A DISCRETE-EVENT SIMULATION MODEL FOR A CONTINUOUS REVIEW PERISHABLE INVENTORY SYSTEM

Mohamed E. Seliaman
Shaikh Arifusalam
Department of Systems Engineering
King Fahd Univeristy of Petroleum and Minerals
Dhahran, Saudi Arabia

Abstract

In this paper we develop a discrete-event simulation model for perishable inventory system. The perishable inventory system follows the (*s,S*) replenishment policy under uncertainty of both demand and lead-time. The performance measure that is used in the model to evaluate the inventory system performance is expected total cost which consists of the inventory holding cost, the ordering cost, the shortage cost and the replacement cost due to outdated items. The model is used to optimize inventory replenishment decisions via SimRunner optimization package.

1. Introduction

Perishable goods are those goods, which have a fixed or specified lifetime after which they are considered unusable, i.e., they cannot be utilized to meet the demand. The planning and control of perishable inventory systems is important because in real life products like milk, blood, drug, food, vegetables and some chemicals do have fixed life times after which they will perish. The presence of these kinds of products after their lifetime will not only occupy space of the store but also effect the lifetime (damage) of the neighboring items. In some cases of perishable goods, which consume electricity for their storage, the loss is greater. The determination of the parameters of inventory models, to meet the demand of these types of goods hence becomes very crucial. The problem becomes difficult when there are stochastic demands and lead times.

It has been mentioned in literature that the analysis of perishable inventory models with stochastic demands and lead times is very difficult and perhaps this is the reason why the research is more focused on heuristics, upper bounds and approximations (Chazana and Gal (1977), Cohen (1976), Nahmias (1975, 1976, 1978), Nansakumar (1993)) and William (2001). More work in this area focused on the issuing policy in blood bank management (Prastacos, 1984) and on the inventory replenishment policy under periodic reviews (Nahmias, 1982).

The perishable inventory models are continuous in nature, but in order to find a acceptable solution these models can be approximated as discrete models. Very little literature is found for the time perishable inventory models (exception being Barlev and Perry (1989)) and recent literature on discrete techniques Alpha and Chakravarthy (1994), Alpha and Frigui (1996), Gravey et al. (1990), Yang and Chaudhry (1996) are few to mention. Zhaotong and Liming (1999) provide discrete time model for perishable inventory systems. They study the discrete time (*s,S*) perishable inventory model with geometrically distributed demand rates, zero lead times. They develop a closed form cost function allowing back orders as well.

Some studies for the continuous review perishable inventory models are Weiss (1980), Schmidt and Nahmias (1985), Ravichandran (1995) and Liu and Lian (1995).

While many authors consider the parameters of (s,S) and the optimal order quantities as the performance measures, William (2001) has considered the number of items perished/discarded as the performance measure for his model. He showed that fixed-critical policies perform best for perishable inventory models where the fixed-per-order-cost are not large. The optimality criteria selected was maximum profit.

Many researchers use simulation as tool in solving many problems not restricting to industrial problems because of its large applications. A spreadsheet inventory management simulation model was developed by Przasnyski (1994) for a reorder cycle system with lost sales. In this paper we present a simulation model for the continuous time (s,S) perishable inventory policy. We consider a perishable inventory system in which units in stock have a common deterministic lifetime and units of the same age will fail together if they are not taken by demands. The inventory system is subject to continuous review. We assume that the demand and lead times are both random variables. We further assume that demands are in batches, with random batch sizes and inter-demand times with back orders. We build the model using ProModel simulation software that is popular in modeling manufacturing systems. Then we use SimRunner simulation analysis and optimization package to find the optimal operating conditions for this perishable inventory system.

The paper is organized as follows. In section 2 the conceptual model is presented. In section 3 we develop the simulation model and provide the assumptions for the model. Analysis of the results is provided in section 4. Finally, conclusions will be outlined in section 5 and the scope for further research will also be discussed.

2. The Conceptual Model

The model starts with the arrival of demand for the perishable goods under consideration. To satisfy this demand a check has to be done whether the arriving demand can be satisfied or not. If there is enough stock then the demand will be satisfied. If the inventory level is less than the arriving demand, then the demand is backlogged. The (s,S) replenishment policy works as follows: at any inventory level $I(t)$, if an arriving demand is such that $I(t)$ would be s or lower, a replenishment order will be placed which will satisfy the latest demand, eliminate backorders if any, and bring the inventory level back to S. The conceptual model is depicted in Figure 1.

