Model Development for Auto Spare Parts Inventory Control and Management

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Abstract

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 enjoys more insights from analysts (in the Management Science, Information Technology and Industrial/Mechanical Engineering fields) 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. Besides the selling of vehicles, the spare parts of various models of heavy duty vehicles are stored and managed by the company. The management of these models which is complex was further complicated by the vast number of parts required in each model. In fact, more than 20,000 active parts needed to be controlled. The management of these parts can only be done with the aid of a computer; hence the spare parts complex has a 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. From the part number, the location of the spare parts in the stock room is identified.

Key Words: Spare parts inventory, Information Technology,

Introduction

The spare part company faces three major demands of spare parts from the complex; the first is demand from a transport company. Spare part companies cater for their failure (down time for spare parts) and maintenance demands. The Spare parts company gives this transport firm highest priority so as not to incur any type of costs or consequences as the case may be[1] [2] [3]. The second demand comes from the maintenance section of the company. Demand from the maintenance section is as a result of spare parts demands for maintaining their vehicles, for maintaining after-sales service of vehicles whose owners had service level agreement with the company as well as those that just take their vehicles to their maintenance workshop for either regular servicing or for repairs when they have broken down completely. The third is from the external customers that directly buy spare parts from the complex for their personal use. 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 and motor manufacturing companies or 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. The major purpose of the study is to *design and develop a model that can perform a discrete event simulation of stochastic demands for spare parts inventory control*. The objectives also include:

Development of stochastic simulation model [4][5][6] which integrates 7 policies for spare parts inventory together. The policies are continuous review, one to one lot, service differentiation, backordering, demand lead time, threshold rationing and clearing mechanism. To use the developed model in finding the Fill Rate and Average Number of backorder for the three demand classes (Gold, Silver and Bronze), using the above developed models in the light of the noted inventory control policies. Formulation of composite graphical representations of the models which can be used for pedagogical purposes.

Background Studies

The use of simulation in modeling [8] [9] 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.

A study was carried out by Kocago in 2004 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. Wang et al [45] performed a simulation of spare parts inventory model which is very relevant literature to this study. In the simulation model, a supplier has a periodic review inventory system that provides several lead-time options to its customers. The inventory replenishment lead time is a multiple of the inventory review cycle. They consider an inventory-commitment problem, in which the supplier allocates its on-hand inventory to two groups of customers. When inventory runs out, the supplier backorders demand to future cycles. They formulated the inventory commitment decision using dynamic programming algorithm. The simulator also explores the optimal inventory replenishment issue and evaluates the performance of the models. Persson and Saccani [27] developed a simulation model in order to support a case study concerning a world player of heavy equipment. Its spare parts distribution system, configuration and allocation decisions were modeled. Discrete event simulation which was well suited for time-dependant relations was used. Supply Chain Simulation applied to the case study provides useful insights on the decision choices and the cost structure related to the spare parts distribution system[7][8][9].

A simulation model was developed by Sarker and Haque for the system operating with block replacement and continuous review inventory policy. The Focus of the study was to ensure availability of spare parts for a production system use, when necessary; there is always a tendency to overstock them. Excess inventory involves substantial working capital. The stock level of spare parts is dependent on the maintenance policy. Therefore, maintenance programs should be designed to reduce both maintenance and inventory related costs. In this paper, a manufacturing system is considered with stochastic item failure, replacement and order lead times of statistically identical items. A simulation based-decision support system for multi-product inventory control management was developed by [25]. The system permits management to obtain an inventory system-wide view of the effect of changes in decision variables on the performance measures of a furniture manufacturing firm. The simulation model considers the effect of variations in demand; re-order point, stock-control level, time between reviews, and lead time. The decision support system [10][11][12] generates policy scenarios based on management specifications. The effect of each scenario on system performance was then analyzed.

Simulation [13][14][15] is chosen because of the stochastic and complex nature of spare parts problem in a study by Ilgin and Gupta [19]. The parts recovered from discarded and end-of-life products can be used as a source of spare parts during post product life cycle. Therefore, they developed a simulation model of the manufacturing system and integrated a Genetic Algorithm (GA) [17][18]19] to determine the optimal final order quantities for a number of critical spare parts. However, accurate determination of the final order quantity is complicated as it requires the prediction of spare parts demand for the post product life cycle.

