Automated Inventory Control System for Nigeria Power Holding

Ekechukwu Boniface [1], Henry Nwokoye[1] , Abara Josiah Chukwuemeka[2]

[1]Department of Computer Science, Nnamdi Azikiwe University, PMB5025 Awka, Anambra State, Nigeria
boni_eke@yahoo.com
[2]Department of Physics, Federal Poly, Nekede, Oweri.

Abstract

The problem of increasing criticalities and complexities of spare parts in service companies, maintenance industries as well as power generation companies motivated this research for solution. The causes of the problems were traced to factors like demand unpredictability, parts indigenization, high service levels, large investments on parts and a lot of items in the inventory. Power Holding Company of Nigeria (PHCN) currently holds in excess of millions in spare parts inventory between the six power generation facilities. These inventory items are used to service the generation facilities, and so are critical to the continued operation of the company. The company may want to release some capital from its inventory investment by reducing stock levels. In addition, 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. Therefore, it is imperative to accurately forecast spare parts requirements and to optimize existing inventory policies using significant decision support. This research has developed Inventory Control Software that has provided automated and graphical interface ability for decision making. Stochastic simulation model for spare parts inventory was developed.

Key Words: Inventory Management,Stochastic demands, shorter lead times, spare parts requirements

---

1.0 Introduction

Inventory Control is based 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. Heightened operational risks, lower availability and gross consequences like affecting the overall performance of a utility or plant are the results of insufficient stock. While on the other hand oversized inventories might result to undesirable expenditures and the improper use of capital. As Inventory levels are affected by customer service expectations, demand uncertainty, and the flexibility of the supply chain, employing strategies to obtain optimal balance between the two extremes makes for a better company in terms of reduction in disservice and customer dissatisfaction. [1] Inventory control concerns Spare/Service Parts which are interchangeable part kept in the stock for the repair and replacement of failed parts. And the importance of inventory control in spare parts supply chain management has increased in the past decades to reduce the down time of critical equipments. This has profound impact on the maintenance and repair market as to providing a competitive edge for companies that can ensure a means of guaranteeing constant up-time of equipment/utilities at all times in view of stochastic item failure resulting in stochastic spare parts demands, replacement and order lead times of statistically identical items. The practical application of adopting a coordinated model-driven decision support approach for spare parts inventory management and control system has been employed in this research. The entire supply chain has the potential to simultaneously reduce service parts inventory investment levels and to improve parts availability at all times. In specific terms, the model was seen to be easily implemented in Power Generation, Transmission and Distribution Companies as well as other industries for the following purposes. To curb the incessant incidents of lost sales which is always evident in power outages and brownouts by managing the inventory in a way that the repair, replacement and maintenance demands are met. Ability to check the criticality of spare parts with the information gotten from obtaining a better understanding of the service level expected by a particular demand class as well as the fill rate and the average number of backorder of those demands made this system very useful. There is enhanced inventory management for industries that have agreements of a contractual nature for servicing machines/vehicles/airplanes. This system can be used as an efficient, effective and interesting spare parts inventory pedagogical tool, both in the academic and the commercial institutions.

2.0 Background Studies

The Power Holding Company of Nigeria PHCN operates a maintenance-like environment which focuses on providing constant support for the operation of a single unit, plant or component (or a fleet or group of components), and ensuring that operational requirements are achieved. [2]Maintenance activities that affect forecasting of spares demand constitute a major component of inventory control in this context. In addition, expensive parts need to be stocked to guard the operation from unwanted (and costly) stock-outs. Typically, each demand is satisfied from a part taken from stock (if available), or else a backorder occurs. The “lost sales” rule that is common in final product inventory problems is regularly not applicable to the spare parts area, because if no spares are available, extended equipment downtime sometimes caused by lack of an effective maintenance culture or unpredicted outages is generated. Decayed infrastructures as well as faults in power generating plants are speculated causes of this erratic supply of power. Most times a fault with one of the stations could affect the national grid due to the low number of power stations with quality production levels. Due to these reasons, the Nigeria government wants to privatize the power sector. Privatization of the sector will give room for more people and their monies to build power stations because when there is increase in power generation, a fault in one of the stations will not lead to collapse of the whole system. [1]