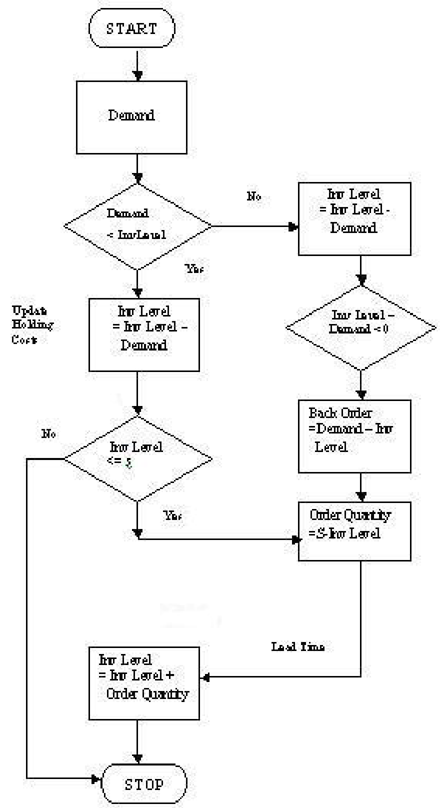

Figure 1: Flow chart for the Inventory model for perishable goods.

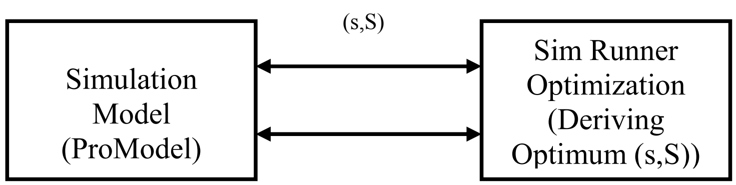

Figure 2: Simulation model linked with optimization support tool.

3. Simulation Model

The perishable inventory system conceptual model depicted in Figure 1 is developed into a simulation model and implemented using ProModel simulator. The following are the assumptions based on which the model is built.

i) Inter-demand times are independent and identically distributed with a random distribution function.
ii) The batch sizes of the demand are also randomly distributed.
iii) The product is assumed to have a constant lifetime.
iv) All units arrive new (unused).
v) Inventory is reviewed continuously.
vi) All unmet demands are backordered.
vii) The replenishment lead-time is also considered as random variable.

The fourth assumption is that the items arriving should be new, which means that the lifetime of the product starts after reaching the store.

3.1. Model Verification and Validation

The developed model has been verified and validated using three approaches. In the first approach deterministic input values are used to run the simulation. The systems states are checked and found to agree logically with the constant input values. In the second approach, the ProModel step mode trace is used to trace the events that occur over the course of a simulation. Also dynamic plots for the system states are constructed during the simulation run-time. In the third approach the animation of both the inventory system and output statistics is observed. This animation reflected a reasonable performance of the simulation model.

3.2. Pre-Analysis

Also known as Statistical Advantage, SimRunner Pre-Analysis is used to run several tests to identify the initial bias (warm-up period), determine appropriate run length to reach steady state, find the number of replications necessary to ensure that each event occurs at least once, and to obtain the model averages. This will improve the accuracy of the statistical data generated from the model analysis. These tests recommend the use of 10 simulation runs, each of one-year length.

4. Simulation Optimization

The model developed is linked with the SimRunner to determine the optimum values for the parameters of the inventory model (*s,S*). SimRunner simulation optimization is a multi-variable optimization that tries different combinations of input factors (*s* and *S* for our model) to find the combination that provides the best objective function (output) value (Total Cost in our case). The simulation optimization model is applied to a hypothesized perishable inventory system. This system is characterized as follows:

1. The demand process is Poisson with a mean of 2 arrivals per day.
2. The lifetime is fixed to 5 days.
3. The demand quantity is uniformly distributed between 1 and 20 units.
4. The replenishment lead time is exponentially distributed with a mean of one day.
5. The inventory carrying cost per unit per unit time is $0.005.
6. The replacement cost per unit decayed is $8.
7. The shortage penalty per unit short is $1.
8. The ordering cost per order is $5.
9. The allowed range for the reorder point is between 50 and 250 units while the inventory maximum capacity ranges between 600 and 1000 units.

