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
27	-218694.965	-277203.356	81169.8628	0	6875	55000	-469728.4582
28	-250363.925	-292540.396	81067.2228	0	6875	55000	-516837.0982
29	23933.995	35296.104	95740.9628	0	6875	55000	99971.0618
30	-2603.445	30600.104	95786.6428	0	6875	55000	68783.3018
31	-29140.885	25904.104	95832.3228	0	6875	55000	37595.5418
32	-55678.325	21208.104	95878.0028	0	6875	55000	6407.7818
33	1667897.235	269246.324	88057.2928	0	6875	55000	1970200.852
34	1670711.795	272387.044	88024.0128	0	6875	55000	1976122.852
35	1673526.355	275527.764	87990.7328	0	6875	55000	1982044.852
36	1676340.915	278668.484	87957.4528	0	6875	55000	1987966.852
37	9927596.885	2241190.204	118337.6928	0	6875	55000	12232124.78
38	10068750.09	2305086.924	118609.6928	0	6875	55000	12437446.7
39	10209903.29	2368983.644	118881.6928	0	6875	55000	12642768.62
40	10351056.49	2432880.364	119153.6928	0	9500	76000	12827090.54
41	8351743.735	1362965.124	116215.3928	0	9500	76000	9754924.252
42	8456998.135	1391704.884	92373.0928	0	9500	76000	9865076.112
43	8562252.535	1420444.644	92200.7928	0	9500	76000	9998897.972
44	6852290.115	1449184.404	92028.4928	0	9500	76000	8317503.012
45	2441320.205	783137.904	91757.8428	0	9500	76000	3240215.952
46	2434630.805	790333.904	91487.1928	0	9500	76000	3240451.902
47	2427941.405	797529.904	91216.5428	0	9500	76000	3240687.852
48	2421252.005	804725.904	90945.8928	0	9500	76000	3240923.802
49	2445220.955	429274.364	91375.6928	0	9500	76000	2889871.012
50	2242625.805	424605.324	91805.4928	0	9500	76000	2683036.622
51	176441.425	419936.284	92235.2928	0	9500	76000	612613.0018
52	138091.105	415267.244	77042.1328	0	9500	76000	554400.4818

Table 64. Simulation Output Statistics for JIT Model for Period 1 - 26

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
1	0	57050	74690	12744	1000220	500140	103	57005	0	74550	0	12713	0
2	0	57050	74690	12744	1000265	500280	134	57005	0	74550	0	12713	0
3	0	57050	74690	12744	1000310	500420	165	57005	0	74550	0	12713	0
4	0	57050	74690	12744	1000355	500560	196	57005	0	74550	0	12713	0
5	0	264425	166705	7128	1000451	500746	215	264329	0	166519	0	7109	0
6	0	264425	166705	7128	1000547	500932	234	264329	0	166519	0	7109	0
7	0	264425	166705	7128	1000643	501118	253	264329	0	166519	0	7109	0
8	0	264425	166705	7128	1000739	501304	272	264329	0	166519	0	7109	0
9	0	644525	282205	16200	1000798	501649	332	644466	0	281860	0	16140	0
10	0	644525	282205	16200	1000857	501994	392	644466	0	281860	0	16140	0
11	0	644525	282205	16200	1000916	502339	452	644466	0	281860	0	16140	0
12	0	644525	282205	16200	1000975	502684	512	644466	0	281860	0	16140	0
13	0	114100	100100	11304	1001131	502743	584	113944	0	100041	0	11232	0
14	0	114100	100100	11304	1001287	502802	656	113944	0	100041	0	11232	0
15	0	114100	100100	11304	1001443	502861	728	113944	0	100041	0	11232	0
16	0	114100	100100	11304	1001599	502920	800	113944	0	100041	0	11232	0
17	0	196875	122815	12240	1001645	503213	807	196829	0	122522	0	12233	0
18	0	196875	122815	12240	1001691	503506	814	196829	0	122522	0	12233	0
19	0	196875	122815	12240	1001737	503799	821	196829	0	122522	0	12233	0
20	0	196875	122815	12240	1001783	504092	828	196829	0	122522	0	12233	0
21	0	285775	160160	13608	1001934	504455	835	285624	0	159797	0	13601	0
22	0	285775	160160	13608	1002085	504818	842	285624	0	159797	0	13601	0
23	0	285775	160160	13608	1002236	505181	849	285624	0	159797	0	13601	0
24	0	285775	160160	13608	1002387	505544	856	285624	0	159797	0	13601	0
25	0	205100	122815	11448	1002399	505912	915	205088	0	122447	0	11389	0
26	0	205100	122815	11448	1002411	506280	974	205088	0	122447	0	11389	0

Table 65. Simulation Output Statistics for JIT for Period 27 - 52

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
27	0	205100	122815	11448	1002423	506648	1033	205088	0	122447	0	11389	0
28	0	205100	122815	11448	1002435	507016	1092	205088	0	122447	0	11389	0
29	0	269325	255640	13248	1002528	507196	1097	269232	0	255460	0	13243	0
30	0	269325	255640	13248	1002621	507376	1102	269232	0	255460	0	13243	0
31	0	269325	255640	13248	1002714	507556	1107	269232	0	255460	0	13243	0
32	0	269325	255640	13248	1002807	507736	1112	269232	0	255460	0	13243	0
33	0	636300	353430	12312	1002975	507747	1168	636132	0	353419	0	12256	0
34	0	636300	353430	12312	1003143	507758	1224	636132	0	353419	0	12256	0
35	0	636300	353430	12312	1003311	507769	1280	636132	0	353419	0	12256	0
36	0	636300	353430	12312	1003479	507780	1336	636132	0	353419	0	12256	0
37	2	1763825	0	16128	401939	0	1392	2365365	0	507780	605089	16072	0
38	2	1764000	0	16128	0	0	1448	2165939	199426	0	1717958	16072	0
39	2	1764000	0	16128	0	0	1504	1764000	800791	0	2830827	16072	0
40	2	1764000	0	16128	0	0	1560	1764000	1402156	0	3943696	16072	0
41	2	1764000	0	16128	0	0	1570	1764000	1554786	0	4617103	16118	0
42	2	1764000	0	16128	0	0	1580	1764000	1707416	0	5290510	16118	0
43	2	1764000	0	16128	0	0	1590	1764000	1860046	0	5963917	16118	0
44	2	1764000	0	16128	0	0	1600	1764000	2012676	0	6637324	16118	0
45	0	734825	404250	18144	0	0	1659	734825	2012589	404250	6637184	18085	0
46	1	734825	404250	18144	0	0	1718	734825	2012502	404250	6637044	18085	0
47	1	734825	404250	18144	0	0	1777	734825	2012415	404250	6636904	18085	0
48	1	734825	404250	18144	0	0	1836	734825	2012328	404250	6636764	18085	0
49	0	121625	256025	4104	0	0	1864	121625	2012274	256025	6636536	4076	0
50	0	121625	256025	4104	0	0	1892	121625	2012220	256025	6636308	4076	0
51	0	121625	256025	4104	0	0	1920	121625	2012166	256025	6636080	4076	0
52	0	121625	256025	4104	0	0	1948	121625	2012112	256025	6635852	4076	0

Table 66. Cumulative Profit for Item 1 for period 1 - 26 (JIT Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
1	57050	1000220	57005	0	0	267353.45	80017.6	5705	27674.955	153955.895
2	57050	1000265	57005	0	0	267353.45	80021.2	5705	27674.955	153952.295
3	57050	1000310	57005	0	0	267353.45	80024.8	5705	27674.955	153948.695
4	57050	1000355	57005	0	0	267353.45	80028.4	5705	27674.955	153945.095
5	264425	1000451	264329	0	0	1239703.01	80036.08	26442.5	128272.5675	1004951.863
6	264425	1000547	264329	0	0	1239703.01	80043.76	26442.5	128272.5675	1004944.183
7	264425	1000643	264329	0	0	1239703.01	80051.44	26442.5	128272.5675	1004936.503
8	264425	1000739	264329	0	0	1239703.01	80059.12	26442.5	128272.5675	1004928.823
9	644525	1000798	644466	0	0	3022545.54	80063.84	64452.5	312659.0775	2565370.123
10	644525	1000857	644466	0	0	3022545.54	80068.56	64452.5	312659.0775	2565365.403
11	644525	1000916	644466	0	0	3022545.54	80073.28	64452.5	312659.0775	2565360.683
12	644525	1000975	644466	0	0	3022545.54	80078	64452.5	312659.0775	2565355.963
13	114100	1001131	113944	0	0	534397.36	80090.48	11410	55349.91	387546.97
14	114100	1001287	113944	0	0	534397.36	80102.96	11410	55349.91	387534.49
15	114100	1001443	113944	0	0	534397.36	80115.44	11410	55349.91	387522.01
16	114100	1001599	113944	0	0	534397.36	80127.92	11410	55349.91	387509.53
17	196875	1001645	196829	0	0	923128.01	80131.6	19687.5	95504.0625	727804.8475
18	196875	1001691	196829	0	0	923128.01	80135.28	19687.5	95504.0625	727801.1675
19	196875	1001737	196829	0	0	923128.01	80138.96	19687.5	95504.0625	727797.4875
20	196875	1001783	196829	0	0	923128.01	80142.64	19687.5	95504.0625	727793.8075
21	285775	1001934	285624	0	0	1339576.56	80154.72	28577.5	138629.4525	1092214.888
22	285775	1002085	285624	0	0	1339576.56	80166.8	28577.5	138629.4525	1092202.808
23	285775	1002236	285624	0	0	1339576.56	80178.88	28577.5	138629.4525	1092190.728
24	285775	1002387	285624	0	0	1339576.56	80190.96	28577.5	138629.4525	1092178.648
25	205100	1002399	205088	0	0	961862.72	80191.92	20510	99494.01	761666.79
26	205100	1002411	205088	0	0	961862.72	80192.88	20510	99494.01	761665.83

