RESEARCH REVIEW JOURNALS
Volume-04
Issue-04
April -2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com [UGC Listed Journal]

Developing a Supply Chain Model for Attribute Acceptance Single Sampling Plan through Simulation Technique

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ARTICLE DETAILS

Article History
Published Online: 15 April 2019

Keywords
Acceptance Sampling, Economic Order Quantity, Simulation Model, Supply Chain Management.

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ABSTRACT

Simulation is the present day need to develop new models as the real time systems involve more cost and time. In this paper, an attempt is made to design a supply chain model for single sampling plan for attributes using simulation technique and Goldsim, a simulation software which reduces considerable modeling task, time consuming computation work and costs involved for them. The findings would be helpful for the real time model builders.

1. Introduction

In the current scenario the survival of the industries is possible only with an ample management of supply chain activities. The appropriate management of supply chain also helps to increase the competitiveness of the industry. Sampling is a process used in statistical analysis in which a predetermined number of observations are taken from a large population. The methodology used to select a sample from a large population depends on the type of analysis being performed. Acceptance Sampling is a common quality control technique used in the industry to determine whether to accept or reject a material in the production lot. It is usually done when the raw-material arrives for production or during the production process within the factory or when the product leaves the factory as finished goods. Most often, when producer supplies goods to a consumer, a decision is made based on samples taken from the lot. Acceptance or rejection of the lot is determined by the number of defective items found in lot during the inspection process. The lot is accepted if the number of defective items is less or equal to the acceptance number or otherwise the lot is rejected. In acceptance sampling, these kind of sampling plans are used to confirm the goods supplied by the supplier adhere to quality standards of the buyer.

2. Review of Literature

An integrated production-inventory model is presented by Sana (2011) for supplier, manufacturer and retailer supply chain by considering perfect and imperfect quality items. She employed an analytical method to optimize the production rate and raw material order size for maximum expected average profit by considering unit production cost, and idle times in different sectors on collaborative marketing systems like textile, footwear, chemical, food, and etc.

Single sampling plans are widely used for appraising the incoming product quality. In such situations, it is logical to have a comparison between various sampling plans and their matching single sampling plans. Wasserman (1990) presented a strategy to match operating performance of CSP-1 plans with single sampling plans based upon the long run proportion accepted about two target operating levels Acceptable Quality Level (AQL) and Limiting Quality Level (LQL). He also observed that it is not possible to match OC curves when this strategy is used. Radhakrishnan & Ravisankar (2009) presented a procedure for constructing single sampling plans for three attribute classes using AQL as the quality standard. These plans were also compared with the two–class attribute plans.

Many classic studies (Peach and Littauer (1946), Liltauer (1946), Burgess (1948), Grubbs (1949), Cameron (1952), Golub (1953) and Guenther (1969)) have given tables for determining the single sampling plan for the given producer quality, consumer quality with respective risks α and β based on Binomial, Hyper geometric and Poisson probability models. They have given methods and tables for finding the acceptance number 'c' when the sample size 'n' is fixed or finding 'n' when 'c' is fixed or finding both 'n' and 'c' when minimizing sum of risks. There is huge gap in minimizing the cost though there are limited studies talks on inspection cost alone. This paper attempts to fill this gap by including various costs associated to a supply chain process. However the scope of the scope of this study is limited to development of supply chain model with Poisson model alone.

3. Economic Order Quantity

The result of increased order quantity under conditions of permissible delay in payments needs to order less often. The Economic Order Quantity (EOQ) model of Goyal (1985) is an extension of the classical economic order quantity model for items having probabilistic demand. The theoretical results obtained by Teng (2002) reveals the following two managerial phenomena:

(i) In certain cases, the economic replenishment interval and order quantity decreases under the permissible delay in payments, which contradicts to Goyal's (1985) conclusion. It makes economic sense for some customers to order less quantity (or shorten the replenishment time interval) and to take the benefits of the permissible delay more frequently.