His paper presents an analysis of power outages in transmission lines associated with the Nigerian grid. He opined that the

Nigerian power transmission network is characterized by prolonged and frequent outages. His analysis portrayed various outages like planned outages and forced outages which can be associated with aging equipment/defects (leading to frequent conductor/jumper cuts, frequent earth faults resulting from reduction in overhead clearance and refuse burning, circuit breaker problems), lightning, wind, birds/animals, vandalization, accidents and poor job execution by contractors. [7]

Observed that planned outages on the 132 kV recorded the highest value of only 7% while, the remaining 93% were due to either forced outages or emergency/urgent outages. The study revealed that the existing transmission network is characterized by poor maintenance and is over aged leading to the collapse of several spans; and that prolonged and frequent outages are phenomena in the transmission networks. Most of the transmission lines are very long and fragile leading to frequent conductor cuts. This gives rise to high voltage drops and power losses in the network. The voltages can be as low as 217 for a 330 kV line and 92 for 132 kV lines. Others include high voltage drops associated with single line contingency and small conductor sizing lines which are also subjected to constant tripping and have to run at very high voltage up to 150 for 132 kV line to be able to operate at acceptable limit. High voltages are experienced in some very long lines where the reactors are out of circuits due to low resistance, winding faults and damaged cables as well as overload of several transformers in the network. [6]Proffered solutions which include carrying out a study to identify all weak areas in the network with a view to strengthen the network, carrying out planned and routine maintenance on the network to reduce the incident of collapsed spans, re-enforcing very long and fragile lines to improve the voltage stability and efficiency in the network, introducing additional circuits and loops into the network to reduce the single line contingency constraints associated with most parts of the network, ensuring good protection system taking into consideration the short circuit current in the network should be put in place to assist in fault isolation and protection of the network. [10]Others include addition of more substations into the network to assist in the reduction of long lines and improve the voltage profiles of the network, introduction of vigilant groups to guide against vandalisation which constitute a major setback in the network, and promptly rectifying faults and energizing all the lines to reduce the incidence of vandalisation, and proper clearing should be carried out for transmission lines that have be over grown by trees and weeds to reduce the effect of constant tripping of the lines. [2]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. [14]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. [13]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.

3.0 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 [3] is 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 “lost sales” rule that is common in final product inventory problems is regularly not applicable to the spare parts area, because if no spares are available, extended equipment downtime sometimes caused by lack of an effective maintenance culture or unpredicted outages is generated. The excessive purchasing leads to a backup of parts in inventory. Given the tremendous costs associated with plant shutdowns or de-rates (reduction in power output), the Company cannot simply ignore a typical demand. Rather, they need a better understanding of the fill rates and average number of backorders for all demand classes and how these results relate to the level of risk that the company can tolerate. [11]Such knowledge can lead to optimal management of costs, tradeoffs, and risk, while maintaining safe plant operations. Essentially, the Company must maintain a balance between the plant availability and output against the electricity demand and the plant’s capacity through a better understanding of spare parts demand. This would be of potential improvement because if the Company can understand when they will need parts, then they can plan accordingly to promote just-in-time delivery and minimal inventory. Currently, work/job orders trigger the companies’ reaction to demand for spare parts.

