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Computerised inventory management for a manufacturing industry: A case study in Nigeria

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Various authors have suggested that the cost of purchasing and holding inventory can account for as much as 60%–80% of the total cost of a product or service. Usually, only some of the inventory (about 10%) contributes to 70%–80% of locked up inventory or has 70%–80% consumption value or their availability is vital for maintenance of the manufacturing process. Hence, the need for an effective and efficient inventory management is germane to any manufacturing industry. This paper presents the software, ‘manInvent’, an interactive system developed using visual basic 6.0, with a view to reduce manual interaction with the inventory management of a Nigerian manufacturing industry. Working with 5 years’ production data for the industry, the objective of the software ‘manInvent’ was validated with respect to the manual inventory system of the industry, and the result is shown.

Keywords: alternate inventory management, software, deterministic models, inventory system, EOQ, WIP, plastic production, database, cost, statistical analysis

JEL classification: D80, D83, C20

Introduction

We all hold money, and one wonders if we all know the reasons we hold it. Economics objectively gave us three reasons why we keep money, and they are: the precautionary motive, the transactional motive and the speculative motive (Keynes 1923). Like money, companies keep inventory for these reasons stated above and even more. Inventory management is the act of keeping track of the quantity of material and number of item that should be and are presently in inventory at any time; supplies data required by other diameters of manufacturing cycle and links manufacturing to costing, book-keeping and general manufacturing. Inventory management, also often referred to as inventory control, can be referred to as the actual steps taken to maintain proper stock level in raw materials and finished goods (Adejuyigbe 2002).

Over the years, inventory managers have been faced with the questions of how to monitor the inventory, how much should be ordered and when orders should be placed. This has led to the development of various models aimed at providing viable answers to the questions of inventory managers. The methodology for modelling inventory situations is straightforward and three simple steps are involved (Adam and Ebert 1982):

1. Examine the inventory situation carefully, listing characteristics and assumptions concerning the situation.
2. Develop the total annual relevant cost equation.
3. Optimise the cost equation to find the optimum for how much to order (order quantity) and when to reorder (reorder point).

Problem statement

Since 1915, when the first inventory model was published, many papers about independent demand inventory modelling have been published (Fleming 1992). These provide a theoretical foundation for the field of inventory management and make research in inventory models one of the most developed fields of operations research (OR). However, the practical implementation of inventory models is far behind the development of inventory modeling (Silver 1981).

The discrepancy between theory and practice of inventory may come from both the academic and practical areas (Zanakis et al. 1980). Much of the research is aimed at rigorous analysis of underlying equations representing inventory problems and developing mathematical decision models. This type of theoretical work is most highly valued by the academic community. Therefore, there is often less attention given to providing workable solutions to real problems. On the other hand, inventory managers may not be aware of the mechanics and applicability of the theoretical models. This will also hinder the practical application of inventory models because an understanding of the fundamental structure of complex models is the first step necessary to providing a workable solution to the problem being considered (Liang 1997). In developing countries like Nigeria, observation shows that inventory managers in the medium to small-scale industries generally tend to shun change to the *modus operandi* – manual inventory management.

A proposed solution

The inventory models that have been developed have helped inventory managers in making decisions, but the judgement of human experts in inventory management cannot be replaced. The human experts help inventory managers by recommending workable inventory models to them after thorough analysis and evaluation of their inventory problems. The employment of computer technology has provided an efficient approach (both to the human experts and inventory managers) to solving this problem, accompanied with the benefits of using the computer.

Types of inventory control

There are principally four types of inventory control system. Choosing the right one boils down to which system holds the most value for the company (Rubin 2007).