(ii) If a supplier wants to reduce his large level of inventory, then he should charge an excessive interest rate on his customer's outstanding amount after the credit term expires. Consequently, his customers will order to buy more quantity than the classical economic order quantity.

Although the Economic Order Quantity (EOQ) formula is probably one of the most famous formulae in the industrial management field, the composition and estimation of the cost parameters have always been vague and imprecise at best. In view of the inherently, the fuzzy aspect of the cost determination and the EOQ formula are re-examined in a fuzzy-set-theoretic perspective Park K. S. (1987).

In addition, Maddah & Jaber (2008) extend the model by allowing several batches of imperfect quality items to be consolidated and shipped in one lot. This is likely to be useful when there are economies of scale in shipping of imperfect quality items. The analyzed effect of screening speed and variability of the supply process on the order quantity showed that the order quantity in the model is larger than that of the classical EOQ model when the variability of the yield rate is reasonably low.

A sensitivity analysis is made to investigate the effects of five important parameters (the inspection rate, the annual demand, the defective rate, the holding cost, and the receiving cost) on the optimal solution (Lin, 2013).In this paper, we propose a simulation model with imperfect quality in reordering system.

4. Objective of the Study

The main objective of this study is to develop a supply chain model for single sampling plan for attributes through simulation technique.

5. Research Methodology

In this study, the simulation technique is used to design the model for single sampling plan in supply chain management to find Economic Order quantity. Simulation is an important tool that provides a way in which alternative designs, plans and/or policies can be evaluated without having to experiment in a real system, which may be costly, time-consuming, or simply impractical to do. Moreover Simulation allows asking “What if?” questions about a system without having to experiment on the actual system which incurs the costs and delays associated with field tests, prototypes, etc.

By simulating the attached underlying forces of a manufacturing supply chain by defining the “links” in the chain (Retailer, Distributor, Manufacturer, Tier 1 supplier(s), Tier 2 supplier(s), etc.) and how organizations interact with each other. The model would simulate the movement of materials from purchase to finished product through the supply chain and could be used to identify ways in which the system could be modified (e.g., via technology or improved decision rules) to operate more efficiently.

GoldSim (12.0) is specifically designed software to quantitatively address the inherent uncertainty which is present in real-world systems. It is a user-friendly and highly supported for graphical presentation. It also provides powerful tools for representing uncertainty in processes, parameters and future events, and for evaluating such systems in a computationally efficient manner. In addition, it provides powerful capabilities for superimposing the occurrence and consequences of discrete events into continuously varying systems. In this study, GoldSim is used for the realistic simulation of discrete events such as financial transactions and amount of resources utilized.

6. Rational for Simulation

This paper discusses supply chain models with the re-ordering system. Re-ordering system is having the basic assumption of the items submitted for production process or purchase by the people. However, practically there are possibilities of getting imperfect items i.e., defective or it might not meet the required standards of production process. Therefore, there is a need for rectification of the defective / imperfect items. Hence, the researcher applies acceptance sampling in-between (during the production process) the stage of purchase and production process. Generally after purchase, the entire lot is been sent for production process. But in this proposed model, the purchased lot is being sent for sampling inspection. At this stage, if the acceptance sampling results are positive and if the lot is accepted, then the lot is being sent to production process. If the lot is rejected then it will be sent to 100% screening. And after that, the lot will be again sent to the previous stage, sampling inspection for testing. In some situations the lot will be sent back to the supplier himself for replacement, but this situation is not considered in this study.

In the proposed model, if there is any defective which is being found, say for example 1%, that particular defective lot is being sent for sampling inspection. Sampling inspection will decide whether the lot has to be sent for direct production or it has to undergo screening. If the lot is being sent for production directly, then the finished product will also reflect the same percentage of defective, which was detected in the raw material lot. This means the production level has to be increased, i.e. instead of producing 100 items, 101 items have to be produced.

