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Automated Inventory Control and Management for Auto Spare Parts in Developing Nations

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Abstract

Inventory and its control is an aspect that has received considerable attention in contemporary times. This is attributed to the fact that salvaging the challenges posed by inventory drawbacks lies at the heart of management considerations and decisions in companies. For clarity,' Inventory Control focuses on acquiring, storing and managing the inventory in such a manner that it is available as and when due so as to cater for contingencies, maximize profit and to minimize wastage, losses or disservice to the customers. It is worthy of note that lost sales due to disservice are enormous**.** As it regards Spare/Service Parts which are interchangeable part kept in the inventory for the repair and replacement of failed parts. Spare parts industries and vehicle manufacturing companies strive to achieve the aim of inventory control which is to secure the best balance between "too much and too little." They must provide supply (sales), repair and maintenance services to their customers who would never desire downtime for their equipments because downtime is lost production capacity. Irrespective of the fact that spare part demands are stochastic (unpredictable) and provision of after-sales service compulsory, companies that can predict approximate optimal values for inventory decision making only topple their contemporaries in terms of sales and efficient service delivery. This research has designed and developed a model that performs a discrete event simulation of stochastic demands for spare parts inventory control.

Introduction

To a great extent, logical heuristics for inventory management and control which the study provides by employing simulation approaches will go a long way in ensuring optimization of inventory policies. The potentials of this work therein would be better portrayed in its application to real world inventory challenges.

In specific terms, the model can be easily implemented in spare parts/service parts/motor manufacturing companies/industries for the purposes of: Managing the inventory system in such a manner that demands (repair or replacement) are met. This would curb the incidents of lost sales as customers would not encounter any type downtime and lost production capacity. Knowing the service level of a particular demand class as well as the fill rate and the average number of backorder of demands and using that information to check criticality of spare parts. Certainly the structure of the company of study by itself inhibits service differentiation of demands thereby creating an environment where rationing can be applied. Thus, the approach in this research is to incorporate rationing to the current practice of the company with three demand classes differentiated by their demand lead-times. The motivation in taking this approach is that the researcher believes it will result in better system performance given certain service level requirements. Consideration was made to orders from the transport firm as the highest priority (***Gold***) class, failure and maintenance orders from the maintenance section as the medium priority (***Silver)*** class while orders from external customer as the lowest priority ***Bronze*** class. The researcher also established two static threshold levels in order to model a single location system facing an assumed Poisson arrival rates for the classes. The Gold class has zero lead time while the Silver has a shorter but positive lead time than the bronze counterpart. However, the proposed simulation of a Model-Driven Decision Support system would incorporate the 7 (continuous review, one to one lot, service differentiation, backordering, demand lead time, threshold rationing and clearing mechanism) spare parts inventory policies with replenishment lead times inclusive so as to find to find the fill rates as well as the average number of backorders for the demand classes. This is because the knowledge of the fill rates (probability of no stockout) and the rate at which demands are backordered can help the company predict optimal parameters for inventory. Note that the magnificent power of information technology is once again used to provide succor to this ailing but important sector of the society. The study employs the availability of the computing power and speed to build a hypothetical system which can impact positively inventory control. In specific terms, a robust programming languages (VB. Net) is used to model events and to provide optimal heuristics for proposed inventory policies. In other words this study depicts the details of a Discrete Event Simulation of stochastic demands for Spare parts Inventory Control. The immense dynamics and criticality of spare parts and the large revenues accrued, as essential motivating factors for providing control in manufacturing companies has never showed any sign of decrease. In fact, in the vast technological environment of today the complexities of Spare Parts Inventory Control enjoy more insights from analysts (in the Management Science, Information Technology and Industrial/Mechanical Engineering field) as inventory policies get modeled to ensure customer satisfaction. In other words manual ways of handling inventory has failed to cope with factors like stochastic demands, better service levels, and shorter lead times and providing perfect heuristics for Inventory-related decision making. To this end, significant results for forecasting spare parts requirements can be achieved through the use of novel decision models.