Materials and Methods

To accurately develop a decision support simulation model that will check the stochastic demand of spare parts and to optimize inventory so as to find the fill rate and the average number of backorders, the simulation project life cycle proposed by McHaney [26] s employed. In view of the above assertion, the present procedure considering the case study is also presented as well as the weaknesses of the present system. In addition, is the arrival of demands and the inventory situations that require the implementation of a particular policy for decision making. The researcher (simulation analyst) studied relevant details of the Spare Parts Complex of Manufacturing Company in Nnewi which satisfies the basic requirements for the models of the study. The interview of relevant staff of the spare parts complex, documents obtained from the company as well as observing the real life procedure of the company are sources of relevant information.

System Design

A typical flowchart representation of the stochastic model of (S, S-1) is shown in Fig 3.5. The flowchart model has 53 modules which are all linked together and labeled. The interpretations of the modules were shown in section 3.6.6**.** The flowchart has six typical event channels. The module in each channel is differentiated with the line color. The event channel with a line colour of purple shows the system behavior on arrival of a gold demand.

The event channel with blue line color shows the system behavior on arrival of a silver demand. The channel with yellow line color shows the system behavior on the due time of a silver demand while that of dark red is the system behavior on arrival of a replenishment order.

The channel with green color shows the system behavior on arrival of a bronze demand and the channel with the red color shows the system behavior on the due time of a bronze demand. The equation that follows can only be adapted to the mode being developed in interval (t, t + L_r-L_d), after which the he equation that follows can only be adapted to the model being developed in interval (t, t + L_r-L_d), after which the demands during the demand lead time is added:

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

While the average number of high priority backorders is given by:

$$ANB_3 = \lambda_1 \left\{ 1 - \left[\int_0^{L_r - L_d} e^{(\sum \lambda_k)t} (\sum \lambda_k)^{S-S^*} \frac{t^{S-S^*-1}}{(S-S^*-1)!} \left\{ \sum_{x=0}^{S^*-1} \frac{e^{-\lambda_1[(L_r-L_d)-t]^x} [\lambda_1 (L_r - L_d) - t]^x}{x!} \right\} dt + \sum_{x=0}^{S^*-1} \frac{e^{-\lambda_1 L_d} (\lambda_1 L_d)^x}{x!} \right] \right\}_i \quad (2)$$

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. [6], 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 stock-out cost per unit backordered (πi) and a delay cost per unit per period of delay (ˆ πi), where i = 1, 2. Without loss of generality we assume $\pi 1 \geq \pi 2$ and ˆ$\pi 1 \geq$ ˆ$\pi 2$, 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*.[20][21][22] 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.

Results and Discussions

The sorted values and the corresponding events which each value represents shown in the fifth and the sixth columns, respectively, were also shown in Table 1 below:

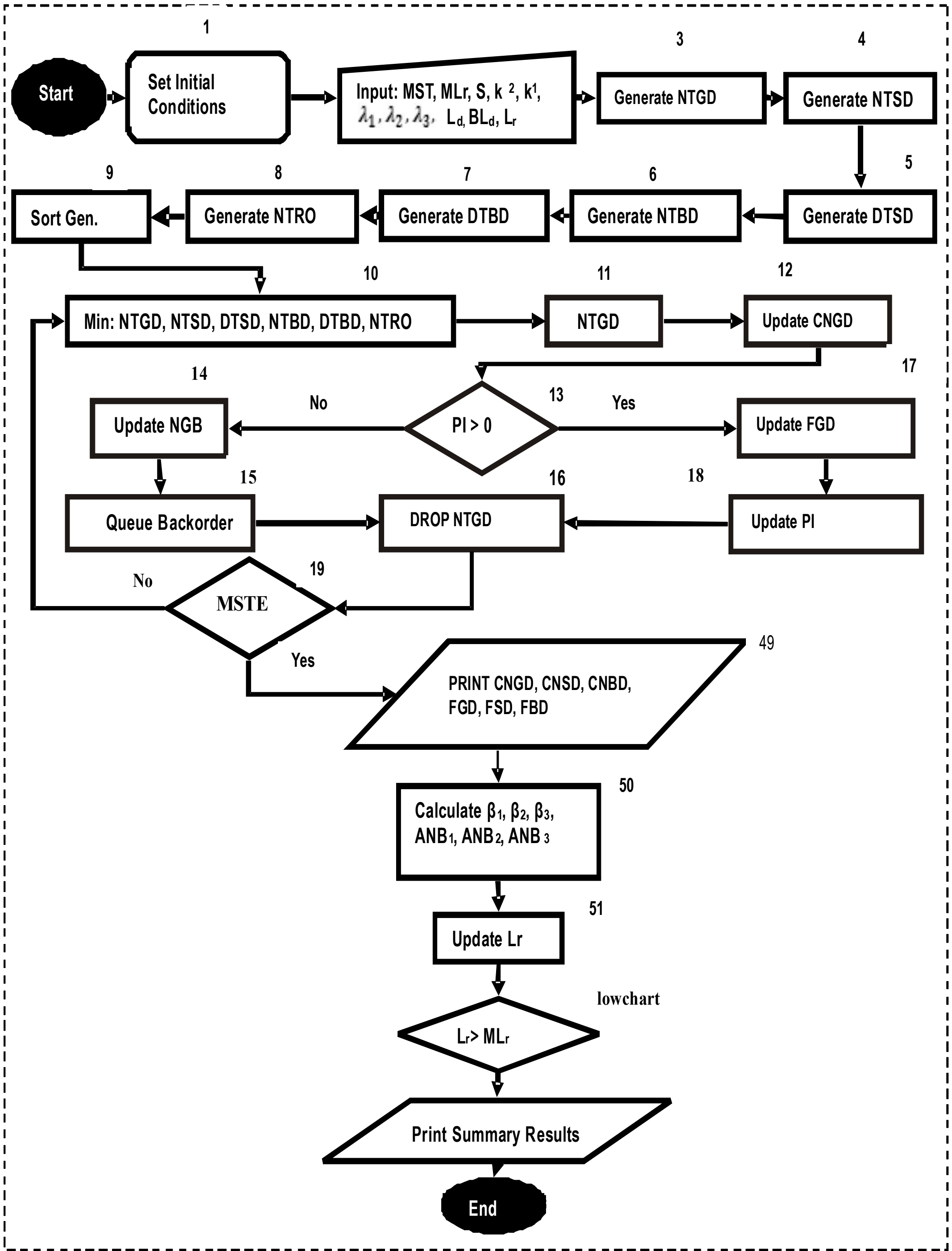

Fig. 1: Flowchart For Stochastic Simulation Model (S, S – 1)