Table 67. Cumulative Profit for Item 1 for period 27 - 52 (JIT Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
27	205100	1002423	205088	0	0	961862.72	80193.84	20510	99494.01	761664.87
28	205100	1002435	205088	0	0	961862.72	80194.8	20510	99494.01	761663.91
29	269325	1002528	269232	0	0	1262698.08	80202.24	26932.5	130649.5575	1024913.783
30	269325	1002621	269232	0	0	1262698.08	80209.68	26932.5	130649.5575	1024906.343
31	269325	1002714	269232	0	0	1262698.08	80217.12	26932.5	130649.5575	1024898.903
32	269325	1002807	269232	0	0	1262698.08	80224.56	26932.5	130649.5575	1024891.463
33	636300	1002975	636132	0	0	2983459.08	80238	63630	308669.13	2530921.95
34	636300	1003143	636132	0	0	2983459.08	80251.44	63630	308669.13	2530908.51
35	636300	1003311	636132	0	0	2983459.08	80264.88	63630	308669.13	2530895.07
36	636300	1003479	636132	0	0	2983459.08	80278.32	63630	308669.13	2530881.63
37	1763825	401939	2365365	0	0	11093561.85	32155.12	176382.5	855631.5075	10029392.72
38	1764000	0	2165939	199426	9971.3	10158253.91	0	176400	855716.4	9116166.21
39	1764000	0	1764000	800791	40039.55	8273160	0	176400	855716.4	7201004.05
40	1764000	0	1764000	1402156	70107.8	8273160	0	176400	855716.4	7170935.8
41	1764000	0	1764000	1554786	77739.3	8273160	0	176400	855716.4	7163304.3
42	1764000	0	1764000	1707416	85370.8	8273160	0	176400	855716.4	7155672.8
43	1764000	0	1764000	1860046	93002.3	8273160	0	176400	855716.4	7148041.3
44	1764000	0	1764000	2012676	100633.8	8273160	0	176400	855716.4	7140409.8
45	734825	0	734825	2012589	100629.45	3446329.25	0	73482.5	356463.6075	2915753.693
46	734825	0	734825	2012502	100625.1	3446329.25	0	73482.5	356463.6075	2915758.043
47	734825	0	734825	2012415	100620.75	3446329.25	0	73482.5	356463.6075	2915762.393
48	734825	0	734825	2012328	100616.4	3446329.25	0	73482.5	356463.6075	2915766.743
49	121625	0	121625	2012274	100613.7	570421.25	0	12162.5	59000.2875	398644.7625
50	121625	0	121625	2012220	100611	570421.25	0	12162.5	59000.2875	398647.4625
51	121625	0	121625	2012166	100608.3	570421.25	0	12162.5	59000.2875	398650.1625
52	121625	0	121625	2012112	100605.6	570421.25	0	12162.5	59000.2875	398652.8625

Table 68. Cumulative Profit for Item 2 for period 1 - 26 (JIT Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
1	74690	500140	74550	0	0	186375	40011.2	7469	36232.119	102662.681
2	74690	500280	74550	0	0	186375	40022.4	7469	36232.119	102651.481
3	74690	500420	74550	0	0	186375	40033.6	7469	36232.119	102640.281
4	74690	500560	74550	0	0	186375	40044.8	7469	36232.119	102629.081
5	166705	500746	166519	0	0	416297.5	40059.68	16670.5	80868.5955	278698.7245
6	166705	500932	166519	0	0	416297.5	40074.56	16670.5	80868.5955	278683.8445
7	166705	501118	166519	0	0	416297.5	40089.44	16670.5	80868.5955	278668.9645
8	166705	501304	166519	0	0	416297.5	40104.32	16670.5	80868.5955	278654.0845
9	282205	501649	281860	0	0	704650	40131.92	28220.5	136897.6455	499399.9345
10	282205	501994	281860	0	0	704650	40159.52	28220.5	136897.6455	499372.3345
11	282205	502339	281860	0	0	704650	40187.12	28220.5	136897.6455	499344.7345
12	282205	502684	281860	0	0	704650	40214.72	28220.5	136897.6455	499317.1345
13	100100	502743	100041	0	0	250102.5	40219.44	10010	48558.51	151314.55
14	100100	502802	100041	0	0	250102.5	40224.16	10010	48558.51	151309.83
15	100100	502861	100041	0	0	250102.5	40228.88	10010	48558.51	151305.11
16	100100	502920	100041	0	0	250102.5	40233.6	10010	48558.51	151300.39
17	122815	503213	122522	0	0	306305	40257.04	12281.5	59577.5565	194188.9035
18	122815	503506	122522	0	0	306305	40280.48	12281.5	59577.5565	194165.4635
19	122815	503799	122522	0	0	306305	40303.92	12281.5	59577.5565	194142.0235
20	122815	504092	122522	0	0	306305	40327.36	12281.5	59577.5565	194118.5835
21	160160	504455	159797	0	0	399492.5	40356.4	16016	77693.616	265426.484
22	160160	504818	159797	0	0	399492.5	40385.44	16016	77693.616	265397.444
23	160160	505181	159797	0	0	399492.5	40414.48	16016	77693.616	265368.404
24	160160	505544	159797	0	0	399492.5	40443.52	16016	77693.616	265339.364
25	122815	505912	122447	0	0	306117.5	40472.96	12281.5	59577.5565	193785.4835
26	122815	506280	122447	0	0	306117.5	40502.4	12281.5	59577.5565	193756.0435

Table 69 Cumulative Profit for Item 2 for period 27 - 52 (JIT Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
27	122815	506648	122447	0	0	306117.5	40531.84	12281.5	59577.5565	193726.6035
28	122815	507016	122447	0	0	306117.5	40561.28	12281.5	59577.5565	193697.1635
29	255640	507196	255460	0	0	638650	40575.68	25564	124010.964	448499.356
30	255640	507376	255460	0	0	638650	40590.08	25564	124010.964	448484.956
31	255640	507556	255460	0	0	638650	40604.48	25564	124010.964	448470.556
32	255640	507736	255460	0	0	638650	40618.88	25564	124010.964	448456.156
33	353430	507747	353419	0	0	883547.5	40619.76	35343	171448.893	636135.847
34	353430	507758	353419	0	0	883547.5	40620.64	35343	171448.893	636134.967
35	353430	507769	353419	0	0	883547.5	40621.52	35343	171448.893	636134.087
36	353430	507780	353419	0	0	883547.5	40622.4	35343	171448.893	636133.207
37	0	0	507780	605089	30254.45	1269450	0	0	0	1239195.55
38	0	0	0	1717958	85897.9	0	0	0	0	-85897.9
39	0	0	0	2830827	141541.35	0	0	0	0	-141541.35
40	0	0	0	3943696	197184.8	0	0	0	0	-197184.8
41	0	0	0	4617103	230855.15	0	0	0	0	-230855.15
42	0	0	0	5290510	264525.5	0	0	0	0	-264525.5
43	0	0	0	5963917	298195.85	0	0	0	0	-298195.85
44	0	0	0	6637324	331866.2	0	0	0	0	-331866.2
45	404250	0	404250	6637184	331859.2	1010625	0	40425	196101.675	442239.125
46	404250	0	404250	6637044	331852.2	1010625	0	40425	196101.675	442246.125
47	404250	0	404250	6636904	331845.2	1010625	0	40425	196101.675	442253.125
48	404250	0	404250	6636764	331838.2	1010625	0	40425	196101.675	442260.125
49	256025	0	256025	6636536	331826.8	640062.5	0	25602.5	124197.7275	158435.4725
50	256025	0	256025	6636308	331815.4	640062.5	0	25602.5	124197.7275	158446.8725
51	256025	0	256025	6636080	331804	640062.5	0	25602.5	124197.7275	158458.2725
52	256025	0	256025	6635852	331792.6	640062.5	0	25602.5	124197.7275	158469.6725

Table 70 Cumulative Profit for Item 3 for period 1 - 26 (JIT Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
1	12744	103	12713	0	0	100305.57	8.24	1274.4	6182.1144	92840.8156
2	12744	134	12713	0	0	100305.57	10.72	1274.4	6182.1144	92838.3356
3	12744	165	12713	0	0	100305.57	13.2	1274.4	6182.1144	92835.8556
4	12744	196	12713	0	0	100305.57	15.68	1274.4	6182.1144	92833.3756
5	7128	215	7109	0	0	56090.01	17.2	712.8	3457.7928	51902.2172
6	7128	234	7109	0	0	56090.01	18.72	712.8	3457.7928	51900.6972
7	7128	253	7109	0	0	56090.01	20.24	712.8	3457.7928	51899.1772
8	7128	272	7109	0	0	56090.01	21.76	712.8	3457.7928	51897.6572
9	16200	332	16140	0	0	127344.6	26.56	1620	7858.62	117839.42
10	16200	392	16140	0	0	127344.6	31.36	1620	7858.62	117834.62
11	16200	452	16140	0	0	127344.6	36.16	1620	7858.62	117829.82
12	16200	512	16140	0	0	127344.6	40.96	1620	7858.62	117825.02
13	11304	584	11232	0	0	88620.48	46.72	1130.4	5483.5704	81959.7896
14	11304	656	11232	0	0	88620.48	52.48	1130.4	5483.5704	81954.0296
15	11304	728	11232	0	0	88620.48	58.24	1130.4	5483.5704	81948.2696
16	11304	800	11232	0	0	88620.48	64	1130.4	5483.5704	81942.5096
17	12240	807	12233	0	0	96518.37	64.56	1224	5937.624	89292.186
18	12240	814	12233	0	0	96518.37	65.12	1224	5937.624	89291.626
19	12240	821	12233	0	0	96518.37	65.68	1224	5937.624	89291.066
20	12240	828	12233	0	0	96518.37	66.24	1224	5937.624	89290.506
21	13608	835	13601	0	0	107311.89	66.8	1360.8	6601.2408	99283.0492
22	13608	842	13601	0	0	107311.89	67.36	1360.8	6601.2408	99282.4892
23	13608	849	13601	0	0	107311.89	67.92	1360.8	6601.2408	99281.9292
24	13608	856	13601	0	0	107311.89	68.48	1360.8	6601.2408	99281.3692
25	11448	915	11389	0	0	89859.21	73.2	1144.8	5553.4248	83087.7852
26	11448	974	11389	0	0	89859.21	77.92	1144.8	5553.4248	83083.0652