Literature Review

The use of simulation in modeling the spare parts inventory management problem represents a popular alternative to mathematical programming since simulation has the ability of describing multivariate non-linear relationships which can be difficult to put in an explicit analytical form. Several authors have explored this alternative, this sub–heading dealt with reviewing how their efforts contrast with the contribution of this study.

Kocaga (2004), performed a study on a spare parts service system of a major semiconductor equipment manufacturer facing two kinds of orders of different criticality. The more critical down orders need to be supplied immediately, whereas the less critical maintenance orders allow a given demand lead time to be fulfilled. He proposed a policy that rations the maintenance orders under a one-for-one replenishment policy with backordering and for Poisson demand arrivals for both classes. He then coded a discrete event simulation algorithm in C with the next-event time advance mechanism to advance the simulation clock. The researcher carried out a review of related literature on spare parts management and control. This is to convey and portray the knowledge and idea that have been established in and around spare / service parts inventory, its control, management and most especially the approaches employed by authors in order to solve inventory problem. To conclude the review, a summary of the contributions of this study and its approach to this body of knowledge was made evident. The review of pertinent literature was done under the following subheadings: Spare parts, Inventory control and management, Service Differentiation and Rationing, Clearing Mechanism, Demand Lead Time, Echelon in Spare Parts Inventory, Review of Spare Parts Inventory Simulation Models, Decision Support System (DSS) and Model driven DSS. The allocation of inventory to demand classes has become increasingly dynamic, complex and lies at the heart of almost every management problem. This is due to limited capacity and perishable inventory (seats in an airplane, rooms in a hotel, and cars in a rental fleet) etc. Several industries have innovated ways to deal with demands from customers inview of the service level agreements and price as the case maybe. Like in the aviation industry they use the terms first class, business class, or economy class to mark different classes involved in their business and to innovate ways to deal with these customers to ensure customer satisfaction. Differentiating between classes of customer is also not alien in the Spare Parts industries. Just as different customers may require different product specifications, they may also require different service levels. Here, the classes mostly maintain two extremes which have been used to denote the customers with high and low service level agreements. Or according to Isotupa (2005), to show that some of the equipments/parts are very critical for the smooth running of the operations and needs to be serviced on a priority basis, while other equipment is less critical and will have lower priority. The two extremes are Ordinary/Priority as was used by Isotupa (2005), Critical/Non-critical as was used by Rosetti and Thomas, Gold and silver as was used by Vicil and Jackson (2006) and High/Low Priority Demand as was used by Okonkwo (2010) and so many other authors. Different class of customers may represent different importance to the supplier in a like manner or different customer may have differing stock out costs, penalty costs or different minimum service level. That is why it is overly necessary to distinguish between classes of customers (Customer Differentiation) i.e. the consequence of multiple demand classes, hence the handling of different customers in a non-uniform way. According to Okonkwo (2010), "…for this system of multiple demand classes the easiest policy would be to use different stockpiles for each demand class. This way, it would be very easy to assign a different service level to each class. Also the practical implementation of this policy would be relatively easy and will require less mathematical analysis. But the drawback of this policy is that there is no advantage from the so-called ***portfolio*** effect. In other words, the advantage of pooling demand from different demand sources together would no longer be utilized. Therefore, as a result of the increasing variability of demand, more safety stock would be needed to ensure a minimum required service level which in turn means more inventories.

Methodology

This research has analyzed some models developed for spare parts inventory control and management and why they are unsuitable for solving the problems that motivated this study. The models that were examined are the database model, and the mathematical model. The database model, is used to computerized spare parts inventory database. Each of the parts that is supplied or replenished is continuously keyed into the computer and the inventory stock parameters are updated automatically. The company uses a software package for its inventory control. This is used to identify the part number of the spare parts. Once the vehicle model is inputted, it invokes a dialogue box from where spare parts section is selected and from the pull down menu, the particular spare part is chosen. The software will search and pop up the part number of the spare part. From the part number, the location of the spare parts in the stock room is identified. This is how the company performs their inventory management and control. The service differentiation has two classes of customers with demand arrivals follow a Poisson process which is activated either as a result of failure of a spare part (High Priority Demand - HD) which constitutes the critical class customer or is used to maintain a spare part to avoid failure of the system (Low Priority Demand - LD) and it constitutes the non critical class customer. Both arrivals, HD with arrival rate of λ_1 and LD with arrival rate of λ_2 for each spare part are filled from the same pool of inventory, which implies a total arrival rate of $\sum \lambda_k$. For the rationing policy of this model, on the arrival of a replenishment order, if there is a high priority backorder, it takes a higher priority and therefore is immediately filled, if there is no high priority backorder, but a low priority backorder, it is cleared only if the physical stock is above $S*$, otherwise, the physical inventory is incremented. First backordered first cleared (FBFC) is only considered when the class distinction has been made.

