Optimizing Inventory and Work-in-Process in a Two-Echelon Food Supply Chain – A Case Study

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Abstract

In recent years, operational researchers have put more emphasis on modeling and analyzing multi-echelon supply chain. Discrete-event simulation techniques have been widely used for system performance analysis including inventory and work-in-process optimization for decades. This paper presents a method for modeling the dynamic behavior of a two-echelon food supply chain and evaluating inventory and workforce plan of the supply chain by applying discrete-event simulation. The model consists of two factories, one supplier and one manufacturer. Building the entire supply chain is based on a conventional single simulation to support decision-making when planning inventory and human resource for frozen chicken barbecue. The objective of the simulation study was to optimize inventory and work-in-process of the supply chain. The use of Arena software gives the fruitful results of the study.

1. Introduction

Supply chain management (SCM) is a naturally strategic issue as a consequence of its critical impact on an organization's competitiveness. Modeling of supply chain remains a challenge to operation researchers for the exploration of global optimum. In modeling and optimization of inventory control, the methods of operations research and simulation techniques are widely employed. Complicated systems of inventory, in which stochastic variables appear, are most conveniently investigated by simulation. Sobotka [1] proposed a simulation model of a two-level system of inventory control in a construction company logistics. Incidentally, discrete-event simulation techniques have been used extensively for SCM planning. Vorst et al. [2], for instance, improved customer service at lower total chain costs in an actual chilled salads in the Netherlands. They applied discrete-event simulation to evaluate alternative design of the supply chain. Kalasky [3] also used the application of discrete-event simulation in modeling a supply chain for consumer products. Optimization of the simulation model provided the efficient way to produce operating recommendations from the model.

This paper presents an effort of planning the inventory in order to optimize the inventory required for the production of frozen chicken barbecue in a two-echelon supply chain. The entire supply chain was studied by a discrete-event simulation. An additional benefit includes the more understanding of the production line characteristics of the entire supply chain.

2. Supply Chain Description

The two-echelon supply chain consists of a supplier which produces chilled chickens and a producer which supplies frozen chicken barbecues in Thailand. Based on the service responsiveness or demand level, the supply chain

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simulation study was conducted so as to achieve the workforce plan that minimize the inventory level through the workforce adjusted at each workstation.

The adjusting would be an attempt to smooth the flow of the chilled chicken through the chain and in turn eliminate bottleneck which results in work-in-process (WIP) reduction. Figure 1. depicts the modeled business process in the supply chain for frozen chicken barbecue. The companies' goals in this effort were to:

- Construct a model which accurately represents the data
- To run the model through demand levels
- To obtain the workforce and inventory plan with optimal inventory

3. A Method of Investigation and Optimization

By smoothing the flow, WIP will be kept at minimum. This can be accomplished when the appropriate number of workers at each workstation were employed. In simulation experiments, input parameters, i.e., stock of raw material at both factories and the number of workers at each workstation, are adjusted so as to achieve the minimum inventory and WIP at the required utilization of all workstations. In this study, the required utilization was preset to at least 0.80. In order to minimize the number of trials, the initial appropriate number of workers at each workstation is simply computed by the division of the required production rate and the capability, mean processing rate, of the worker. Rounding up is necessary to obtain an integer number. Similarly, the initial appropriate raw material stocks will correspond to the demand level.

The alternative that meets the optimization conditions, minimum inventory and WIP at the desired utilization of all workstations, will be selected. In this study, each simulation run comprised of 16 batches whereas each batch would take twenty one 8-hour working days accounted for one month period.

4. The Simulation Model

Up to this point, sufficient data and information was collected and analyzed for accuracy to build the Arena simulation model [4] of the supply chain operations. Then, as suggested by Law and Kelton [5], the conceptual model was validated by calibration made at each workstation throughout the supply chain. The calibration was conducted by making adjustment of input parameters.