Table 71 Cumulative Profit for Item 3 for period 27 - 52 (JIT Model)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
27	11448	1033	11389	0	0	89859.21	82.64	1144.8	5553.4248	83078.3452
28	11448	1092	11389	0	0	89859.21	87.36	1144.8	5553.4248	83073.6252
29	13248	1097	13243	0	0	104487.27	87.76	1324.8	6426.6048	96648.1052
30	13248	1102	13243	0	0	104487.27	88.16	1324.8	6426.6048	96647.7052
31	13248	1107	13243	0	0	104487.27	88.56	1324.8	6426.6048	96647.3052
32	13248	1112	13243	0	0	104487.27	88.96	1324.8	6426.6048	96646.9052
33	12312	1168	12256	0	0	96699.84	93.44	1231.2	5972.5512	89402.6488
34	12312	1224	12256	0	0	96699.84	97.92	1231.2	5972.5512	89398.1688
35	12312	1280	12256	0	0	96699.84	102.4	1231.2	5972.5512	89393.6888
36	12312	1336	12256	0	0	96699.84	106.88	1231.2	5972.5512	89389.2088
37	16128	1392	16072	0	0	126808.08	111.36	1612.8	7823.6928	117260.2272
38	16128	1448	16072	0	0	126808.08	115.84	1612.8	7823.6928	117255.7472
39	16128	1504	16072	0	0	126808.08	120.32	1612.8	7823.6928	117251.2672
40	16128	1560	16072	0	0	126808.08	124.8	1612.8	7823.6928	117246.7872
41	16128	1570	16118	0	0	127171.02	125.6	1612.8	7823.6928	117608.9272
42	16128	1580	16118	0	0	127171.02	126.4	1612.8	7823.6928	117608.1272
43	16128	1590	16118	0	0	127171.02	127.2	1612.8	7823.6928	117607.3272
44	16128	1600	16118	0	0	127171.02	128	1612.8	7823.6928	117606.5272
45	18144	1659	18085	0	0	142690.65	132.72	1814.4	8801.6544	131941.8756
46	18144	1718	18085	0	0	142690.65	137.44	1814.4	8801.6544	131937.1556
47	18144	1777	18085	0	0	142690.65	142.16	1814.4	8801.6544	131932.4356
48	18144	1836	18085	0	0	142690.65	146.88	1814.4	8801.6544	131927.7156
49	4104	1864	4076	0	0	32159.64	149.12	410.4	1990.8504	29609.2696
50	4104	1892	4076	0	0	32159.64	151.36	410.4	1990.8504	29607.0296
51	4104	1920	4076	0	0	32159.64	153.6	410.4	1990.8504	29604.7896
52	4104	1948	4076	0	0	32159.64	155.84	410.4	1990.8504	29602.5496

Table 72. Overall Cumulative Variant Profit for JIT Model (Period 1 - 26)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
1	153955.895	102662.681	92840.8156	0	9500	19000	330459.3916
2	153952.295	102651.481	92838.3356	0	9500	19000	330442.1116
3	153948.695	102640.281	92835.8556	0	9500	19000	330424.8316
4	153945.095	102629.081	92833.3756	0	9500	19000	330407.5516
5	1004951.863	278698.7245	51902.2172	0	9500	38000	1297552.804
6	1004944.183	278683.8445	51900.6972	0	9500	38000	1297528.724
7	1004936.503	278668.9645	51899.1772	0	9500	38000	1297504.644
8	1004928.823	278654.0845	51897.6572	0	9500	38000	1297480.564
9	2565370.123	499399.9345	117839.42	0	9500	85500	3097109.477
10	2565365.403	499372.3345	117834.62	0	9500	85500	3097072.357
11	2565360.683	499344.7345	117829.82	0	9500	85500	3097035.237
12	2565355.963	499317.1345	117825.02	0	9500	85500	3096998.117
13	387546.97	151314.55	81959.7896	0	9500	19000	601821.3096
14	387534.49	151309.83	81954.0296	0	9500	19000	601798.3496
15	387522.01	151305.11	81948.2696	0	9500	19000	601775.3896
16	387509.53	151300.39	81942.5096	0	9500	19000	601752.4296
17	727804.8475	194188.9035	89292.186	0	9500	28500	982785.937
18	727801.1675	194165.4635	89291.626	0	9500	28500	982758.257
19	727797.4875	194142.0235	89291.066	0	9500	28500	982730.577
20	727793.8075	194118.5835	89290.506	0	9500	28500	982702.897
21	1092214.888	265426.484	99283.0492	0	9500	38000	1418924.421
22	1092202.808	265397.444	99282.4892	0	9500	38000	1418882.741
23	1092190.728	265368.404	99281.9292	0	6875	27500	1429341.061
24	1092178.648	265339.364	99281.3692	0	6875	27500	1429299.381
25	761666.79	193785.4835	83087.7852	0	6875	20625	1017915.059
26	761665.83	193756.0435	83083.0652	0	6875	20625	1017879.939

Table 73. Overall Cumulative Variant Profit for JIT Model (Period 27 - 52)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
27	761664.87	193726.6035	83078.3452	0	6875	20625	1017844.819
28	761663.91	193697.1635	83073.6252	0	6875	20625	1017809.699
29	1024913.783	448499.356	96648.1052	0	6875	34375	1535686.244
30	1024906.343	448484.956	96647.7052	0	6875	34375	1535664.004
31	1024898.903	448470.556	96647.3052	0	6875	34375	1535641.764
32	1024891.463	448456.156	96646.9052	0	6875	34375	1535619.524
33	2530921.95	636135.847	89402.6488	0	6875	61875	3194585.446
34	2530908.51	636134.967	89398.1688	0	6875	61875	3194566.646
35	2530895.07	636134.087	89393.6888	0	6875	61875	3194547.846
36	2530881.63	636133.207	89389.2088	0	6875	61875	3194529.046
37	10029392.72	1239195.55	117260.2272	26000	6875	213125	11146723.5
38	9116166.21	-85897.9	117255.7472	26000	6875	213125	8908399.057
39	7201004.05	-141541.35	117251.2672	26000	6875	213125	6937588.967
40	7170935.8	-197184.8	117246.7872	26000	9500	294500	6770497.787
41	7163304.3	-230855.15	117608.9272	26000	9500	228000	6796058.077
42	7155672.8	-264525.5	117608.1272	26000	9500	228000	6754755.427
43	7148041.3	-298195.85	117607.3272	26000	9500	228000	6713452.777
44	7140409.8	-331866.2	117606.5272	26000	9500	228000	6672150.127
45	2915753.693	442239.125	131941.8756	0	9500	104500	3385434.693
46	2915758.043	442246.125	131937.1556	13000	9500	104500	3372441.323
47	2915762.393	442253.125	131932.4356	13000	9500	104500	3372447.953
48	2915766.743	442260.125	131927.7156	13000	9500	104500	3372454.583
49	398644.7625	158435.4725	29609.2696	0	9500	28500	558189.5046
50	398647.4625	158446.8725	29607.0296	0	9500	28500	558201.3646
51	398650.1625	158458.2725	29604.7896	0	9500	28500	558213.2246
52	398652.8625	158469.6725	29602.5496	0	9500	28500	558225.0846

Base Model with Doubled Capacity

Table 74 Simulation Output Statistics for Base Model with Doubled Capacity for Period 1 - 26

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
1	0	253750	331870	56592	1197095	757320	44023	57005	0	74550	0	12713	0
2	0	253750	331870	56592	1393840	1014640	87902	57005	0	74550	0	12713	0
3	0	253750	331870	56592	1590585	1271960	131781	57005	0	74550	0	12713	0
4	0	253750	331870	56592	1787330	1529280	175660	57005	0	74550	0	12713	0
5	0	350	0	144	1523351	1362761	168695	264329	0	166519	0	7109	0
6	0	350	0	144	1259372	1196242	161730	264329	0	166519	0	7109	0
7	0	350	0	144	995393	1029723	154765	264329	0	166519	0	7109	0
8	0	350	0	144	731414	863204	147800	264329	0	166519	0	7109	0
9	0	350	0	144	87298	581344	131804	644466	0	281860	0	16140	0
10	0	350	0	144	0	299484	115808	87648	556818	281860	0	16140	0
11	0	350	0	144	0	17624	99812	350	1200934	281860	0	16140	0
12	0	350	0	144	0	0	83816	350	1845050	17624	264236	16140	0
13	0	350	0	144	0	0	72728	350	1958644	0	364277	11232	0
14	0	350	0	144	0	0	61640	350	2072238	0	464318	11232	0
15	0	350	0	144	0	0	50552	350	2185832	0	564359	11232	0
16	0	350	0	144	0	0	39464	350	2299426	0	664400	11232	0
17	0	408800	254870	25488	0	0	52719	408800	2087455	254870	532052	12233	0
18	0	408800	254870	25488	0	0	65974	408800	1875484	254870	399704	12233	0
19	0	408800	254870	25488	0	0	79229	408800	1663513	254870	267356	12233	0
20	0	408800	254870	25488	0	0	92484	408800	1451542	254870	135008	12233	0
21	0	1222900	684530	58320	0	389725	137203	1222900	514266	294805	0	13601	0
22	1	1222900	684530	58320	423010	914458	181922	799890	0	159797	0	13601	0
23	1	1222900	684530	58320	1360286	1439191	226641	285624	0	159797	0	13601	0
24	1	1222900	684530	58320	2297562	1963924	271360	285624	0	159797	0	13601	0
25	1	1306550	780780	72576	3399024	2622257	332547	205088	0	122447	0	11389	0
26	1	1306550	780780	72576	4500486	3280590	393734	205088	0	122447	0	11389	0