The model is run for 10 replications for different combinations of the performance measures *s* and *S*. On the whole the number of experiments can be calculated as 10x200x400, as all the possible combinations times the number of replications. SimRunner optimization algorithm was used to perform all the experiments. The best 10 solutions found are listed in table 1 below:

Top

Table 1. Best 10 solutions summarized

s	*S*	Holding cost	Shortage cost	Ordering cost	Decay cost	Total cost
242	1000	415.08	835.69	1793.5	60609.6	63653.88
243	1000	416.36	835.69	1793.5	60609.6	63655.15
244	1000	417.64	835.69	1793.5	60609.6	63656.43
245	1000	418.93	835.69	1794	60648	63696.62
246	1000	420.18	835.69	1794.5	60719.2	63769.57
247	1000	422.08	835.56	1795	60750.4	63803.04
248	1000	423.46	835.56	1795	60750.4	63804.42
239	996	439.97	867.58	1798.5	60892	63998.05
190	909	319.78	849.64	1801	61028.8	63999.22
191	909	321.5	849.54	1801	61028.8	64000.84
241	996	442.57	867.58	1799	60930.4	64039.54
249	1000	407.63	868.6	1797.5	60994.4	64068.13

.

5. Conclusion

The perishable inventory model was selected for the study, as it is the area of great interest where the lifetime of the products is very small. Improper ordering of these types of goods can lead to heavy losses. To be realistic the demand times and the lead times both were considered as random variables. Perishable inventory systems with stochastic demands and lead times are complex in nature. The use of analytical tools to model and analyze such systems is very limited. Discrete event simulation models are becoming increasingly popular for planning and evaluating such systems. In this paper, it has been shown that simulation can be used as a tool to determine optimum inventory policies with the help of simulation software, which are supported with optimization tools. The approach can be extended to integrate the vendor decisions in the model.

6. Acknowledgement

The author wishes to acknowledge the support provided by the Department of Systems Engineering, King Fahd University of Petroleum and Minerals (KFUPM), Dhahran Saudi Arabia for conducting this research.

References

Alpha, A.S. and Chakravorthy, S. (1994) A discrete queue with the Markovian arrival process and phase type primary and secondary services, *Stochastic Models*, **10**, 437-451.

Alpha, A.S. and Frigui, I. (1994) Discrete NT-policy single server queue with markovian arrival process, *European journal of Operations Research*, **88**, 599-613.

Chazan, D. and Gal, s. (1977) A markovian model for perishable product inventory. *Management Science,* **23**, 512-521.

Cohen, M.A. (1976) Analysis of single critical number ordering policies for perishable inventories. *Operations Research,* **24**, 726-741.

Fries, B. (1975) Optimal ordering policy for a perishable commodity with fixed lifetime. *Operations Research,* **23**, 46-61.

Gravey, A., Louvion, J.R., and Boyer, P. (1990) On the Geo/D/1 and Geo/D/1/n queue queues, *Performance Evaluation*, **11**, 117-125.

Liu, L. and Lian, Z. (1995) An (*s,S*) continuous review model for perishable inventory, Working paper, IEEM95.11, HKUST, to appear in *Operations Research (Jan-Feb.1999)*.

Nahmias, S. (1975) A comparison of alternative approximations for ordering perishable inventory. *INFOR,* **13**, 175-184.

Nahmias, S. (1976) Myopic approximations for the perishable inventory problem. *Management Science,* **22**, 1002-1008

Nahmias, S. (1978) The fixed-charge perishable inventory problem. *Operations Research,* **26**, 464-481.

Nansakumar, P. and Morton, T.E. (1993) Near myopic heuristics for the fixed-life perishable problem. *Management Science,* **39**, 680-707.

Przasnyski, Z.H. (1994-July) Spreadsheet simulation model for inventory management. *Simulation (H.W. Wilson-AST)* **63**,32-43.

Ravichandran, n. (1995) Stochastic Analysis of a continuous review perishable inventory system with positive lead time and poison demand, *European journal of Operations Research*, **84**, 444-457.

Schmidt, C.P. and Nahmias, S. (1985) (S-1,S) policies for perishable inventory. *Management Science,* **31**, 719-728.

Weiss, H.J. (1980) Optimal ordering policies for continuous review perishable inventory models. *Operations Research,* **28**, 365-374.

William, L. Cooper. (2001) Pathwise properties and performance bounds for a perishable inventory system. *Operations Research,* **49(3)**, 455-466.

Yang, T. and Chaudhry, M.L. (1996) On steady-state queue size distributions of the discrete-time G1/G/1 queue. *Advanced Applied Probability,* **28**, 1177-1200.

Zhatong Lian and Liming Liu (1999) A discrete-time model for perishable inventory systems, A*nnals of Operations Research,* **87**, 103-116.

Zhatong Lian and Liming Liu (2001-Sep) Continuous review perishable inventory systems, *IIE Transactions*, **33**, 809-822.