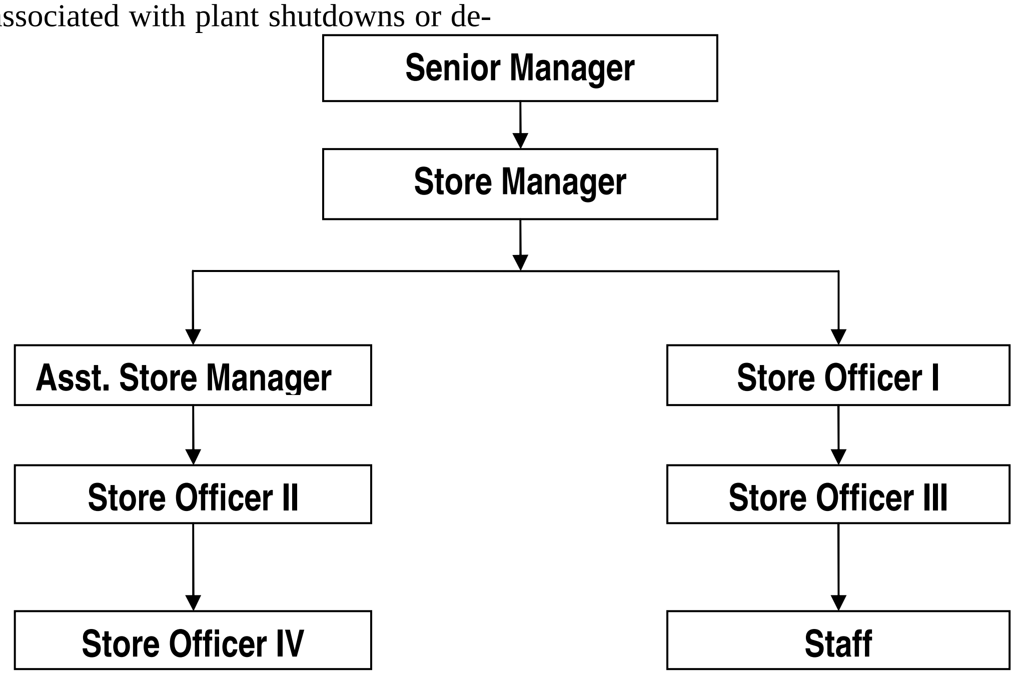
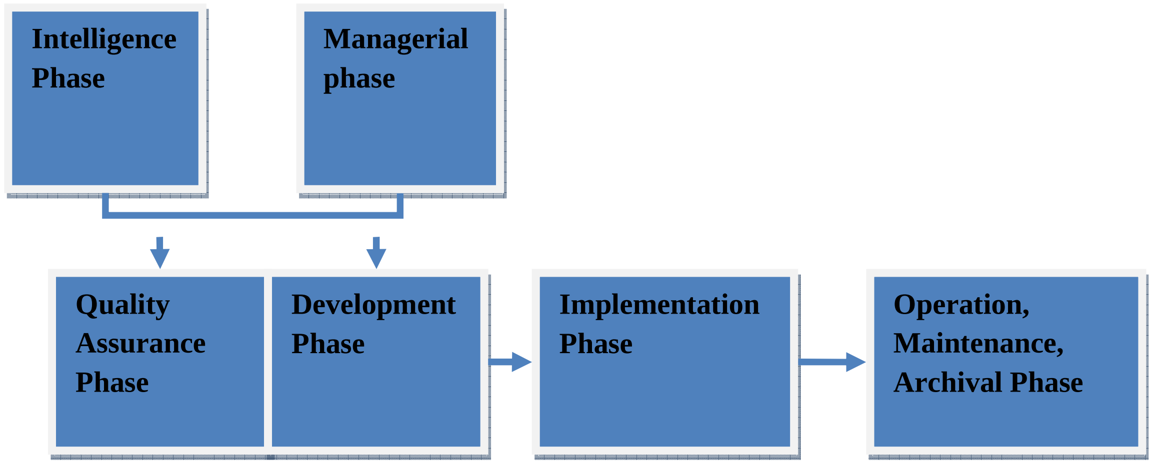


Fig. 1 Organogram of Inventory Department of PHCN

A diagrammatic representation of the major phases of the Simulation Project Life Cycle and a detailed explanation of what the phases entail.



.

Fig. 2: General Simulation Life Cycle.[4]

Phase 1: Intelligence Phase

The simulation analyst should emerge from this phase with knowledge of the problem that exists and should have at least a preliminary understanding of the problem's nature. Often the problem definition (describing the questions the simulation needs to answer) and feasibility (Technical, Economic, Legal, Operational and Schedule) are assessed at this point in time.