In his mathematical analysis he tried considering an arbitrary time t, if there was no demand in the interval (t, t + L_r), the on hand inventory at time t + L_r would be S. For a low priority demand arriving at an arbitrary time t + L_r – L_d to be filled at its due date t + L_R, the minimum inventory level must be S^*+ 1. This would only occur if the high priority demands at interval (t, t + L_r) and low priority demands at interval (t, t + L_r-L_d) is (S – S^*- 1) or less. The low priority demands for interval (t + L_r-L_d, t + L_r) are not considered as the due date for such demands will be beyond t + L_r.

Hence,

$$\beta_1 = \left[\int_0^{L_r - L_d} e^{(\sum \lambda_k)t} (\sum \lambda_k)^{S-S^*} \frac{t^{S-S^*-1}}{(S-S^*-1)!} \{ \sum_{x=0}^{S^*-1} \frac{e^{-\lambda_1 [(L_r-L_d)-t]^x} [\lambda_1(L_r - L_d) - t]^x}{x!} \} dt + \sum_{x=0}^{S^*-1} \frac{e^{-\lambda_1 L_d} (\lambda_1 L_d)^x}{x!} \right]_i$$

While the average number of high priority backorders is given by

$$ANB_1 = \lambda_1 \left\{ 1 - \left[\int_0^{L_r - L_d} e^{(\sum \lambda_k)t} (\sum \lambda_k)^{S-S^*} \frac{t^{S-S^*-1}}{(S-S^*-1)!} \{ \sum_{x=0}^{S^*-1} \frac{e^{-\lambda_1 [(L_r-L_d)-t]^x} [\lambda_1(L_r - L_d) - t]^x}{x!} \} dt + \sum_{x=0}^{S^*-1} \frac{e^{-\lambda_1 L_d} (\lambda_1 L_d)^x}{x!} \right] \right\}_i$$

3.8

In the paper which is titled ‘A Threshold Inventory Rationing Policy For Service Differentiated Demand Classes’ and was written by Deshpand, V., Morris A. C, Karen D. (2002). Here , they assumed demand from class *i* follows a Poisson process with rate λi, implying a total demand rate of $\lambda = \lambda 1 + \lambda 2$. Any unmet demand is backlogged and incurs two penalty costs: a stockout cost per unit backordered (πi) and a delay cost per unit per period of delay (ˆ πi), where $i = 1, 2$. With no loss of generality we assume $\pi 1 \geq \pi 2$ and $\hat{}\pi 1 \geq \hat{}\pi 2$, and therefore refer to class 1demand as having ‘higher priority’.

Inventory is replenished according to a (Q, r, K) policy that operates as follows. When the inventory position (on-hand plus on-order minus backorders) reaches the level r, a replenishment order for Q units is placed and arrives $\tau > 0$ time units later. Demands from both classes are filled on a FCFS basis as long as the on-hand inventory level is greater than or equal to K. Once the on-hand inventory level falls below K, class 2 demand is backlogged (i.e., no longer filled) while class 1 demand continues to be filled as long as inventory is available. Their objective is to determine the policy parameters (Q, r, K) which minimize expected annual cost for the system. They assume that each replenishment order incurs a fixed setup cost of s, while inventory holding costs are incurred at rate h for each unit of inventory carried on-hand. Let C (Q, r, K) denote the expected annual cost for a given (Q, r, K) policy and $H(Q, r, K)$, $S(Q, r, K)$, and $Z(Q, r, K)$ denote the associated expected annual holding, setup, and penalty costs, respectively. Our problem is then stated as min

$Q, r, K, K \leq r + Q$

$C\ (Q, r, K)$ (1)

$C\ (Q, r\ , K) = S(Q, r, K) + H(Q, r, K) + Z(Q, r, K).$

Note that since the maximum possible on-hand inventory is $r + Q$, we limit our search for optimal threshold rationing level to $K \leq r + Q$.