Table 75 Simulation Output Statistics for Base Model with Doubled Capacity for Period 27 - 52

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
27	1	1306550	780780	72576	5601948	3938923	454921	205088	0	122447	0	11389	0
28	1	1306550	780780	72576	6703410	4597256	516108	205088	0	122447	0	11389	0
29	0	233800	221760	11520	6667978	4563556	514385	269232	0	255460	0	13243	0
30	0	233800	221760	11520	6632546	4529856	512662	269232	0	255460	0	13243	0
31	0	233800	221760	11520	6597114	4496156	510939	269232	0	255460	0	13243	0
32	0	233800	221760	11520	6561682	4462456	509216	269232	0	255460	0	13243	0
33	0	601300	334180	11664	6526850	4443217	508624	636132	0	353419	0	12256	0
34	0	601300	334180	11664	6492018	4423978	508032	636132	0	353419	0	12256	0
35	0	601300	334180	11664	6457186	4404739	507440	636132	0	353419	0	12256	0
36	0	601300	334180	11664	6422354	4385500	506848	636132	0	353419	0	12256	0
37	0	1274700	599830	8784	5331689	3872461	499560	2365365	0	1112869	0	16072	0
38	0	1274700	599830	8784	4241024	3359422	492272	2365365	0	1112869	0	16072	0
39	0	1274700	599830	8784	3150359	2846383	484984	2365365	0	1112869	0	16072	0
40	0	1274700	599830	8784	2059694	2333344	477696	2365365	0	1112869	0	16072	0
41	0	1053500	370370	8928	1196564	2030307	470506	1916630	0	673407	0	16118	0
42	0	1053500	370370	8928	333434	1727270	463316	1916630	0	673407	0	16118	0
43	0	1053500	370370	8928	0	1424233	456126	1386934	529696	673407	0	16118	0
44	0	1053500	370370	8928	0	1121196	448936	1053500	1392826	673407	0	16118	0
45	0	312550	172480	7776	0	889566	438627	312550	1815014	404110	0	18085	0
46	0	312550	172480	7776	0	657936	428318	312550	2237202	404110	0	18085	0
47	0	312550	172480	7776	0	426306	418009	312550	2659390	404110	0	18085	0
48	0	312550	172480	7776	0	194676	407700	312550	3081578	404110	0	18085	0
49	0	115150	241780	3888	0	180659	407512	115150	3087999	255797	0	4076	0
50	0	115150	241780	3888	0	166642	407324	115150	3094420	255797	0	4076	0
51	0	115150	241780	3888	0	152625	407136	115150	3100841	255797	0	4076	0
52	0	115150	241780	3888	0	138608	406948	115150	3107262	255797	0	4076	0

Table 76 Cumulative Profit for Item 1 for period 1 - 26 (Base Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
1	253750	1197095	57005	0	0	267353.45	95767.6	25375	123094.125	23116.725
2	253750	1393840	57005	0	0	267353.45	111507.2	25375	123094.125	7377.125
3	253750	1590585	57005	0	0	267353.45	127246.8	25375	123094.125	-8362.475
4	253750	1787330	57005	0	0	267353.45	142986.4	25375	123094.125	-24102.075
5	350	1523351	264329	0	0	1239703.01	121868.08	35	169.785	1117630.145
6	350	1259372	264329	0	0	1239703.01	100749.76	35	169.785	1138748.465
7	350	995393	264329	0	0	1239703.01	79631.44	35	169.785	1159866.785
8	350	731414	264329	0	0	1239703.01	58513.12	35	169.785	1180985.105
9	350	87298	644466	0	0	3022545.54	6983.84	35	169.785	3015356.915
10	350	0	87648	556818	27840.9	411069.12	0	35	169.785	383023.435
11	350	0	350	1200934	60046.7	1641.5	0	35	169.785	-58609.985
12	350	0	350	1845050	92252.5	1641.5	0	35	169.785	-90815.785
13	350	0	350	1958644	97932.2	1641.5	0	35	169.785	-96495.485
14	350	0	350	2072238	103611.9	1641.5	0	35	169.785	-102175.185
15	350	0	350	2185832	109291.6	1641.5	0	35	169.785	-107854.885
16	350	0	350	2299426	114971.3	1641.5	0	35	169.785	-113534.585
17	408800	0	408800	2087455	104372.75	1917272	0	40880	198308.88	1573710.37
18	408800	0	408800	1875484	93774.2	1917272	0	40880	198308.88	1584308.92
19	408800	0	408800	1663513	83175.65	1917272	0	40880	198308.88	1594907.47
20	408800	0	408800	1451542	72577.1	1917272	0	40880	198308.88	1605506.02
21	1222900	0	1222900	514266	25713.3	5735401	0	122290	593228.79	4994168.91
22	1222900	423010	799890	0	0	3751484.1	33840.8	122290	593228.79	3002124.51
23	1222900	1360286	285624	0	0	1339576.56	108822.88	122290	593228.79	515234.89
24	1222900	2297562	285624	0	0	1339576.56	183804.96	122290	593228.79	440252.81
25	1306550	3399024	205088	0	0	961862.72	271921.92	130655	633807.405	-74521.605
26	1306550	4500486	205088	0	0	961862.72	360038.88	130655	633807.405	-162638.565

Table 77 Cumulative Profit for Item 1 for period 27 - 52 (Base Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
27	1306550	5601948	205088	0	0	961862.72	448155.84	130655	633807.405	-250755.525
28	1306550	6703410	205088	0	0	961862.72	536272.8	130655	633807.405	-338872.485
29	233800	6667978	269232	0	0	1262698.08	533438.24	23380	113416.38	592463.46
30	233800	6632546	269232	0	0	1262698.08	530603.68	23380	113416.38	595298.02
31	233800	6597114	269232	0	0	1262698.08	527769.12	23380	113416.38	598132.58
32	233800	6561682	269232	0	0	1262698.08	524934.56	23380	113416.38	600967.14
33	601300	6526850	636132	0	0	2983459.08	522148	60130	291690.63	2109490.45
34	601300	6492018	636132	0	0	2983459.08	519361.44	60130	291690.63	2112277.01
35	601300	6457186	636132	0	0	2983459.08	516574.88	60130	291690.63	2115063.57
36	601300	6422354	636132	0	0	2983459.08	513788.32	60130	291690.63	2117850.13
37	1274700	5331689	2365365	0	0	11093561.85	426535.12	127470	618356.97	9921199.76
38	1274700	4241024	2365365	0	0	11093561.85	339281.92	127470	618356.97	10008452.96
39	1274700	3150359	2365365	0	0	11093561.85	252028.72	127470	618356.97	10095706.16
40	1274700	2059694	2365365	0	0	11093561.85	164775.52	127470	618356.97	10182959.36
41	1053500	1196564	1916630	0	0	8988994.7	95725.12	105350	511052.85	8276866.73
42	1053500	333434	1916630	0	0	8988994.7	26674.72	105350	511052.85	8345917.13
43	1053500	0	1386934	529696	26484.8	6504720.46	0	105350	511052.85	5861832.81
44	1053500	0	1053500	1392826	69641.3	4940915	0	105350	511052.85	4254870.85
45	312550	0	312550	1815014	90750.7	1465859.5	0	31255	151618.005	1192235.795
46	312550	0	312550	2237202	111860.1	1465859.5	0	31255	151618.005	1171126.395
47	312550	0	312550	2659390	132969.5	1465859.5	0	31255	151618.005	1150016.995
48	312550	0	312550	3081578	154078.9	1465859.5	0	31255	151618.005	1128907.595
49	115150	0	115150	3087999	154399.95	540053.5	0	11515	55859.265	318279.285
50	115150	0	115150	3094420	154721	540053.5	0	11515	55859.265	317958.235
51	115150	0	115150	3100841	155042.05	540053.5	0	11515	55859.265	317637.185
52	115150	0	115150	3107262	155363.1	540053.5	0	11515	55859.265	317316.135

Table 78 Cumulative Profit for Item 2 for period 1 - 26 (Base Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
1	331870	757320	74550	0	0	186375	60585.6	33187	160990.137	-68387.737
2	331870	1014640	74550	0	0	186375	81171.2	33187	160990.137	-88973.337
3	331870	1271960	74550	0	0	186375	101756.8	33187	160990.137	-109558.937
4	331870	1529280	74550	0	0	186375	122342.4	33187	160990.137	-130144.537
5	0	1362761	166519	0	0	416297.5	109020.88	0	0	307276.62
6	0	1196242	166519	0	0	416297.5	95699.36	0	0	320598.14
7	0	1029723	166519	0	0	416297.5	82377.84	0	0	333919.66
8	0	863204	166519	0	0	416297.5	69056.32	0	0	347241.18
9	0	581344	281860	0	0	704650	46507.52	0	0	658142.48
10	0	299484	281860	0	0	704650	23958.72	0	0	680691.28
11	0	17624	281860	0	0	704650	1409.92	0	0	703240.08
12	0	0	17624	264236	13211.8	44060	0	0	0	30848.2
13	0	0	0	364277	18213.85	0	0	0	0	-18213.85
14	0	0	0	464318	23215.9	0	0	0	0	-23215.9
15	0	0	0	564359	28217.95	0	0	0	0	-28217.95
16	0	0	0	664400	33220	0	0	0	0	-33220
17	254870	0	254870	532052	26602.6	637175	0	25487	123637.437	461447.963
18	254870	0	254870	399704	19985.2	637175	0	25487	123637.437	468065.363
19	254870	0	254870	267356	13367.8	637175	0	25487	123637.437	474682.763
20	254870	0	254870	135008	6750.4	637175	0	25487	123637.437	481300.163
21	684530	389725	294805	0	0	737012.5	31178	68453	332065.503	305315.997
22	684530	914458	159797	0	0	399492.5	73156.64	68453	332065.503	-74182.643
23	684530	1439191	159797	0	0	399492.5	115135.28	68453	332065.503	-116161.283
24	684530	1963924	159797	0	0	399492.5	157113.92	68453	332065.503	-158139.923
25	780780	2622257	122447	0	0	306117.5	209780.56	78078	378756.378	-360497.438
26	780780	3280590	122447	0	0	306117.5	262447.2	78078	378756.378	-413164.078