Phase 2: Managerial Phase

A means of gathering information needs to be established. This requires obtaining support from management, domain experts, system users and other individuals in order to understand and document the system that will be modeled. In other words, simulation requires teamwork and in most cases cannot be done a lone individual. The managerial phase facilitates organizational involvement in a simulation project. A number of overhead tasks are accomplished here including development of proposal, securing a budget, acquiring managerial support and forming a project team. Often the development of a simulation proposal is used to organize effort and to ensure all participants are working toward a common goal.

Phase 3: Development Phase

Simulation models are created here. System design, detail design and coding all take place and rely on the interaction of the analyst and other members of the simulation team. The actions involved in this phase include: Determine the system (defining subsystem, environment and boundaries), Model Scale (determining how much detail to include) and Model Scope (determining the portion of the system to be represented). Others include Model View (Event/Process/Activity), Concept Modeling, Simulation input data validation, Selection of a language or tool and Model Construction (writing of model codes).

Phase 4: Quality Assurance Phase

While the model is been coded in complete or at least in prototype form, the analyst must ensure proper validation and verification. The ideas of testing and completion or integration are important here. It may be necessary to take testing one step further and begin development of face validity through interaction with end user and management. Generally quality assurance accompanies the entire modeling life cycle.

Phase 5: Implementation Phase

Here, model use begins and decision activities take place. This implies that after the model has been conceptualized, coded, verified and validated, it is ready to provide information through experimentation. Experimentation is the process of initializing key parameters in the model and setting up production runs to make inferences about the behavior of the system under study. This phase involves the following actions; experimental design (length of simulation time, replications, reseeding random number stream, initial conditions and variables of interest), Production runs and output (sensitivity) analysis.

Phase 6: Operations, Maintenance and Archival Phase.

The phase involves storing the model with consideration of its potential future use. This may not be the case all the time as the objectives for model development vary. [9]Another common activity at this point is conversion. This may not apply to all situations but it may involve turning the model over to the customer or end user. The end users may adopt the simulation as a tool requiring little or no additional intervention from the simulation team. The storage component of the archive phase reflects the investment in the simulation project. Documentation and physical simulation code, as well as data and other records from the project should be stored in a secure, safe place for future access. The third component in the archive phase is maintenance. Here, the simulation is monitored and adjusted to reflect environmental changes or newly available organizational information [12]. Often, a member of the simulation project team will be appointed as the contact person for maintenance issues.

4.0 System Design

Random variables form the basis for the generation of all random numbers. Algebraic methods are simple to maintain, fast and reproducible, hence they are widely used. [5]The inverse transform algebraic method will be used in the simulation development. **Mathematical specifications** for random phenomenon has a negative exponential density function, expressed thus:

$$F(t) = \lambda e^{-\lambda t}$$

$$F(x) = \int_0^x \lambda e^{-\lambda t} dt = 1 - e^{-\lambda t} \quad (1)$$

The given value of x is 0 < x < 1

$$F(x) = 1 - e^{-\lambda t}$$

$$e^{-\lambda t} = 1 - F(x)$$

$$-\lambda x = In\{1 - F(x)\}$$

$$x = -(1/\lambda) In R(x)$$ Where $R(x) = 1 - F(x)$

R(x) is a random number between zero and one, and x is the variable. Thus generating a sequence uniform random decimal numbers $F(x_1), F(x_2), F(x_3), \ldots$, the exponential distributed random variable

$(x_1),(x_2),(x_3),...$ can be obtained. Random numbers as generated above are not strictly random since, if one knows the seed (Y_0), all the remaining numbers in the sequence can be known. Consequently, these random numbers are often 'Pseudo-Random Numbers', however, this is a philosophical assertion: if the random numbers appear to be independent draws from the U, (0, 1) . distribution and they pass a series of statistical tests. Then for all practical purposes they are random [5]. All the housekeeping involved is expatiated automatically on a computer clock, until the next change occurs. This procedure is repeated and it goes on like this for the duration of the simulation