- Manual inventory management system. This involves the use of spreadsheets, bin cards, record books, etc. respectively to monitor inventory. Maintaining data integrity is a major downside to manual inventory management as a single data entry or formula error can cause major inaccuracies in the data output (Lysons 2001).
- Barcoding. This is an automated method of inventory management which involves the use of series of parallel vertical lines to assign a unique identity code to an item. Barcodes manage inventory at the warehouse level as they facilitate movement of inventory within the confines of the warehouse (Kenneth 2002).
- Radio frequency identification (RFID). This technology works by having a tag which emits information, which is then collected by a reader.
- Warehouse management system (WMS). WMS aims at controlling the movement and storage of materials within a warehouse and processing the associated transactions, including shipping, receiving, putaway and picking. The system monitors the progress of products through the warehouse. It involves the physical warehouse infrastructure, tracking systems, and communication between product stations (Piasecki 2012).

Research methodology and methods

A plastic manufacturing industry was used as the case study. Due to the sensitivity of the research, some factories in the area were not disposed to releasing production information, and moreover, we were conversant with the case study prior to this research. Inventory data collected through the questionnaires, interaction with the company's inventory manager and direct evaluation of the inventory lot were analysed. Mathematical and logical relationships between the inventory lot, raw materials, work-in-progress (WIP), economic order quantity (EOQ) and finished goods were established and compared with the two major

existing inventory models, i.e. deterministic models and probabilistic models.

The relationship established for the case study was analogous with the deterministic models. The following assumptions were thereby made for the model's algorithm:

1. Multiple items are stored in the system and the demand for each item is deterministic with a rate of demand that is constant and independent of time.
2. There are common constraints concerning all items which require coordinated ordering of stocks for the items.
3. No shortages are allowed and the entire quantity ordered for each item is supplied as a single lot, i.e., orders are not split into separate batches.
4. The inventory system will continue to operate within a sufficiently long period of time and the objective of inventory control is minimisation of the sum of average annual costs for all items subject to a given constraint.

The algorithm finds optimal values of the order quantity and the reorder point for each item so as to minimise the sum of costs for all items subject to the given limit of storage area or storage volume of the warehouse (Taha 2007). Input data of the algorithm are:

- number of items n stored in the system
- overall storage area/volume f
- area/volume taken by a unit of stock of the i -th item f_i , $i = 1, 2, \dots, n$
- rate of demand for the i -th item λ_i , $i = 1, 2, \dots, n$
- procurement lead time for the i -th item τ_i , $i = 1, 2, \dots, n$
- cost of a unit of stock for the i -th item C_i , $i = 1, 2, \dots, n$
- fixed cost of an order for the i -th item A_i , $i = 1, 2, \dots, n$
- inventory holding costs for the i -th item L_i , $i = 1, 2, \dots, n$.

The algorithm computes optimal values of the inventory control parameters for each item such that to minimise the cost function, R :

$$R = \sum_{j=1}^n \left(\frac{\lambda_j}{Q_j} A_j + L_j C_j \frac{Q_j}{2} \right)$$

subject to the constraint that,

$$\sum_{j=1}^n f_j Q_j = f_1 Q_1 + \dots + f_n Q_n \leq f$$

Output data of the algorithm are:

- optimal quantity of an order for the i -th item, $i = 1, 2, \dots, n$
- optimal time of an operating cycle for the i -th item $i = 1, 2, \dots, n$
- optimal reorder point for the i -th item, $i = 1, 2, \dots, n$
- optimal average annual costs in the system.

Where

$n = 3$ items

$i_1 =$ Polypropylene (PP)

$i_2 =$ Premix

$i_3 = \text{Masterbach}$
 $f = 9000 \text{ m}^2$
 $f_1 = 6,620 \text{ m}^2$
 $f_2 = 2,206 \text{ m}^2$
 $f_3 = 177 \text{ m}^2$
 $\lambda = \lambda_1 = \lambda_2 = \lambda_3 = 8 \text{ tons/day}$
 $\tau = \tau_1 = \tau_2 = \tau_3 = 2 \text{ weeks}$
 $C_1 = \text{N}1\ 500$
 $C_2 = \text{N}1\ 200$
 $C_3 = \text{N}1\ 000$
 $A_1 = A_2 = A_3 = \text{N}50\ 000$
 $I_1 = I_2 = I_3 = \text{N}5\ 000$ (depending on inventory size)

The inventory lot was maximised using the constraint that:

$$\sum_{j=1}^n f_j Q_j = f_1 Q_1 + \dots + f_n Q_n \leq f$$

That is, the addition of the lot size for each of the raw materials (f_1, f_2 , and f_3) multiplied by its respective ordered quantity (Q_1, Q_2 , and Q_3) must be less or equal to the overall lot size, f . Where f as stated is 9000 m^2 for the case study.