Table 79 Cumulative Profit for Item 2 for period 27 - 52 (Base Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
27	780780	3938923	122447	0	0	306117.5	315113.84	78078	378756.378	-465830.718
28	780780	4597256	122447	0	0	306117.5	367780.48	78078	378756.378	-518497.358
29	221760	4563556	255460	0	0	638650	365084.48	22176	107575.776	143813.744
30	221760	4529856	255460	0	0	638650	362388.48	22176	107575.776	146509.744
31	221760	4496156	255460	0	0	638650	359692.48	22176	107575.776	149205.744
32	221760	4462456	255460	0	0	638650	356996.48	22176	107575.776	151901.744
33	334180	4443217	353419	0	0	883547.5	355457.36	33418	162110.718	332561.422
34	334180	4423978	353419	0	0	883547.5	353918.24	33418	162110.718	334100.542
35	334180	4404739	353419	0	0	883547.5	352379.12	33418	162110.718	335639.662
36	334180	4385500	353419	0	0	883547.5	350840	33418	162110.718	337178.782
37	599830	3872461	1112869	0	0	2782172.5	309796.88	59983	290977.533	2121415.087
38	599830	3359422	1112869	0	0	2782172.5	268753.76	59983	290977.533	2162458.207
39	599830	2846383	1112869	0	0	2782172.5	227710.64	59983	290977.533	2203501.327
40	599830	2333344	1112869	0	0	2782172.5	186667.52	59983	290977.533	2244544.447
41	370370	2030307	673407	0	0	1683517.5	162424.56	37037	179666.487	1304389.453
42	370370	1727270	673407	0	0	1683517.5	138181.6	37037	179666.487	1328632.413
43	370370	1424233	673407	0	0	1683517.5	113938.64	37037	179666.487	1352875.373
44	370370	1121196	673407	0	0	1683517.5	89695.68	37037	179666.487	1377118.333
45	172480	889566	404110	0	0	1010275	71165.28	17248	83670.048	838191.672
46	172480	657936	404110	0	0	1010275	52634.88	17248	83670.048	856722.072
47	172480	426306	404110	0	0	1010275	34104.48	17248	83670.048	875252.472
48	172480	194676	404110	0	0	1010275	15574.08	17248	83670.048	893782.872
49	241780	180659	255797	0	0	639492.5	14452.72	24178	117287.478	483574.302
50	241780	166642	255797	0	0	639492.5	13331.36	24178	117287.478	484695.662
51	241780	152625	255797	0	0	639492.5	12210	24178	117287.478	485817.022
52	241780	138608	255797	0	0	639492.5	11088.64	24178	117287.478	486938.382

Table 80 Cumulative Profit for Item 3 for period 1 - 26 (Base Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
1	56592	44023	12713	0	0	100305.57	3521.84	5659.2	27452.7792	63671.7508
2	56592	87902	12713	0	0	100305.57	7032.16	5659.2	27452.7792	60161.4308
3	56592	131781	12713	0	0	100305.57	10542.48	5659.2	27452.7792	56651.1108
4	56592	175660	12713	0	0	100305.57	14052.8	5659.2	27452.7792	53140.7908
5	144	168695	7109	0	0	56090.01	13495.6	14.4	69.8544	42510.1556
6	144	161730	7109	0	0	56090.01	12938.4	14.4	69.8544	43067.3556
7	144	154765	7109	0	0	56090.01	12381.2	14.4	69.8544	43624.5556
8	144	147800	7109	0	0	56090.01	11824	14.4	69.8544	44181.7556
9	144	131804	16140	0	0	127344.6	10544.32	14.4	69.8544	116716.0256
10	144	115808	16140	0	0	127344.6	9264.64	14.4	69.8544	117995.7056
11	144	99812	16140	0	0	127344.6	7984.96	14.4	69.8544	119275.3856
12	144	83816	16140	0	0	127344.6	6705.28	14.4	69.8544	120555.0656
13	144	72728	11232	0	0	88620.48	5818.24	14.4	69.8544	82717.9856
14	144	61640	11232	0	0	88620.48	4931.2	14.4	69.8544	83605.0256
15	144	50552	11232	0	0	88620.48	4044.16	14.4	69.8544	84492.0656
16	144	39464	11232	0	0	88620.48	3157.12	14.4	69.8544	85379.1056
17	25488	52719	12233	0	0	96518.37	4217.52	2548.8	12364.2288	77387.8212
18	25488	65974	12233	0	0	96518.37	5277.92	2548.8	12364.2288	76327.4212
19	25488	79229	12233	0	0	96518.37	6338.32	2548.8	12364.2288	75267.0212
20	25488	92484	12233	0	0	96518.37	7398.72	2548.8	12364.2288	74206.6212
21	58320	137203	13601	0	0	107311.89	10976.24	5832	28291.032	62212.618
22	58320	181922	13601	0	0	107311.89	14553.76	5832	28291.032	58635.098
23	58320	226641	13601	0	0	107311.89	18131.28	5832	28291.032	55057.578
24	58320	271360	13601	0	0	107311.89	21708.8	5832	28291.032	51480.058
25	72576	332547	11389	0	0	89859.21	26603.76	7257.6	35206.6176	20791.2324
26	72576	393734	11389	0	0	89859.21	31498.72	7257.6	35206.6176	15896.2724

Table 81 Cumulative Profit for Item 3 for period 27 - 52 (Base Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
27	72576	454921	11389	0	0	89859.21	36393.68	7257.6	35206.6176	11001.3124
28	72576	516108	11389	0	0	89859.21	41288.64	7257.6	35206.6176	6106.3524
29	11520	514385	13243	0	0	104487.27	41150.8	1152	5588.352	56596.118
30	11520	512662	13243	0	0	104487.27	41012.96	1152	5588.352	56733.958
31	11520	510939	13243	0	0	104487.27	40875.12	1152	5588.352	56871.798
32	11520	509216	13243	0	0	104487.27	40737.28	1152	5588.352	57009.638
33	11664	508624	12256	0	0	96699.84	40689.92	1166.4	5658.2064	49185.3136
34	11664	508032	12256	0	0	96699.84	40642.56	1166.4	5658.2064	49232.6736
35	11664	507440	12256	0	0	96699.84	40595.2	1166.4	5658.2064	49280.0336
36	11664	506848	12256	0	0	96699.84	40547.84	1166.4	5658.2064	49327.3936
37	8784	499560	16072	0	0	126808.08	39964.8	878.4	4261.1184	81703.7616
38	8784	492272	16072	0	0	126808.08	39381.76	878.4	4261.1184	82286.8016
39	8784	484984	16072	0	0	126808.08	38798.72	878.4	4261.1184	82869.8416
40	8784	477696	16072	0	0	126808.08	38215.68	878.4	4261.1184	83452.8816
41	8928	470506	16118	0	0	127171.02	37640.48	892.8	4330.9728	84306.7672
42	8928	463316	16118	0	0	127171.02	37065.28	892.8	4330.9728	84881.9672
43	8928	456126	16118	0	0	127171.02	36490.08	892.8	4330.9728	85457.1672
44	8928	448936	16118	0	0	127171.02	35914.88	892.8	4330.9728	86032.3672
45	7776	438627	18085	0	0	142690.65	35090.16	777.6	3772.1376	103050.7524
46	7776	428318	18085	0	0	142690.65	34265.44	777.6	3772.1376	103875.4724
47	7776	418009	18085	0	0	142690.65	33440.72	777.6	3772.1376	104700.1924
48	7776	407700	18085	0	0	142690.65	32616	777.6	3772.1376	105524.9124
49	3888	407512	4076	0	0	32159.64	32600.96	388.8	1886.0688	-2716.1888
50	3888	407324	4076	0	0	32159.64	32585.92	388.8	1886.0688	-2701.1488
51	3888	407136	4076	0	0	32159.64	32570.88	388.8	1886.0688	-2686.1088
52	3888	406948	4076	0	0	32159.64	32555.84	388.8	1886.0688	-2671.0688