Considering another situation, where the defective item is being sent for screening. The screening is actually good, because all the defective items will be replaced. Therefore, after the production process the finished goods will be free from defectiveness. However, 100% screening policy is a bit costlier when compared to sampling inspection. So, the decision will be taken by considering whether the lot has to be sent for inspection or not. If the lot is sent for inspection, it has to undergo rectification process which involves rectification cost. If the lot is sent for inspection, it incurs just the inspection cost. If the customer is receiving defective lot, then it incurs warrant cost, and to produce extra items it again incurs manufacturing costs. All these aspects need to be considered for having a good production process. However, if analytical models are considered for deriving at some equations, it becomes more complicated since we need to consider more parameters. Hence, the researcher is trying to solve this with the simulation model. In the simulation model, all the parameters are being fixed with numerical values to find out the total cost of implementation and optimal model is being determined.

GoldSim software is being used because this model involves inventory cost, storage cost (if the produced lot has to be kept inside the go down it involves cost for storage), back-order cost (if there is shortage of goods or if there is any delay in delivery of the lot) and ordering cost. The GoldSim has the capability of doing the computations of time durations, cost and inventory levels, etc.

7. Development of Simulation Model

A supply chain process is given in the Figure-1. It is explained that from purchase the lot is being sent to sampling inspection after which the lot is being sent to production process (the arrows are used just for referencing and not to show the flow of the process). Finally, the lot will be sent to sales after production process. Purchase decisions are taken based on the production unit. The level of production will be determined based on the availability of raw material. If there are any changes, it is called as the re-order system, i.e. if stock level is less than the expected level, and then there will be a need for new purchase order.

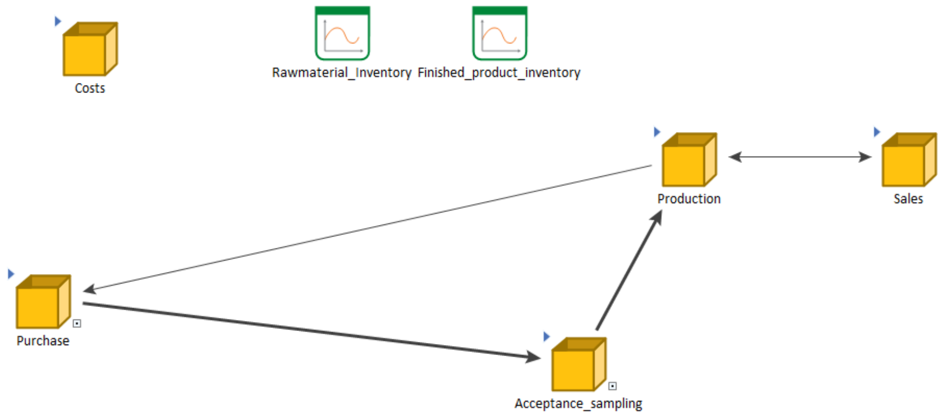


Figure-1: Process flow for the supply chain system

After purchase, the lot is being sent to sampling inspection. At this stage, the decision regarding whether the lot is accepted or rejected is being taken based on the following:

(i) The size of the Lot might be 100 or 1000.
(ii) Optimal order quantity will be determined at the end.
(iii) For any purchase, there is a lead-time which is after placing the purchase order how long it takes for the lot to reach.
(iv) After the sampling inspection, the production process will take place and finally the lot will be sent for sales.
(v) In production, there are chances for two types of situations; they are lower and higher production quantities. If the production quantity is higher, then the finished quantity will be lesser in number. So optimum use of the production capacity is recommended to meet the actual demand. If there is more number of finished goods in hand then the production process has to be stopped.
(vi) Costs for each category will be noted separately.