This constraint was used in developing the software as a condition that must be tested before logical deductions can be made, after which it is made available to the user of the software.

Clarifications

- Total = computed value of PP + computed value of Premix + computed value of Masterbach on the Update Inventory Database submenu
- Value of PP = sum total of available PP into nsascomputed in the update inventory database
- Value of Premix = sum total of available Premix intonsascomputedintheupdateinventorydatabase
- Value of Masterbach = sum total of available Masterbach in tons as computed in the update inventory database
- Stock replenishment = 1 week
- Minimum stock = 40 tons
- Maximum stock = 120 tons
- 1 ton = 40 bags
- 1 bag = 25 kg

Case 1: the available amount of PP is insufficient for complete mixture

If $0.744 * \text{total} > \text{value of PP}$
 and $0.248 * \text{total} \leq \text{value of Premix}$
 and $0.008 * \text{total} \leq \text{value of Masterbach}$, then
 available raw material inventory for production = value of PP + $0.248 * \text{total}$ + $0.008 * \text{total}$

Since it is possible to have the amount of Polypropylene (PP) raw materials in wrong proportion in the store, to avoid operation with wrong information, the logical conditions will eliminate that error.

For example, if there are 30 tons of PP, 20 tons of Masterbach, and 20 tons of premix in the store, the software runs the process below to find the amount of raw materials (in tons) that can be used for the next batch of production:

Total = 70 tons
 PP = $70 * 0.744 = 52.08$ tons
 Premix = $70 * 0.248 = 17.36$ tons
 Masterbach = $70 * 0.00794 = 0.556$ tons

From the relation above, the amount of PP in the store is only 30 tons, hence the command above will calculate the amount of the remaining raw materials that 30 tons of PP will mix with to sufficiently produce. That is,

Available raw materials for production = 30 tons of PP + 17.36 tons of Premix + 0.556 tons of Masterbach = 47.916 tons of raw materials

As opposed to the total inventory of 70 tons, the workable inventory is 47.916 tons

Case 2: the available amount of Premix is insufficient for complete mixture

If $0.248 * \text{total} > \text{value of Premix}$
 and $0.744 * \text{total} \leq \text{value of PP}$
 and $0.00794 * \text{total} \leq \text{value of Masterbach}$
 available raw material inventory for production
 = value of Premix + $0.744 * \text{total}$ + $0.00794 * \text{total}$

Like Case 1 above, when the amount of premix is disproportionate, the software evaluates the available tons of raw materials that can be produced with respect to the least available raw materials.

Case 3: the available amount of Masterbach is insufficient for complete mixture

If $0.00794 * \text{total} > \text{value of Masterbach}$
 and $0.744 * \text{total} \leq \text{value of PP}$
 and $0.248 * \text{total} \leq \text{value of Premix}$
 then, available raw material inventory for production
 = value of Premix + $0.744 * \text{total}$ + $0.00794 * \text{total}$

When the amount of the Masterbach is not sufficient for complete mixture, the protocol above makes sure the available inventory is the amount of the total inventory that the Masterbach can completely mix with.

Case 4: The available amounts of the three raw materials are in sufficient proportion

If $0.00794 * \text{total} \leq \text{value of Masterbach}$
 and $0.744 * \text{total} \leq \text{value of PP}$
 and $0.248 * \text{total} \leq \text{value of Premix}$
 then, available raw material inventory for production
 = $0.248 * \text{total}$ + $0.744 * \text{total}$ + $0.00794 * \text{total}$

This case is the total mixture case, whereby the available raw materials are just in the correct proportion for mixture, no remainder, no excess. This is a very rare case.