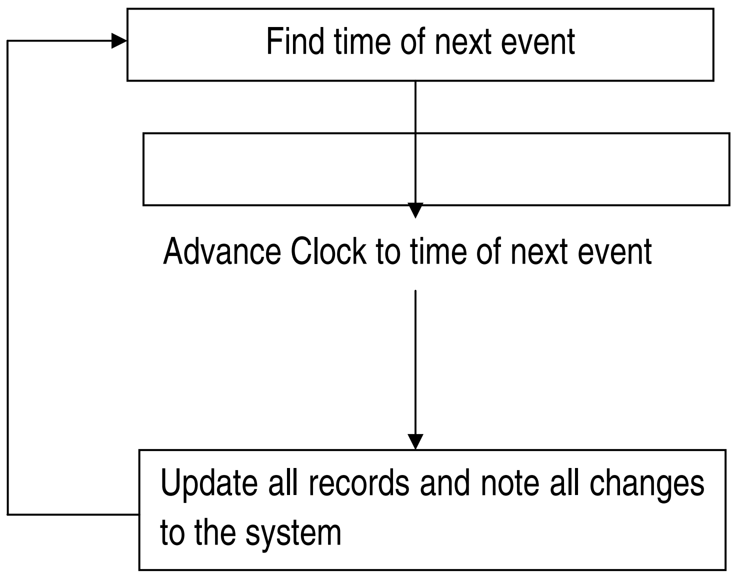


Fig. 3: Algorithm Design Summary Flow Diagram

5.0 Results and Discussion

Fig. 4: Security Login Dialogue Box

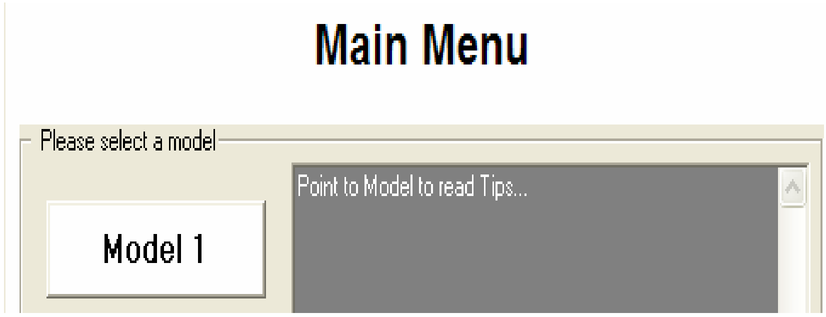


Fig. 5: **Main Menu Dialogue Box of the Model**

The Main Menu displays the only model of this study. By clicking on this model the software launches the software into the simulation environment where several simulation runs can as well as sensitivity analysis can be performed.