7.1 Process Flow for Supply Chain System

The Process Flow is being elaborated below to illustrate how the supply chain system is working:

- **Purchase Policy:** Under Continuous Review system (CRS), purchasing of quantity (Q) is initiated only when stock level of Raw material inventory is less than Re-Order-Point (ROP).
- **Lead-time:** Items are supplied with a standard delay (lead-time) to the acceptance sampling system.
- **Applying rectification and inspection delay**, the lot is stored in Raw material storage for production purpose.

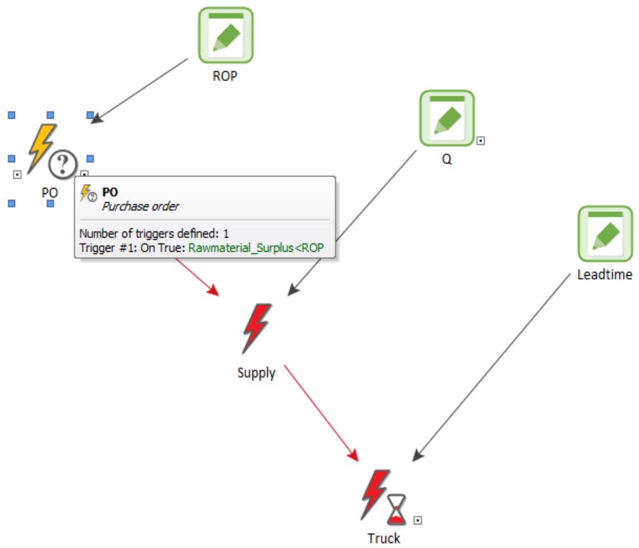


Figure-2: Purchase Policy

- **Acceptance Sampling Policy:** Raw material lot purchased is sent to quality inspection by sampling plan (discussed in next content) and accepted lot taken for production. If the lot is rejected by sampling inspection plan, then it will be taken for 100% inspection (screening) and then taken by production system.