SYSTEM DESIGN AND IMPLEMENTATION

Two allocation policies must be specified: one for when a demand occurs and one then for when a unit of stock is delivered. We refer to the first as the rationing policy and the second as the backorder clearing mechanism. In this study, both policies are governed by a threshold level.

Threshold Rationing Policy:

- $PI > K^2$: Satisfy all demands on FCFS basis.
- $PI > K^1$And$PI > K^2$: Satisfy Gold and Silver demands on FCFS basis and backorder the Bronze demands.
- $PI < K^1$: Satisfy Gold Demands and backorder Silver and Bronze
- $PI = 0$: Backorder all classes of demands

Threshold Backorder Clearing Mechanism:

- On the arrival of a replenishment order an existing backorder will be satisfied on first come serve basis (FCFS), if one exists;
- Otherwise the replenishment other is added to the physical inventory (update inventory).
- Here, clearing backorders allows for partial clearing (i.e. where a backorder is partially filled if the physical inventory cannot be enough to clear the backorder)

Where **PI** is Physical Inventory, $\mathbf{K^2}$ is the First threshold level; $\mathbf{K^1}$ is the Second Threshold level. The problem of determining these fill rates is difficult because OH inventory at any time depends not only on threshold levels (K^2, K^1), but also on how the arriving replenishment orders are treated for the existing backorders. In the developed model, the fill rates for both classes were determined, (i.e. the probability of no stock out). This denotes the probability that an arbitrarily arriving customer demand will be completely served from stock on hand without an inventory-related waiting time.

Assumptions

Below are the assumptions with which the simulation analyst developed the models.

1. Gold, Silver and Bronze Demands are assumed to be Poisson with rate λ_1, λ_2 and λ_3 respectively.

2. With no loss of generality, $\beta_1>\beta_2>\beta_3$

This means that the fill rate requirement for Gold demand is higher than that of the Silver demand and is subsequently higher than that of the Bronze demand. This is because of the prioritized service level agreement with the customers.

3. $L_R>SL_D>BL_D>0$

This is a reasonable assumption because spare parts customers cannot usually quote a demand lead time greater than the replenishment lead time.

4. Backordering for the three classes (Gold, Silver and Bronze).

The service level agreements which the company has with customers are the major cause of backordering because unmet demands are backlogged till the next replenishment.