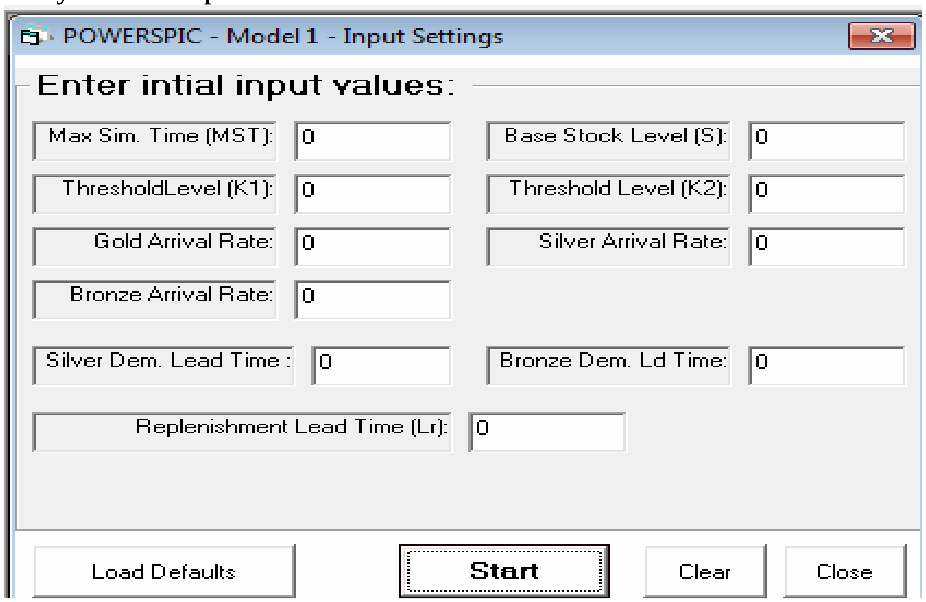


Fig. 6: Input Dialogue Box for the Model

In this dialogue box, the required input parameters for the simulation are keyed in, one after another, in line with the dataset to be simulated. To use the default values, the defaults button is clicked and the values are automatically supplied. The clear button is used to clear the inputted values when the need arises while the close button closes the dialogue box entirely. The Start button prompts the computer to start simulation, which invokes a direction dialogue box

.

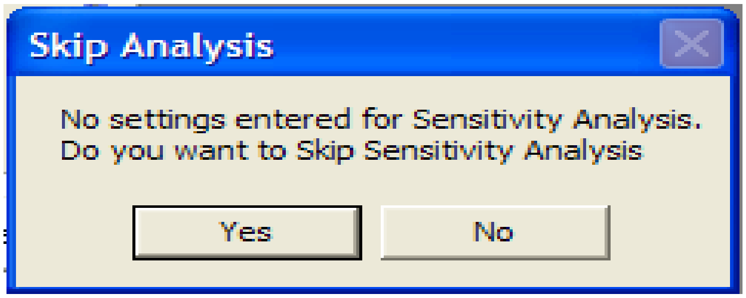


Fig. 7: Start or Continue Simulation Request Dialogue Box

It should be noted that if the *Yes* button is selected the simulation proceeds and completes the run without performing any sensitivity analysis. However, if sensitivity analysis is required, the *No* button is selected, it allows for the setting of the sensitivity analysis that is desired.

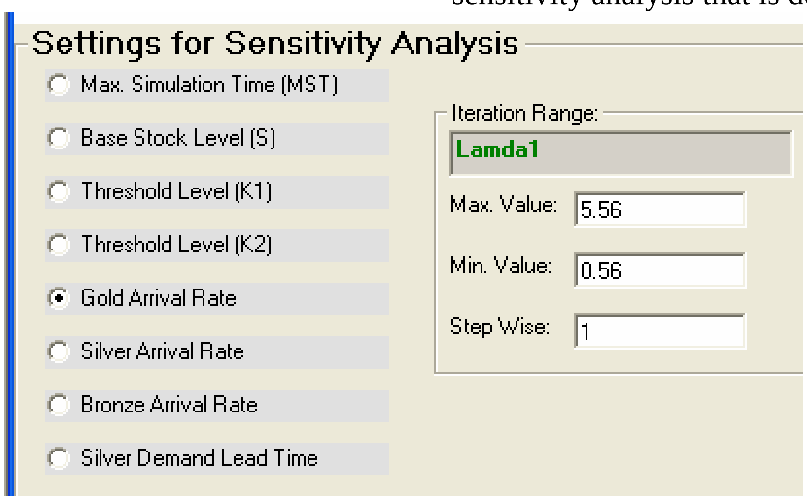


Fig. 8: Sensitivity Analysis Dialogue Box for Model 1

This setting of this sensitivity analysis dialogue box is completely flexible. At this instant, the parameter that is selected for sensitivity analysis is the Gold arrival rate, while the minimum and maximum iteration values are 0.56 and 5.56, respectively. The step wise value is 1. In other words, the value changes while other input parameters remain constant. At each change of the arrival rate, the simulation is run and its outputs are displayed in the intermediate and final simulation outputs. Similarly, any of other sensitivity parameters can be chosen while any value can be inputted in the iteration range as step wise value. After setting the values for the sensitivity analysis, the start button is clicked and a confirmation dialogue box appears, requesting for a *Yes* selection for the simulation to start. Also, when a simulation run for a step increment has been completed, this same dialogue box appears requesting to either continue or terminate the simulation run. If continue button is selected, it will increase the sensitivity parameter to the next step value and run again after which the dialogue box will reappear. It continues like this until the end of the sensitivity analysis.