Table 82 Overall Cumulative Variant Profit for Base Model with Doubled Capacity (Period 1 - 26)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
1	23116.725	-68387.737	63671.7508	0	9500	66500	-48099.2612
2	7377.125	-88973.337	60161.4308	0	9500	66500	-87934.7812
3	-8362.475	-109558.937	56651.1108	0	9500	66500	-127770.3012
4	-24102.075	-130144.537	53140.7908	0	9500	66500	-167605.8212
5	1117630.145	307276.62	42510.1556	0	9500	0	1467416.921
6	1138748.465	320598.14	43067.3556	0	9500	0	1502413.961
7	1159866.785	333919.66	43624.5556	0	9500	0	1537411.001
8	1180985.105	347241.18	44181.7556	0	9500	0	1572408.041
9	3015356.915	658142.48	116716.0256	0	9500	0	3790215.421
10	383023.435	680691.28	117995.7056	0	9500	0	1181710.421
11	-58609.985	703240.08	119275.3856	0	9500	0	763905.4806
12	-90815.785	30848.2	120555.0656	0	9500	0	60587.4806
13	-96495.485	-18213.85	82717.9856	0	9500	0	-31991.3494
14	-102175.185	-23215.9	83605.0256	0	9500	0	-41786.0594
15	-107854.885	-28217.95	84492.0656	0	9500	0	-51580.7694
16	-113534.585	-33220	85379.1056	0	9500	0	-61375.4794
17	1573710.37	461447.963	77387.8212	0	9500	66500	2046046.154
18	1584308.92	468065.363	76327.4212	0	9500	66500	2062201.704
19	1594907.47	474682.763	75267.0212	0	9500	66500	2078357.254
20	1605506.02	481300.163	74206.6212	0	9500	66500	2094512.804
21	4994168.91	305315.997	62212.618	0	9500	180500	5181197.525
22	3002124.51	-74182.643	58635.098	13000	9500	180500	2793076.965
23	515234.89	-116161.283	55057.578	13000	6875	130625	310506.185
24	440252.81	-158139.923	51480.058	13000	6875	130625	189967.945
25	-74521.605	-360497.438	20791.2324	13000	6875	144375	-571602.8106
26	-162638.565	-413164.078	15896.2724	13000	6875	144375	-717281.3706

Table 83 Overall Cumulative Variant Profit for Base Model with Doubled Capacity (Period 27 - 52)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
27	-250755.525	-465830.718	11001.3124	13000	6875	144375	-862959.9306
28	-338872.485	-518497.358	6106.3524	13000	6875	144375	-1008638.491
29	592463.46	143813.744	56596.118	0	6875	27500	765373.322
30	595298.02	146509.744	56733.958	0	6875	27500	771041.722
31	598132.58	149205.744	56871.798	0	6875	27500	776710.122
32	600967.14	151901.744	57009.638	0	6875	27500	782378.522
33	2109490.45	332561.422	49185.3136	0	6875	61875	2429362.186
34	2112277.01	334100.542	49232.6736	0	6875	61875	2433735.226
35	2115063.57	335639.662	49280.0336	0	6875	61875	2438108.266
36	2117850.13	337178.782	49327.3936	0	6875	61875	2442481.306
37	9921199.76	2121415.087	81703.7616	0	6875	116875	12007443.61
38	10008452.96	2162458.207	82286.8016	0	6875	116875	12136322.97
39	10095706.16	2203501.327	82869.8416	0	6875	116875	12265202.33
40	10182959.36	2244544.447	83452.8816	0	9500	161500	12349456.69
41	8276866.73	1304389.453	84306.7672	0	9500	123500	9542062.95
42	8345917.13	1328632.413	84881.9672	0	9500	123500	9635931.51
43	5861832.81	1352875.373	85457.1672	0	9500	123500	7176665.35
44	4254870.85	1377118.333	86032.3672	0	9500	123500	5594521.55
45	1192235.795	838191.672	103050.7524	0	9500	47500	2085978.219
46	1171126.395	856722.072	103875.4724	0	9500	47500	2084223.939
47	1150016.995	875252.472	104700.1924	0	9500	47500	2082469.659
48	1128907.595	893782.872	105524.9124	0	9500	47500	2080715.379
49	318279.285	483574.302	-2716.1888	0	9500	28500	770637.3982
50	317958.235	484695.662	-2701.1488	0	9500	28500	771452.7482
51	317637.185	485817.022	-2686.1088	0	9500	28500	772268.0982
52	317316.135	486938.382	-2671.0688	0	9500	28500	773083.4482

JIT with Doubled Capacity

Table 84 Simulation Output Statistics for JIT Model with Doubled Capacity for Period 1 - 26

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
1	0	57050	74690	12816	1000395	500140	247	57005	0	74550	0	12713	0
2	0	57050	74690	12816	1000440	500280	350	57005	0	74550	0	12713	0
3	0	57050	74690	12816	1000485	500420	453	57005	0	74550	0	12713	0
4	0	57050	74690	12816	1000530	500560	556	57005	0	74550	0	12713	0
5	0	264600	167090	7200	1000801	501131	647	264329	0	166519	0	7109	0
6	0	264600	167090	7200	1001072	501702	738	264329	0	166519	0	7109	0
7	0	264600	167090	7200	1001343	502273	829	264329	0	166519	0	7109	0
8	0	264600	167090	7200	1001614	502844	920	264329	0	166519	0	7109	0
9	0	644700	282590	16272	1001848	503574	1052	644466	0	281860	0	16140	0
10	0	644700	282590	16272	1002082	504304	1184	644466	0	281860	0	16140	0
11	0	644700	282590	16272	1002316	505034	1316	644466	0	281860	0	16140	0
12	0	644700	282590	16272	1002550	505764	1448	644466	0	281860	0	16140	0
13	0	114100	100100	11376	1002706	505823	1592	113944	0	100041	0	11232	0
14	0	114100	100100	11376	1002862	505882	1736	113944	0	100041	0	11232	0
15	0	114100	100100	11376	1003018	505941	1880	113944	0	100041	0	11232	0
16	0	114100	100100	11376	1003174	506000	2024	113944	0	100041	0	11232	0
17	0	197050	123200	12240	1003395	506678	2031	196829	0	122522	0	12233	0
18	0	197050	123200	12240	1003616	507356	2038	196829	0	122522	0	12233	0
19	0	197050	123200	12240	1003837	508034	2045	196829	0	122522	0	12233	0
20	0	197050	123200	12240	1004058	508712	2052	196829	0	122522	0	12233	0
21	0	285950	160160	13680	1004384	509075	2131	285624	0	159797	0	13601	0
22	0	285950	160160	13680	1004710	509438	2210	285624	0	159797	0	13601	0
23	0	285950	160160	13680	1005036	509801	2289	285624	0	159797	0	13601	0
24	0	285950	160160	13680	1005362	510164	2368	285624	0	159797	0	13601	0
25	0	205100	123200	11520	1005374	510917	2499	205088	0	122447	0	11389	0
26	0	205100	123200	11520	1005386	511670	2630	205088	0	122447	0	11389	0

Table 85 Simulation Output Statistics for JIT Model with Doubled Capacity for Period 27 - 52

Period	No. of OT Scheduled	Packaged material A (cans)	Packaged material B (cans)	Packaged material C (cans)	Ending Inventory A (cans)	Ending Inventory B (cans)	Ending Inventory C (cans)	Demand Met A (cans)	Demand Unmet A (cans)	Demand Met B (cans)	Demand Unmet B (cans)	Demand Met C (cans)	Demand Unmet C (cans)
26	0	205100	123200	11520	1005386	511670	2630	205088	0	122447	0	11389	0
27	0	205100	123200	11520	1005398	512423	2761	205088	0	122447	0	11389	0
28	0	205100	123200	11520	1005410	513176	2892	205088	0	122447	0	11389	0
29	0	269500	255640	13248	1005678	513356	2897	269232	0	255460	0	13243	0
30	0	269500	255640	13248	1005946	513536	2902	269232	0	255460	0	13243	0
31	0	269500	255640	13248	1006214	513716	2907	269232	0	255460	0	13243	0
32	0	269500	255640	13248	1006482	513896	2912	269232	0	255460	0	13243	0
33	0	636300	353430	12384	1006650	513907	3040	636132	0	353419	0	12256	0
34	0	636300	353430	12384	1006818	513918	3168	636132	0	353419	0	12256	0
35	0	636300	353430	12384	1006986	513929	3296	636132	0	353419	0	12256	0
36	0	636300	353430	12384	1007154	513940	3424	636132	0	353419	0	12256	0
37	2	2365650	1113420	16128	1007439	514491	3480	2365365	0	1112869	0	16072	0
38	2	2365650	1113420	16128	1007724	515042	3536	2365365	0	1112869	0	16072	0
39	2	2365650	1113420	16128	1008009	515593	3592	2365365	0	1112869	0	16072	0
40	2	2365650	1113420	16128	1008294	516144	3648	2365365	0	1112869	0	16072	0
41	0	1916950	673750	16128	1008614	516487	3658	1916630	0	673407	0	16118	0
42	2	1916950	673750	16128	1008934	516830	3668	1916630	0	673407	0	16118	0
43	0	1916950	673750	16128	1009254	517173	3678	1916630	0	673407	0	16118	0
44	2	1916950	673750	16128	1009574	517516	3688	1916630	0	673407	0	16118	0
45	0	735000	404250	18144	1009836	517656	3747	734738	0	404110	0	18085	0
46	0	735000	404250	18144	1010098	517796	3806	734738	0	404110	0	18085	0
47	0	735000	404250	18144	1010360	517936	3865	734738	0	404110	0	18085	0
48	0	735000	404250	18144	1010622	518076	3924	734738	0	404110	0	18085	0
49	0	121800	256410	4176	1010851	518689	4024	121571	0	255797	0	4076	0
50	0	121800	256410	4176	1011080	519302	4124	121571	0	255797	0	4076	0
51	0	121800	256410	4176	1011309	519915	4224	121571	0	255797	0	4076	0
52	0	121800	256410	4176	1011538	520528	4324	121571	0	255797	0	4076	0