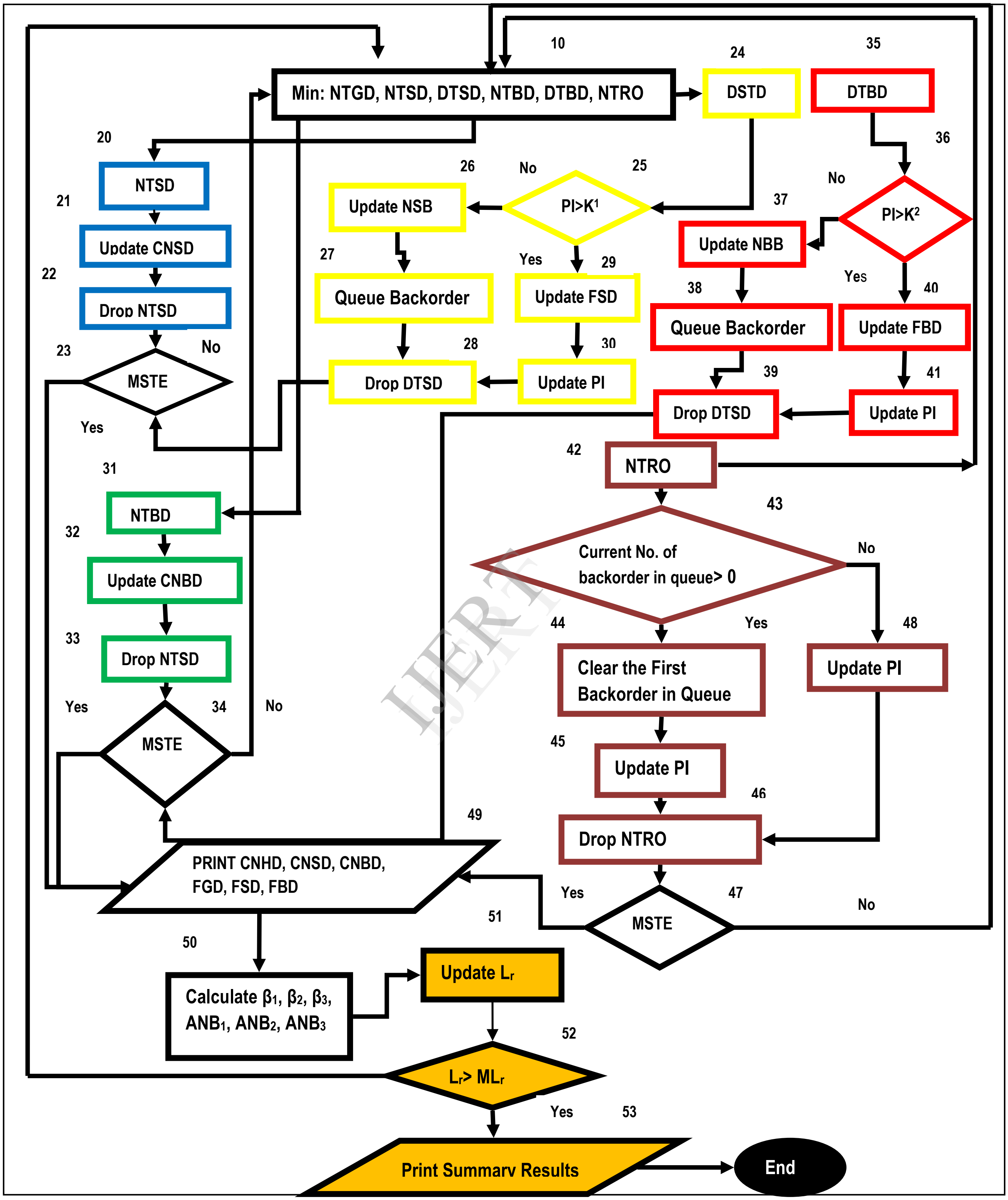
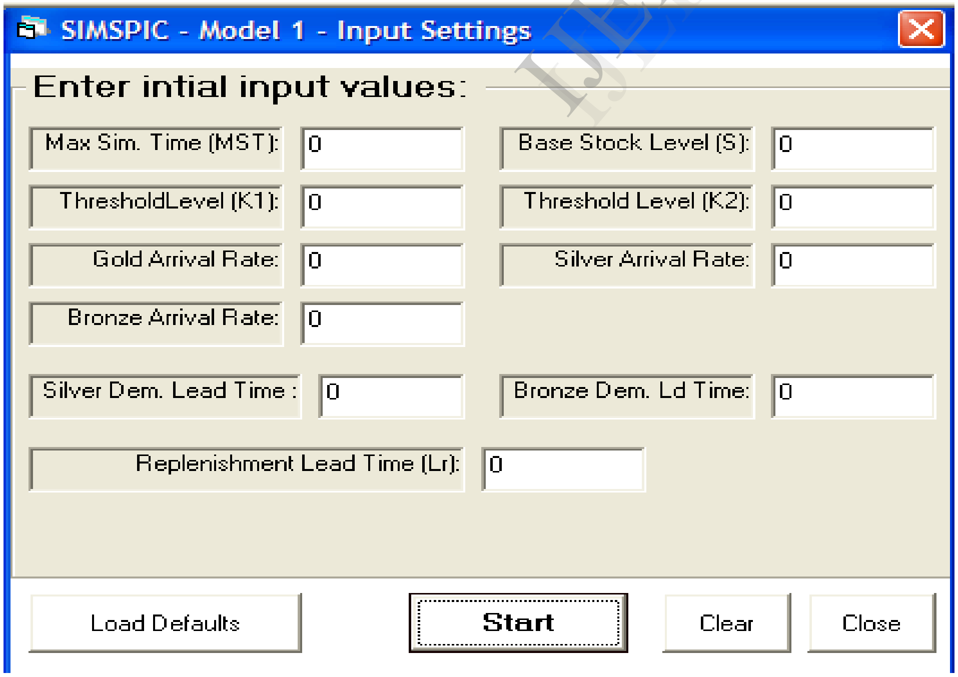