Results

After the software, manInvent, was developed, it was validated using the case study industry. Five years’ (2007 to 2011) production data were collated by the records department and the cost was analysed by the accountant and inventory manager of the company. The costs considered were cost of bin cards, files, file keeping, ordering cost, holding cost of manual inventory materials. Over-stocking and shortage costs were estimated compared with the three-month usage of the software. A three-month usage of the software was used to estimate

the cost which could have been saved if the software had been employed for the considered five years.

$$\text{Mean cost of alternative method} = (479\,000 + 18\,000 + 12\,750 + 11\,950 + 9500) / 5 = \text{₦ } 106\,240$$

$$\text{Mean cost of the manual method} = (627\,000 + 51\,000 + 89\,000 + 37\,000 + 21\,000) / 5 = \text{₦ } 165\,000$$

$$\text{Difference between the costs} = \text{mean cost of manual method} - \text{mean cost of alternative method} = \text{₦ } 165\,000 - \text{₦ } 106\,240 = \text{₦ } 58\,760$$

The mean cost of the alternative inventory management, (manInvent), is lower than the mean cost of the

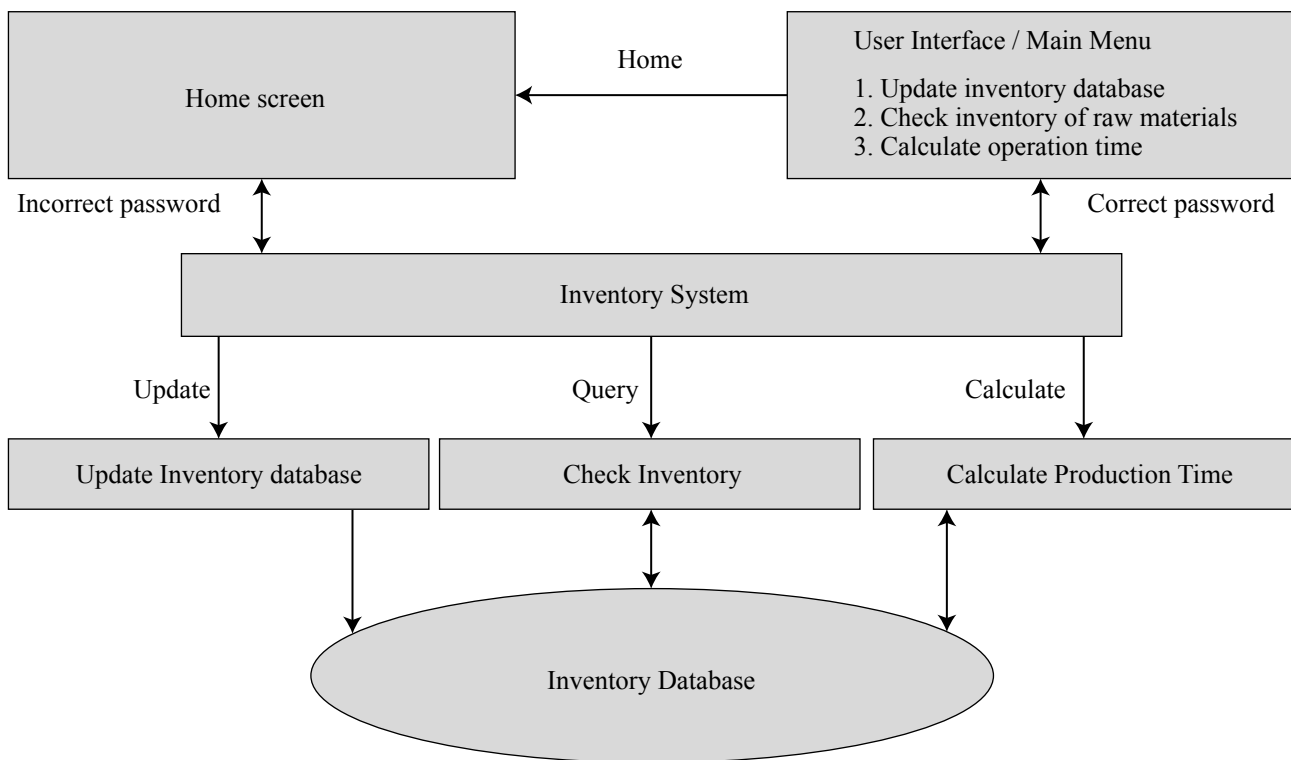


Figure 1: The system architecture, an overview of manInvent

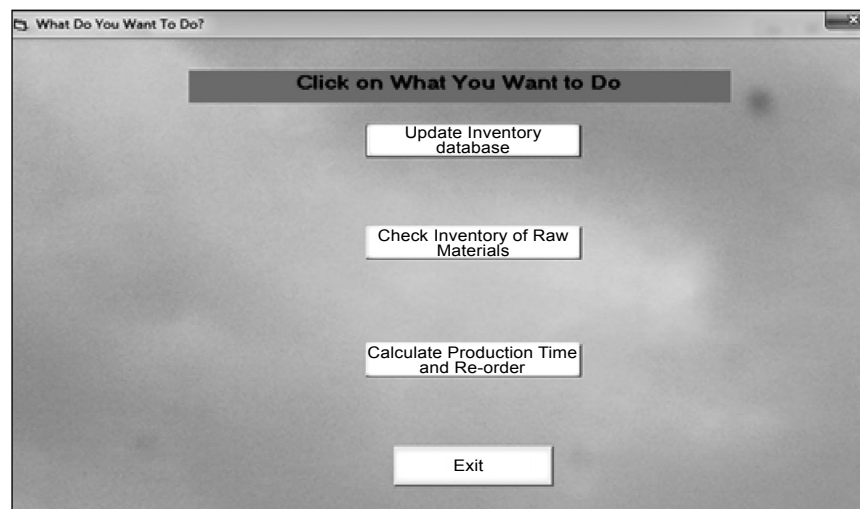


Figure 2: manInvent menu environment

Table 1: Cost incurred using the manual and the alternative (manInvent) inventory management

Years	2007	2008	2009	2010	2011
Alternative inventory management (₦)	479 000	18 000	12 750	11 950	9 500
Manual inventory management (₦)	627 000	51 000	89 000	37 000	21 000

manual inventory management, which implies that the manual control is more capital intensive.