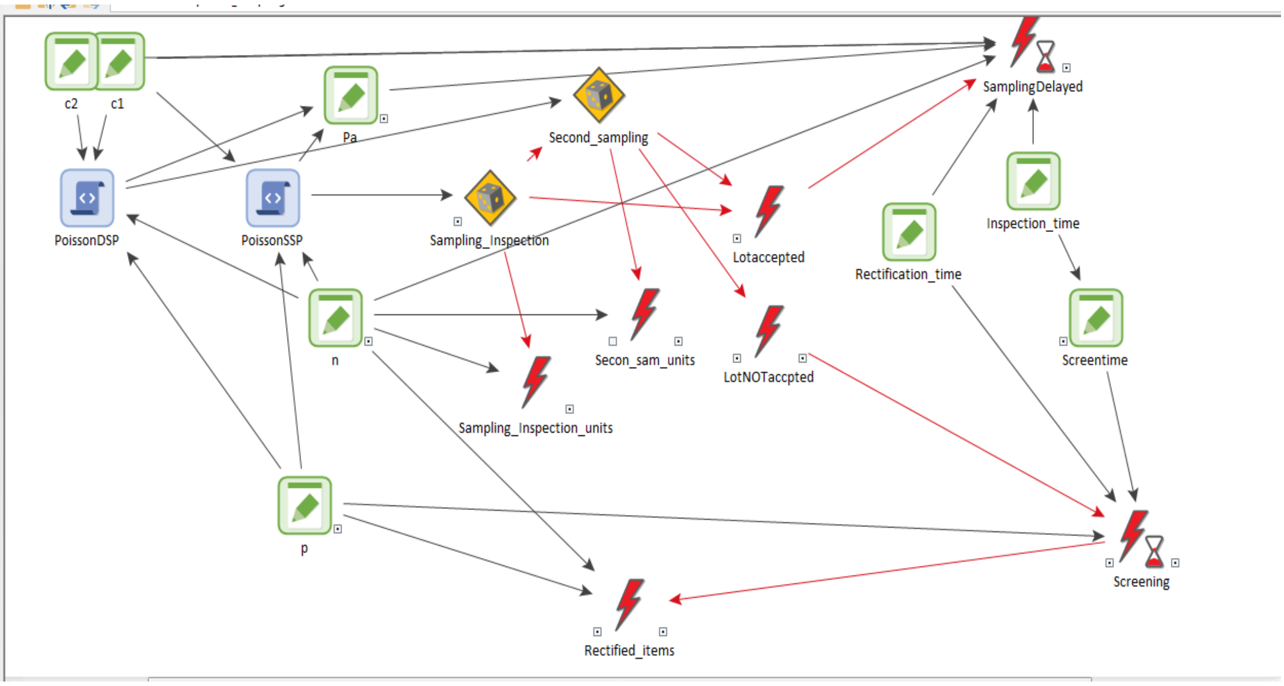


Figure-3: Acceptance Sampling Policy

- **Production Policy**: Raw materials stored are value added by production process and deliver it in a specified interval to the finished products inventory. However, the production initiation and rate depends on availability of raw material, Re-Manufacturing order level (Z) of finished product stock and Average Outgoing Quality (AOQ) of the raw materials.

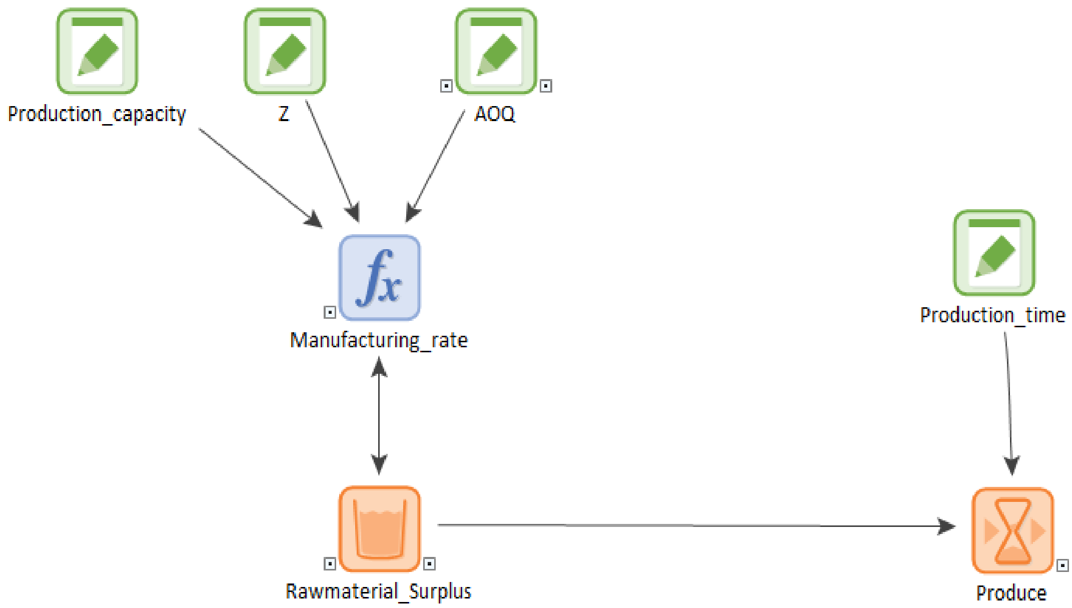


Figure-4: Production Policy

- **Sales Policy:** The stored finished products are delivered on sale requests (demand at constant rate or stochastic). The items found defective and returned by customers are also replaced. There are many reasons why the cost of supply chain management is huge. There are various costs which cause for high supply chain cost such as sample inspection cost, rectification cost, replacement cost, storage cost, shortage cost, ordering cost and also cost involved in external failure, internal failure, raw material purchase cost, and finished product price.