Fig 3.5 A Typical Flowchart of the Model (for L_r Perturbation)

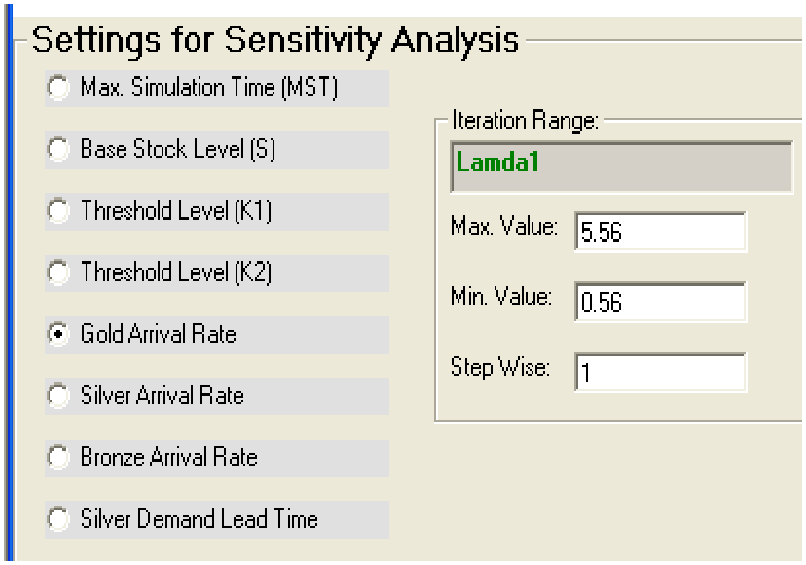
Results and Discussions

As a result of the stochastic nature of the demands, these will be transmitted directly to the generation of replenishment orders and clearing of backorders. Furthermore, each demand triggers off a replenishment order for the simulation model, in line with (S, S-1) policy. With these stochastic and stepwise state transitions, there appears a need to perform manual simulation in readiness for the development of the models. Hence, this study formulates a composite stepwise 2-dimentional graphical representation that captures these stochastic demands and stepwise state transitions. Backorder, Stock Level, NBAD, NSAD and NROT were graphical placed against time so as to portray how the dynamics of a typical inventory vary with an arbitrary time in the light of stochastic demands of spare parts. Note that this concept model is just used to depict the concept and that it is grossly inadequate to showcase an ideal inventory situation.


SIMSPIC - Model 1 - Input Settings

Enter intial input values:

Max Sim. Time (MST): 0
Base Stock Level (S): 0
ThresholdLevel (K1): 0
Threshold Level (K2): 0
Gold Arrival Rate: 0
Silver Arrival Rate: 0
Bronze Arrival Rate: 0
Silver Dem. Lead Time : 0
Bronze Dem. Ld Time: 0
Replenishment Lead Time (Lr): 0



Settings for Sensitivity Analysis

○ Max. Simulation Time (MST)
○ Base Stock Level (S)
○ Threshold Level (K1)
○ Threshold Level (K2)
● Gold Arrival Rate
○ Silver Arrival Rate
○ Bronze Arrival Rate
○ Silver Demand Lead Time

Iteration Range:
Lamda1
Max. Value: 5.56
Min. Value: 0.56
Step Wise: 1

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