.

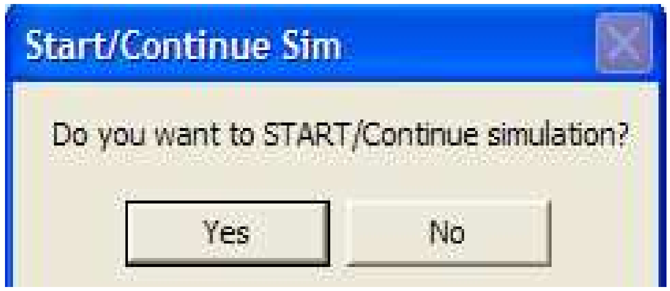


Fig. 9: Continue Simulation Request Dialogue Box

This research has designed an application that aids decision making and enhances spare parts inventory control and management. The problems existing in spare parts complex of Power Holding Company of Nigeria motivated this research. The system does not observe service differentiation through rationing and demand lead time and cannot find the Fill Rates and the Average Number of Backorders for each demand class. Notwithstanding the fact that in some exceptional cases, the company observes demand lead time for some demands. But, more than ever before, this method can no longer withstand the challenges of modern standards of spare parts inventory control. Stochastic Simulation Model integrated seven spare parts inventory policies together

.

References

[1] Onohaebi O. S. (2009) ***"Power Outages in the Nigeria Transmission Grid"*** Research Journal of Applied Sciences, Issue 1, Vol 4, pp 1-9.

[2] Okonkwo, U. C. (2009) "***Simulation, a tool for engineering research through sensitivity analysis of a stochastic queuing model simulator***", International Research and Development Journals Vol. 4, No. 3 pp.120-131.

[3] McHaney R. (2010). "***Understanding Computer Simulation***." Ventus Publishng Aps.

[4] Masood, A. B. (1999) "***A Simulation Model for Multi-Product Inventory Control Management"***Sage Journals Vol 72, No 1 Pp 20-32.

[5] Paradopoulus, H. T. et al 1993 "***Queueing Theory in Manufacturing Systems Analysis & Design***", Chapmell and Hall, London.

[6] Acharya, D., Nagbhushanam, G., and Alam, S.S. (1986), "***Jointly Optimal Block Replacement and Spare Provisioning Policy***", IEEE Transactions on Reliability, Vol. R-35, No. 4, pp447-451.

[7] Arobieke O., Osafehinti S., Oluwajobi F. and Oni O. (2012) "**Electrical Power Outage**

In Nigeria: History, Causes and Possible Solutions" Journal of Energy Technologies and Policy, Vol.2, No.6.

[8] Arslan, H., Ayhan, H., Olsen T. V. (2001). ***Analytic models for when and how to expedite in make-to-order systems***," IIE Transactions, 33, 1019–1029.

[9] Cohen, M. A., P. R. Kleindorfer, and H. L Lee. 1988. "***Service Constrained (s, S) Inventory Systems with Priority Demand Classes and Lost Sales***", *Management Science*, 34(4), 482-499.

[10] Deshpande, V. Cohen, M.A., Donohue K. (2003) "***A threshold inventory rationing policy for service-differentiated demand classes".****Management Science* 49, 683–703.

[11] Dekker, R., Kleijn M. J., Rooij P. J. (1998) ***"A spare parts stocking system based on equipment criticality."*** International Journal of Production Economics, 56:69-77,

[12] Ha, A. Y. 1997 "***Inventory Rationing in a Make-to-Stock Production System with Several Demand Classes and Lost Sales***". *Management Science,* 43(8), 1093-1103.

[13] Harvey, M. 1989 "***Principles of Operations Research: with Applications to Management Decisions",*** 2nd Ed. Prentice-Hall Inc., USA.

[14] Kaplan, A. 1969, "***Stock Rationing***"*Management Science*, 15(5), 260-267.Hopp, Wallace J., Mark L. Spearman and Rachel Q. Zhang, 1997, "***Easily Implementable Inventory Control Policies***," *Operations Research,* Vol. 45, no. 3, p. 327-340.