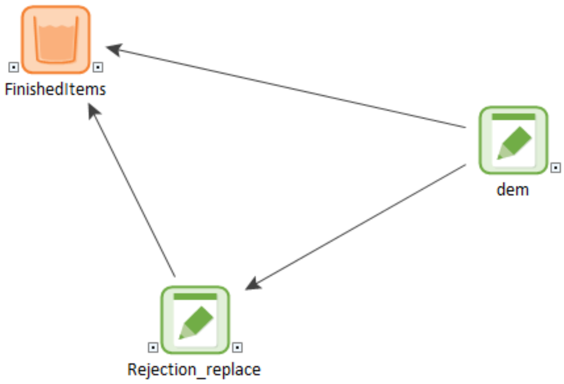


Figure-5: Sales Policy

By considering all these factors one can understand that supply chain cost is not a single winged one. Therefore, this research paper henceforth will consider all these parameters for discussion.

7.2 Operating Procedure for Single Sampling Plan

The operating procedure for Single sampling plan is being elaborated as:

(i) Inspect sample of size n

(ii) Count the number of defects 'x'. if x ≤ c, the acceptance number, then accept the lot.

(iii) If x > c, then reject the lot and apply 100% screening on the lot for removing the defects.

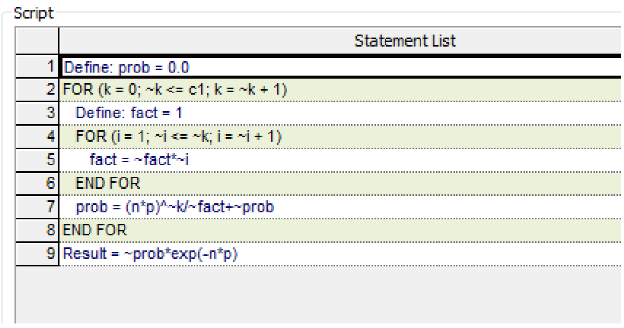
7.3 Algorithm for Single Sampling Plan

Algorithm for single sampling with respective formulas programmed in the GoldSim 12.0 software is mentioned below.

7.4 Probability of Acceptance in Single Sampling Plan

The Probability of acceptance in single sampling plan is given by

$$\boldsymbol{Pa(p)} = \sum_{k=0}^{c} e^{-np} np^{k} /\mathrm{k}!$$



7.5 Simulation results

The results obtained through the simulation process are shown in theFigure-6 and Figure-7.