Table 86 Cumulative Profit for Item 1 for period 1 - 26 (JIT Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
1	57050	1000395	57005	0	0	267353.45	80031.6	5705	27674.955	153941.895
2	57050	1000440	57005	0	0	267353.45	80035.2	5705	27674.955	153938.295
3	57050	1000485	57005	0	0	267353.45	80038.8	5705	27674.955	153934.695
4	57050	1000530	57005	0	0	267353.45	80042.4	5705	27674.955	153931.095
5	264600	1000801	264329	0	0	1239703.01	80064.08	26460	128357.46	1004821.47
6	264600	1001072	264329	0	0	1239703.01	80085.76	26460	128357.46	1004799.79
7	264600	1001343	264329	0	0	1239703.01	80107.44	26460	128357.46	1004778.11
8	264600	1001614	264329	0	0	1239703.01	80129.12	26460	128357.46	1004756.43
9	644700	1001848	644466	0	0	3022545.54	80147.84	64470	312743.97	2565183.73
10	644700	1002082	644466	0	0	3022545.54	80166.56	64470	312743.97	2565165.01
11	644700	1002316	644466	0	0	3022545.54	80185.28	64470	312743.97	2565146.29
12	644700	1002550	644466	0	0	3022545.54	80204	64470	312743.97	2565127.57
13	114100	1002706	113944	0	0	534397.36	80216.48	11410	55349.91	387420.97
14	114100	1002862	113944	0	0	534397.36	80228.96	11410	55349.91	387408.49
15	114100	1003018	113944	0	0	534397.36	80241.44	11410	55349.91	387396.01
16	114100	1003174	113944	0	0	534397.36	80253.92	11410	55349.91	387383.53
17	197050	1003395	196829	0	0	923128.01	80271.6	19705	95588.955	727562.455
18	197050	1003616	196829	0	0	923128.01	80289.28	19705	95588.955	727544.775
19	197050	1003837	196829	0	0	923128.01	80306.96	19705	95588.955	727527.095
20	197050	1004058	196829	0	0	923128.01	80324.64	19705	95588.955	727509.415
21	285950	1004384	285624	0	0	1339576.56	80350.72	28595	138714.345	1091916.495
22	285950	1004710	285624	0	0	1339576.56	80376.8	28595	138714.345	1091890.415
23	285950	1005036	285624	0	0	1339576.56	80402.88	28595	138714.345	1091864.335
24	285950	1005362	285624	0	0	1339576.56	80428.96	28595	138714.345	1091838.255
25	205100	1005374	205088	0	0	961862.72	80429.92	20510	99494.01	761428.79
26	205100	1005386	205088	0	0	961862.72	80430.88	20510	99494.01	761427.83

Table 87 Cumulative Profit for Item 1 for period 27 - 52 (JIT Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 1
27	205100	1005398	205088	0	0	961862.72	80431.84	20510	99494.01	761426.87
28	205100	1005410	205088	0	0	961862.72	80432.8	20510	99494.01	761425.91
29	269500	1005678	269232	0	0	1262698.08	80454.24	26950	130734.45	1024559.39
30	269500	1005946	269232	0	0	1262698.08	80475.68	26950	130734.45	1024537.95
31	269500	1006214	269232	0	0	1262698.08	80497.12	26950	130734.45	1024516.51
32	269500	1006482	269232	0	0	1262698.08	80518.56	26950	130734.45	1024495.07
33	636300	1006650	636132	0	0	2983459.08	80532	63630	308669.13	2530627.95
34	636300	1006818	636132	0	0	2983459.08	80545.44	63630	308669.13	2530614.51
35	636300	1006986	636132	0	0	2983459.08	80558.88	63630	308669.13	2530601.07
36	636300	1007154	636132	0	0	2983459.08	80572.32	63630	308669.13	2530587.63
37	2365650	1007439	2365365	0	0	11093561.85	80595.12	236565	1147576.815	9628824.915
38	2365650	1007724	2365365	0	0	11093561.85	80617.92	236565	1147576.815	9628802.115
39	2365650	1008009	2365365	0	0	11093561.85	80640.72	236565	1147576.815	9628779.315
40	2365650	1008294	2365365	0	0	11093561.85	80663.52	236565	1147576.815	9628756.515
41	1916950	1008614	1916630	0	0	8988994.7	80689.12	191695	929912.445	7786698.135
42	1916950	1008934	1916630	0	0	8988994.7	80714.72	191695	929912.445	7786672.535
43	1916950	1009254	1916630	0	0	8988994.7	80740.32	191695	929912.445	7786646.935
44	1916950	1009574	1916630	0	0	8988994.7	80765.92	191695	929912.445	7786621.335
45	735000	1009836	734738	0	0	3445921.22	80786.88	73500	356548.5	2935085.84
46	735000	1010098	734738	0	0	3445921.22	80807.84	73500	356548.5	2935064.88
47	735000	1010360	734738	0	0	3445921.22	80828.8	73500	356548.5	2935043.92
48	735000	1010622	734738	0	0	3445921.22	80849.76	73500	356548.5	2935022.96
49	121800	1010851	121571	0	0	570167.99	80868.08	12180	59085.18	418034.73
50	121800	1011080	121571	0	0	570167.99	80886.4	12180	59085.18	418016.41
51	121800	1011309	121571	0	0	570167.99	80904.72	12180	59085.18	417998.09
52	121800	1011538	121571	0	0	570167.99	80923.04	12180	59085.18	417979.77

Table 88 Cumulative Profit for Item 2 for period 1 - 26 (JIT Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
1	74690	500140	74550	0	0	186375	40011.2	7469	36232.119	102662.681
2	74690	500280	74550	0	0	186375	40022.4	7469	36232.119	102651.481
3	74690	500420	74550	0	0	186375	40033.6	7469	36232.119	102640.281
4	74690	500560	74550	0	0	186375	40044.8	7469	36232.119	102629.081
5	167090	501131	166519	0	0	416297.5	40090.48	16709	81055.359	278442.661
6	167090	501702	166519	0	0	416297.5	40136.16	16709	81055.359	278396.981
7	167090	502273	166519	0	0	416297.5	40181.84	16709	81055.359	278351.301
8	167090	502844	166519	0	0	416297.5	40227.52	16709	81055.359	278305.621
9	282590	503574	281860	0	0	704650	40285.92	28259	137084.409	499020.671
10	282590	504304	281860	0	0	704650	40344.32	28259	137084.409	498962.271
11	282590	505034	281860	0	0	704650	40402.72	28259	137084.409	498903.871
12	282590	505764	281860	0	0	704650	40461.12	28259	137084.409	498845.471
13	100100	505823	100041	0	0	250102.5	40465.84	10010	48558.51	151068.15
14	100100	505882	100041	0	0	250102.5	40470.56	10010	48558.51	151063.43
15	100100	505941	100041	0	0	250102.5	40475.28	10010	48558.51	151058.71
16	100100	506000	100041	0	0	250102.5	40480	10010	48558.51	151053.99
17	123200	506678	122522	0	0	306305	40534.24	12320	59764.32	193686.44
18	123200	507356	122522	0	0	306305	40588.48	12320	59764.32	193632.2
19	123200	508034	122522	0	0	306305	40642.72	12320	59764.32	193577.96
20	123200	508712	122522	0	0	306305	40696.96	12320	59764.32	193523.72
21	160160	509075	159797	0	0	399492.5	40726	16016	77693.616	265056.884
22	160160	509438	159797	0	0	399492.5	40755.04	16016	77693.616	265027.844
23	160160	509801	159797	0	0	399492.5	40784.08	16016	77693.616	264998.804
24	160160	510164	159797	0	0	399492.5	40813.12	16016	77693.616	264969.764
25	123200	510917	122447	0	0	306117.5	40873.36	12320	59764.32	193159.82
26	123200	511670	122447	0	0	306117.5	40933.6	12320	59764.32	193099.58

Table 89 Cumulative Profit for Item 2 for period 27 - 52 (JIT Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 2
27	123200	512423	122447	0	0	306117.5	40993.84	12320	59764.32	193039.34
28	123200	513176	122447	0	0	306117.5	41054.08	12320	59764.32	192979.1
29	255640	513356	255460	0	0	638650	41068.48	25564	124010.964	448006.556
30	255640	513536	255460	0	0	638650	41082.88	25564	124010.964	447992.156
31	255640	513716	255460	0	0	638650	41097.28	25564	124010.964	447977.756
32	255640	513896	255460	0	0	638650	41111.68	25564	124010.964	447963.356
33	353430	513907	353419	0	0	883547.5	41112.56	35343	171448.893	635643.047
34	353430	513918	353419	0	0	883547.5	41113.44	35343	171448.893	635642.167
35	353430	513929	353419	0	0	883547.5	41114.32	35343	171448.893	635641.287
36	353430	513940	353419	0	0	883547.5	41115.2	35343	171448.893	635640.407
37	1113420	514491	1112869	0	0	2782172.5	41159.28	111342	540120.042	2089551.178
38	1113420	515042	1112869	0	0	2782172.5	41203.36	111342	540120.042	2089507.098
39	1113420	515593	1112869	0	0	2782172.5	41247.44	111342	540120.042	2089463.018
40	1113420	516144	1112869	0	0	2782172.5	41291.52	111342	540120.042	2089418.938
41	673750	516487	673407	0	0	1683517.5	41318.96	67375	326836.125	1247987.415
42	673750	516830	673407	0	0	1683517.5	41346.4	67375	326836.125	1247959.975
43	673750	517173	673407	0	0	1683517.5	41373.84	67375	326836.125	1247932.535
44	673750	517516	673407	0	0	1683517.5	41401.28	67375	326836.125	1247905.095
45	404250	517656	404110	0	0	1010275	41412.48	40425	196101.675	732335.845
46	404250	517796	404110	0	0	1010275	41423.68	40425	196101.675	732324.645
47	404250	517936	404110	0	0	1010275	41434.88	40425	196101.675	732313.445
48	404250	518076	404110	0	0	1010275	41446.08	40425	196101.675	732302.245
49	256410	518689	255797	0	0	639492.5	41495.12	25641	124384.491	447971.889
50	256410	519302	255797	0	0	639492.5	41544.16	25641	124384.491	447922.849
51	256410	519915	255797	0	0	639492.5	41593.2	25641	124384.491	447873.809
52	256410	520528	255797	0	0	639492.5	41642.24	25641	124384.491	447824.769