An important check is to compare the throughputs, production rates, inventory levels and WIP's with those from the actual system. However, both inventory levels and WIP were somewhat higher due to no stock-outs is assumed in the model. Finally, this iterative process continued until the model was considered to be sufficiently accurate. Using batch means method to run terminating simulation for production at various demand levels, the 95% confidence interval (C.I.) of WIP inventory can be determined by the expressions:

$$95\%\text{ C.I. of WIP inventory} = I \pm t_{1-\alpha/2,m-1} \times s/\sqrt{m} \qquad (1)$$

and

$$I_j = \sum_{i\in L} \sum_{t_b\in T} [\, LQ_{ij}(t) + W_{ij}(t)\,]/K \quad \text{for all } j\in J \qquad (2)$$

where

I = inventory mean of m observations
α = significance level of 0.05
s = standard deviation
L = set of workstation in supply chain
J = set of simulation batch
T = set of unit time
m = number of batches for each run
K = length of each batch
$LQ_{ij}(t_b)$ = number of chilled chickens in workstation queue i at time t_b for simulation run j
$W_{ij}(t_b)$ = number of chilled chickens being processed in workstation i at time t_b for simulation run j

5. Output Analysis

The sum of the selected numbers of workers at 3 workstations of supplier's factory generates the optimal monthly workforce for the supplier. In a similar manner, the sum of the selected workforce at 4 workstations of producer's factory generates the optimal monthly work force for the producer. The simulation output recommended the optimal workforce and inventory as summarized in Table 1. There are two aspects that should be mentioned. Firstly, the study does not cover safety stock for the planning. Therefore, it is suggested that the safety stock should be added to the inventory plan so that the customer responsiveness can be guaranteed. Secondly, to cope with the fluctuation of the demand and also the workforce, the operations management will have to place more emphasis on the schedule of man-hour properly. The purpose is to stabilize the workforce as much as possible in order to avoid the trouble of hiring situation. For this reason, some of the workstations may be allowed for less utilization. In addition, over-time schedule could be a good choice to accomplish this. The working period can increase from 8 hours/day to 11 hours/day and 21 days/month to 25 days/month without any trouble.

6. Conclusions

Inventory is considered as a quantitative performance measure for the supply

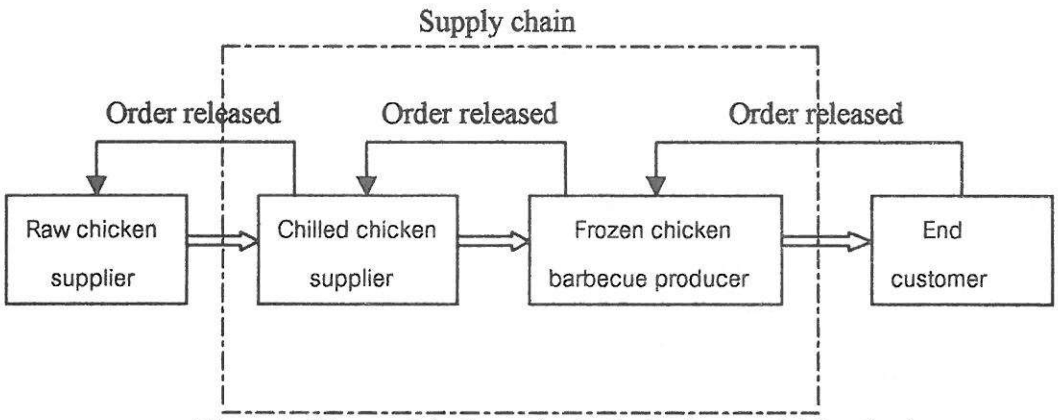

Figure 1. The model of supply chain for frozen chicken barbecue

Table 1. Summary of the most important simulation results

Monthly demand (kg)	Recommended optimal monthly workforce for supplier	Recommended optimal monthly workforce for producer	Recommended inventory for supplier (kg)	Recommended inventory for producer (kg)	95% C.I. of monthly inventory for the chain (kg)
10000	40	19	2954.81	667.24	3622.05 ± 742.11
20000	75	30	4941.73	1209.90	6151.63 ± 963.73
30000	110	43	8035.59	1659.03	9694.62 ± 2176.55
40000	107	42	8147.86	1728.44	9876.30 ± 2284.88
50000	108	42	8737.50	1699.88	10437.38 ± 1584.94

chain. Discrete-event simulation is still an effective tool as alternative of finding an optimal inventory. This paper describes the method to investigation and optimization of inventory and WIP. By simple computations of the initial values of input parameters placed in the simulation experiments, the number of alternatives to be simulated is considerably reduced. The recommended plan, as a result of the simulation study, shows mean reduction of inventory and mean increase of utilization as much as 35.22% and 25.48%, respectively, in the supply chain. Such information obtained from the simulation study should encourage the supply chain to build the stronger relationships and achieve more benefits of commitments and coordinations.

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