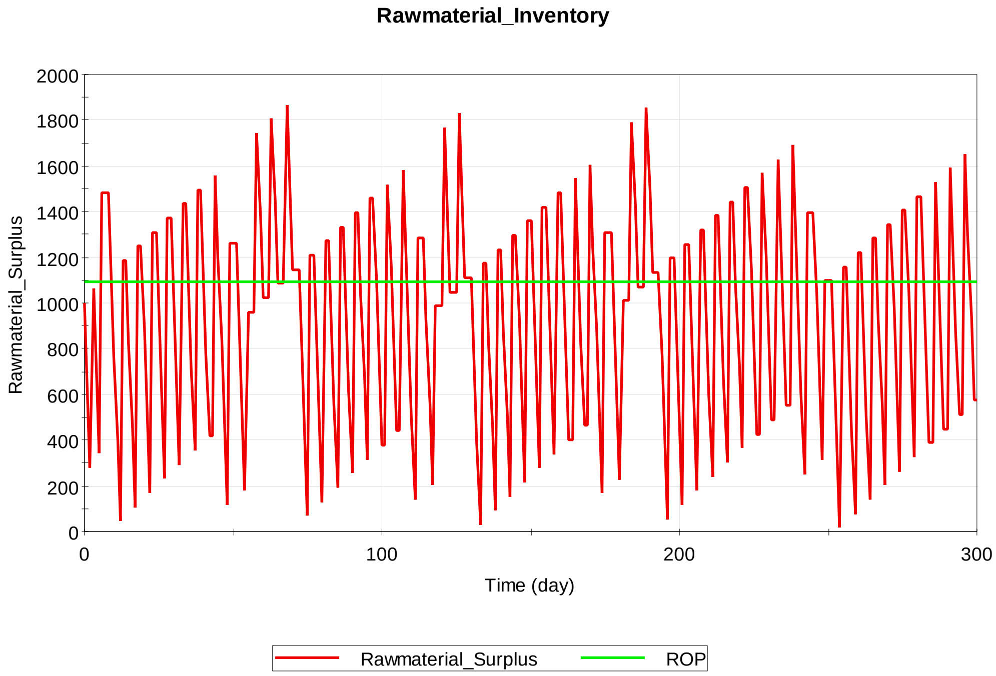


Figure-6:Raw-material Inventory

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
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The Figure-6 shows that the raw-material inventory based on how the inventory is maintained. This pattern is unfortunate because the demand is taken as constant. This can be tried with probabilistic demand also, which can be considered as the future scope of the research. In the figure-6, the raw material inventory, initially the stock level is around 250 units and then there is an increase up to 1000 units. The green (middle horizontal) line indicates re-order point. If the stock level is less than the re-order point then further orders are generated. So, again 2 or 3 orders are created. After certain period once the stock level goes beyond the re-order point the re-order will be stopped. If the stock level decreases due to the consumption by the manufacturing process again the re-order system is initiated, purchase order is issued to the supplier then the supplier will supply the lot accordingly. During this lead time period, consumption will go up. Now the stock level will be near to 0. Then there is an increase in the inventory because of the new arrival. Thus the process is being repeated.

The reason for this pattern in this case is because of the demand is assumed as 200 units. Obviously the pattern will change based on either increase or decrease of the demand. Hence, here we are able to find that there is no shortage in the raw material inventory. So, if there is a shortage, then the production process will be stopped. But in this case there is no stoppage in the production process.

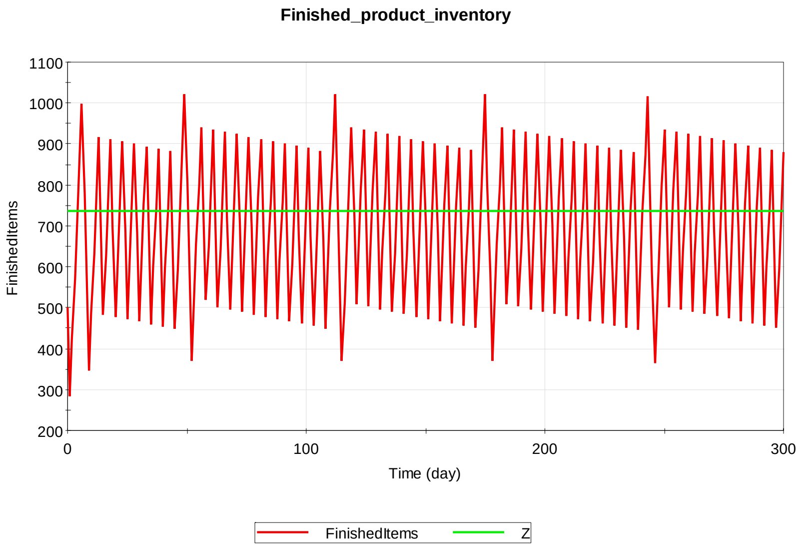

Figure-7: Finished Products Inventory

In finished product inventory, initially we have 500 items. Then the stock level decreases because of consumption by the customer sales. After which, the stock level increases from 500 to 1000 units because of full capacity production. Looking at the re-order level, if the stock level dips then the re-order is generated. After certain lead time (manufacturing lead time) the stock level comes to 900 units. Then there is uniformity and the stock levels are around the exact re-order point. Hence, it shows smooth production process.

7.6 Cost Inputs

For this simulation process we must input certain values for the vaious costs involved in supply chain. Therefore from various research papers and from few qualitative interviews with experts, the researchers were able to find out the cost patterns. This pattern is taken from the Hlioui et al (2015) and is presented in the Table-1.