Table 1. Initial Random Event Generation and Event List

Table 1

Initial Random Events Generation

NTGD	NTSD	NTBD	DTSD	DTBD	NTRO
0.1456	0.0413	0.0223	0.1813	0.1423	0.6456
0.5748	0.9183	0.173	1.0583	0.293	1.0748
0.7217	1.0188	0.1807	1.1588	0.3007	1.2217
0.8291	1.0819	0.2208	1.2219	0.3408	1.3291
0.8434	1.3033	0.5062	1.4433	0.6262	1.3434
0.8507	3.2819	0.5869	3.4219	0.7069	1.3507
1.4811	3.4742	1.0354	3.6142	1.1554	1.9811
2.4103	3.4866	1.1791	3.6266	1.2991	2.9103
2.6307	3.7079	1.3278	3.8479	1.4478	3.1307
4.6978	4.3477	1.4069	4.4877	1.5269	5.1978
4.8211	4.4702	1.6941	4.6102	1.8141	5.3211
4.8775	4.5533	1.7073	4.6933	1.8273	5.3775
5.3769	4.6911	1.7633	4.8311	1.8833	5.8769
5.3938	5.7029	1.8009	5.8429	1.9209	5.8938
5.445	5.9898	1.8422	6.1298	1.9622	5.945
5.6595	6.1649	2.2238	6.3049	2.3438	6.1595
5.711	6.7394	2.3463	6.8794	2.4663	6.211
5.984	6.884	2.4099	7.024	2.5299	6.484
6.1828	7.3633	2.465	7.5033	2.585	6.6828
6.2347	7.6604	2.5277	7.8004	2.6477	6.7347
6.247	8.3148	2.5746	8.4548	2.6946	6.747
6.3946	8.4339	2.999	8.5739	3.119	6.8946
6.6956	8.6047	3.2448	8.7447	3.3648	7.1956
7.4567	9.2697	3.4539	9.4097	3.5739	7.9567
7.9924	9.2797	3.5157	9.4197	3.6357	8.4924
8.1468	9.3527	3.7668	9.4927	3.8868	8.6468
8.1596	9.8854	4.1259	10.0254	4.2459	8.6596
8.2344	9.9089	4.1449	10.0489	4.2649	8.7344
8.3409	10.5799	4.2666	10.7199	4.3866	8.8409
8.6662	12.1696	4.4235	12.3096	4.5435	9.1662
8.6778	12.4122	4.7401	12.5522	4.8601	9.1778
8.9662	12.4923	4.9049	12.6323	5.0249	9.4662
9.2657	12.6569	5.0558	12.7969	5.1758	9.7657

EventList	EventTyp
0.0223	NTBD
0.0413	NTSD
0.1423	DTBD
0.1456	NTGD
0.173	NTBD
0.1807	NTBD
0.1813	DTSD
0.2208	NTBD
0.293	DTBD
0.3007	DTBD
0.3408	DTBD
0.5062	NTBD
0.5223	NTRO
0.5413	NTRO
0.5748	NTGD
0.5869	NTBD
0.6262	DTBD
0.6456	NTRO
0.673	NTRO
0.6807	NTRO
0.7069	DTBD
0.7208	NTRO
0.7217	NTGD
0.8291	NTGD
0.8434	NTGD
0.8507	NTGD
0.9183	NTSD
1.0062	NTRO
1.0188	NTSD
1.0354	NTBD
1.0583	DTSD
1.0748	NTRO
1.0819	NTSD
1.0869	NTRO

Table 2: **Intermediate Simulation Output Results**

Intermediate Simulation Output:

Bronze Arriv	CNGD	CNSD	CNBD	FGD	FSD	FBI
1	1	0	0	1	0	
1	1	0	1	1	0	
1	1	0	1	1	0	
1	2	0	1	2	0	
1	2	0	1	2	0	
1	2	0	1	2	0	
1	2	0	1	2	0	
1	2	0	2	2	0	
1	3	0	2	2	0	
1	3	0	2	2	0	
1	3	0	2	2	0	

Table 3: Final Simulation Output Reports

Final Simulation Output:

Gold Arrival Rate	B1	B2	B3	ANB1	ANB2	ANB3
Gold Arrival Rate	0.0526	0.0155	0.0078	0.5305	3.1995	2.54
Gold Arrival Rate	0.0258	0.012	0.0039	1.5197	3.2108	2.5499
Gold Arrival Rate	0.0219	0.003	0.0073	2.5039	3.2404	2.5414
Gold Arrival Rate	0.0184	0.0066	0.732	3.4944	3.2287	2.56
Gold Arrival Rate	0.0126	[illegible]	0.0074	4.5025	3.2397	2.5412
Gold Arrival Rate	0.0093	[illegible]	0.	5.5085	3.2056	2.56

At the end of each stepwise increment, the output results generated for each perturbation is registered in the intermediate and final simulation outputs. Figures above show a print screen of intermediate and final generated outputs results respectively. The intermediate simulation output screen will display values for first the parameter whose sensitivity analysis [23][24][25] was performed. Then, it displays the values for CNGD, CNSD, CNSD, FGD, FSD, FBD, NB1, N B2, NB3, PI and the event that caused that result while the final simulation output displays B1, B2, B3, ANB1, ANB2 and ANB3

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