Table 90 Cumulative Profit for Item 3 for period 1 - 26 (JIT Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
1	12816	247	12713	0	0	100305.57	19.76	1281.6	6217.0416	92787.1684
2	12816	350	12713	0	0	100305.57	28	1281.6	6217.0416	92778.9284
3	12816	453	12713	0	0	100305.57	36.24	1281.6	6217.0416	92770.6884
4	12816	556	12713	0	0	100305.57	44.48	1281.6	6217.0416	92762.4484
5	7200	647	7109	0	0	56090.01	51.76	720	3492.72	51825.53
6	7200	738	7109	0	0	56090.01	59.04	720	3492.72	51818.25
7	7200	829	7109	0	0	56090.01	66.32	720	3492.72	51810.97
8	7200	920	7109	0	0	56090.01	73.6	720	3492.72	51803.69
9	16272	1052	16140	0	0	127344.6	84.16	1627.2	7893.5472	117739.6928
10	16272	1184	16140	0	0	127344.6	94.72	1627.2	7893.5472	117729.1328
11	16272	1316	16140	0	0	127344.6	105.28	1627.2	7893.5472	117718.5728
12	16272	1448	16140	0	0	127344.6	115.84	1627.2	7893.5472	117708.0128
13	11376	1592	11232	0	0	88620.48	127.36	1137.6	5518.4976	81837.0224
14	11376	1736	11232	0	0	88620.48	138.88	1137.6	5518.4976	81825.5024
15	11376	1880	11232	0	0	88620.48	150.4	1137.6	5518.4976	81813.9824
16	11376	2024	11232	0	0	88620.48	161.92	1137.6	5518.4976	81802.4624
17	12240	2031	12233	0	0	96518.37	162.48	1224	5937.624	89194.266
18	12240	2038	12233	0	0	96518.37	163.04	1224	5937.624	89193.706
19	12240	2045	12233	0	0	96518.37	163.6	1224	5937.624	89193.146
20	12240	2052	12233	0	0	96518.37	164.16	1224	5937.624	89192.586
21	13680	2131	13601	0	0	107311.89	170.48	1368	6636.168	99137.242
22	13680	2210	13601	0	0	107311.89	176.8	1368	6636.168	99130.922
23	13680	2289	13601	0	0	107311.89	183.12	1368	6636.168	99124.602
24	13680	2368	13601	0	0	107311.89	189.44	1368	6636.168	99118.282
25	11520	2499	11389	0	0	89859.21	199.92	1152	5588.352	82918.938
26	11520	2630	11389	0	0	89859.21	210.4	1152	5588.352	82908.458

Table 91 Cumulative Profit for Item 3 for period 27 - 52 (JIT Model with Doubled Capacity)

Period	Quantity Packaged	Ending Inventory	Quantity of Demand Met	Quantity of Demand Not Met	Order Cut Cost	Selling Price in Period	Holding Cost in Period	Regular Labor Cost in Period	Other Fixed Cost in Period	Overall Cumulative Profit for Item 3
27	11520	2761	11389	0	0	89859.21	220.88	1152	5588.352	82897.978
28	11520	2892	11389	0	0	89859.21	231.36	1152	5588.352	82887.498
29	13248	2897	13243	0	0	104487.27	231.76	1324.8	6426.6048	96504.1052
30	13248	2902	13243	0	0	104487.27	232.16	1324.8	6426.6048	96503.7052
31	13248	2907	13243	0	0	104487.27	232.56	1324.8	6426.6048	96503.3052
32	13248	2912	13243	0	0	104487.27	232.96	1324.8	6426.6048	96502.9052
33	12384	3040	12256	0	0	96699.84	243.2	1238.4	6007.4784	89210.7616
34	12384	3168	12256	0	0	96699.84	253.44	1238.4	6007.4784	89200.5216
35	12384	3296	12256	0	0	96699.84	263.68	1238.4	6007.4784	89190.2816
36	12384	3424	12256	0	0	96699.84	273.92	1238.4	6007.4784	89180.0416
37	16128	3480	16072	0	0	126808.08	278.4	1612.8	7823.6928	117093.1872
38	16128	3536	16072	0	0	126808.08	282.88	1612.8	7823.6928	117088.7072
39	16128	3592	16072	0	0	126808.08	287.36	1612.8	7823.6928	117084.2272
40	16128	3648	16072	0	0	126808.08	291.84	1612.8	7823.6928	117079.7472
41	16128	3658	16118	0	0	127171.02	292.64	1612.8	7823.6928	117441.8872
42	16128	3668	16118	0	0	127171.02	293.44	1612.8	7823.6928	117441.0872
43	16128	3678	16118	0	0	127171.02	294.24	1612.8	7823.6928	117440.2872
44	16128	3688	16118	0	0	127171.02	295.04	1612.8	7823.6928	117439.4872
45	18144	3747	18085	0	0	142690.65	299.76	1814.4	8801.6544	131774.8356
46	18144	3806	18085	0	0	142690.65	304.48	1814.4	8801.6544	131770.1156
47	18144	3865	18085	0	0	142690.65	309.2	1814.4	8801.6544	131765.3956
48	18144	3924	18085	0	0	142690.65	313.92	1814.4	8801.6544	131760.6756
49	4176	4024	4076	0	0	32159.64	321.92	417.6	2025.7776	29394.3424
50	4176	4124	4076	0	0	32159.64	329.92	417.6	2025.7776	29386.3424
51	4176	4224	4076	0	0	32159.64	337.92	417.6	2025.7776	29378.3424
52	4176	4324	4076	0	0	32159.64	345.92	417.6	2025.7776	29370.3424

Table 92 Overall Cumulative Variant Profit for JIT Model with Doubled Capacity (Period 1 - 26)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
1	153941.895	102662.681	92787.1684	0	9500	19000	330391.7444
2	153938.295	102651.481	92778.9284	0	9500	19000	330368.7044
3	153934.695	102640.281	92770.6884	0	9500	19000	330345.6644
4	153931.095	102629.081	92762.4484	0	9500	19000	330322.6244
5	1004821.47	278442.661	51825.53	0	9500	38000	1297089.661
6	1004799.79	278396.981	51818.25	0	9500	38000	1297015.021
7	1004778.11	278351.301	51810.97	0	9500	38000	1296940.381
8	1004756.43	278305.621	51803.69	0	9500	38000	1296865.741
9	2565183.73	499020.671	117739.6928	0	9500	85500	3096444.094
10	2565165.01	498962.271	117729.1328	0	9500	85500	3096356.414
11	2565146.29	498903.871	117718.5728	0	9500	85500	3096268.734
12	2565127.57	498845.471	117708.0128	0	9500	85500	3096181.054
13	387420.97	151068.15	81837.0224	0	9500	19000	601326.1424
14	387408.49	151063.43	81825.5024	0	9500	19000	601297.4224
15	387396.01	151058.71	81813.9824	0	9500	19000	601268.7024
16	387383.53	151053.99	81802.4624	0	9500	19000	601239.9824
17	727562.455	193686.44	89194.266	0	9500	28500	981943.161
18	727544.775	193632.2	89193.706	0	9500	28500	981870.681
19	727527.095	193577.96	89193.146	0	9500	28500	981798.201
20	727509.415	193523.72	89192.586	0	9500	28500	981725.721
21	1091916.495	265056.884	99137.242	0	9500	38000	1418110.621
22	1091890.415	265027.844	99130.922	0	9500	38000	1418049.181
23	1091864.335	264998.804	99124.602	0	6875	27500	1428487.741
24	1091838.255	264969.764	99118.282	0	6875	27500	1428426.301
25	761428.79	193159.82	82918.938	0	6875	20625	1016882.548
26	761427.83	193099.58	82908.458	0	6875	20625	1016810.868

Table 93 Overall Cumulative Variant Profit for JIT Model with Doubled Capacity (Period 27 - 52)

Period	CP1	CP2	CP3	Overtime Costs	Unit RM Cost in Period	Variable Raw Material Cost	Overall CVP
27	761426.87	193039.34	82897.978	0	6875	20625	1016739.188
28	761425.91	192979.1	82887.498	0	6875	20625	1016667.508
29	1024559.39	448006.556	96504.1052	0	6875	34375	1534695.051
30	1024537.95	447992.156	96503.7052	0	6875	34375	1534658.811
31	1024516.51	447977.756	96503.3052	0	6875	34375	1534622.571
32	1024495.07	447963.356	96502.9052	0	6875	34375	1534586.331
33	2530627.95	635643.047	89210.7616	0	6875	61875	3193606.759
34	2530614.51	635642.167	89200.5216	0	6875	61875	3193582.199
35	2530601.07	635641.287	89190.2816	0	6875	61875	3193557.639
36	2530587.63	635640.407	89180.0416	0	6875	61875	3193533.079
37	9628824.915	2089551.178	117093.1872	26000	6875	213125	11596344.28
38	9628802.115	2089507.098	117088.7072	26000	6875	213125	11596272.92
39	9628779.315	2089463.018	117084.2272	26000	6875	213125	11596201.56
40	9628756.515	2089418.938	117079.7472	26000	9500	294500	11514755.2
41	7786698.135	1247987.415	117441.8872	0	9500	228000	8924127.437
42	7786672.535	1247959.975	117441.0872	26000	9500	228000	8898073.597
43	7786646.935	1247932.535	117440.2872	0	9500	228000	8924019.757
44	7786621.335	1247905.095	117439.4872	26000	9500	228000	8897965.917
45	2935085.84	732335.845	131774.8356	0	9500	104500	3694696.521
46	2935064.88	732324.645	131770.1156	0	9500	104500	3694659.641
47	2935043.92	732313.445	131765.3956	0	9500	104500	3694622.761
48	2935022.96	732302.245	131760.6756	0	9500	104500	3694585.881
49	418034.73	447971.889	29394.3424	0	9500	28500	866900.9614
50	418016.41	447922.849	29386.3424	0	9500	28500	866825.6014
51	417998.09	447873.809	29378.3424	0	9500	28500	866750.2414
52	417979.77	447824.769	29370.3424	0	9500	28500	866674.8814