Table-1 Inputs for Various Costs*

Type	Item of cost	Cost
Raw Material	Material cost	0.5
Finished product	Manufacturing cost	0.5
Raw Material	Storage cost	1
Finished product	Storage cost	1
Raw Material	Inspection Cost	12
Finished product	Backorder(Shortage) cost	40
Raw Material	Rectification cost	65
Finished product	Replacement (warranty) cost	90
Fixed	Ordering Cost	300

**Source: Hlioui et al (2015)*

The material cost of raw material is 50%, manufcaturing cost of finished product is 50%, which is like 50 paise, 50 paise (0.5, 0.5). The storage cost of raw material and finished product is Re.1 each, per unit per day. Inspection cost of raw maetrials is Rs. 12, back order cost is Rs. 40, rectification cost for raw material is Rs. 65 which involves inspection, changing cost, etc. Replacement cost for finished product is Rs. 90 which involves warranty, delivery charges, etc. The cost of the product is actually Re. 1, but when it reaches the customer, they have to pay Rs. 90, which involves all the related costs. When there is any optimization is being done in future, automatically the number of defective is expected to be low. There might be some stress to reduce the number of defectives. Hence, this is the finished cost for the product.

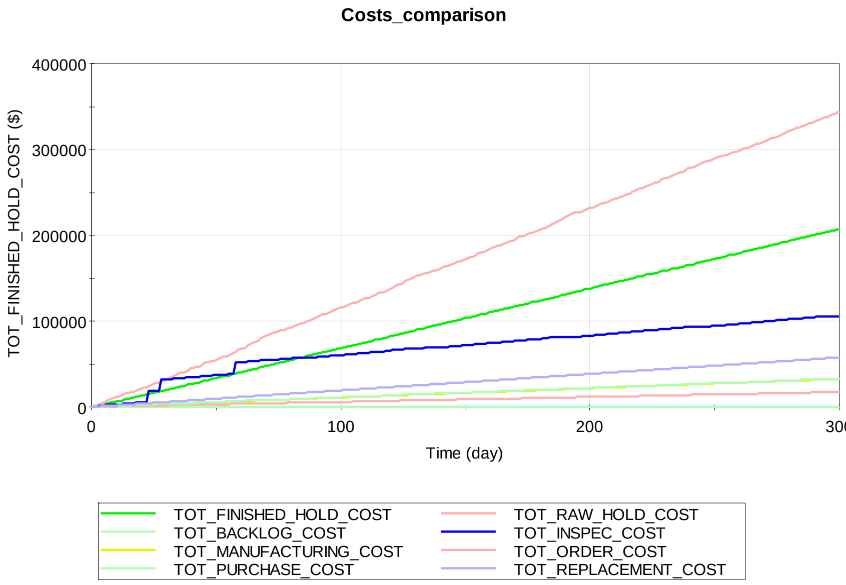

Figure-8: Cost Composition of Finished Products

According to the outcome of the simulation model, the raw material holding cost is higher than the other costs, hence it proves that the model is good. The green line depicts the finished holding cost which is the storage cost at moderate level. The storage cost is the one which kills the profit of the company. Hence, this cost requires more concentration. The blue line indicates inspection cost and is lower in the order of cost. This is because of the imperfect quality inspection cost coming into existence. If the perfect quality is maintained, there is no necessity for inspection cost. But practically in developing countries the inspection cost will be involved especially in agricultural products. The other costs are very low due to simulation effect.

8. Conclusion

It is concluded from the present study that the raw material holding cost is higher than the other costs which are very low due to simulation effect. The pattern arrived in figure 6 is unfortunate as the demand is taken as constant. The present study may be extended as further research by taking the demand as probabilistic one. Further, this model differs from the Hilioui et al (2015) in two ways, (i) Failure and maintenance of prodcution unit is assumed to be negligibale event (ii) Poisson model approximation is applied rather than Binomial model.

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