From Table 1, the cost of inventory management for each year reduced at a high extent when the computerised inventory management is employed. Depending on the production size, the sum of production cost in the fiscal year 2007, which was ₦ 627 000 compared with the cost of production in 2008, ₦ 51 000, shows the dependability of production cost incurred on the size of production. However, it should be noted that, regardless of production, cost is always incurred on inventory keeping, which is called the holding cost.

Two statistical analyses were carried out, one to test for chance (correlation) and the other to test for the difference in mean costs (difference of two means). Using a confidence level of 99% (significance level of 0.01), the null hypotheses were both rejected, affirming the superiority of the computerised system over the manual inventory system.

Conclusion and recommendations

The overall objective of inventory control is to maintain stock levels so that the three main costs, holding cost, ordering cost and stock-out costs are at a minimum (Lucey 1984). The two main considerations to ensure this are to determine when to order and how much to order. The results received from the application of the software “manInvent” developed during this research work clearly shows that the use of computer programmed software in inventory management is the best tool for achieving these objectives. The validation of the software at the case study was observed to ensure better working environment, reduction in task

time due to counting, calculation and other mathematical tasks during file keeping, and also ensures high work efficiency, productivity and forecasting production requirements.

Based on the results obtained and conclusion drawn, it is recommended that the procedures adopted in the software ‘manInvent’ be used in inventory management in the manufacturing sector of the country as this will enhance productivity and thus lead to technological advancements in the nation and also competitiveness in the manufacturing world. It is also recommended that the software be extended to other medium and small-scale manufacturing industries as this will bring about reduction in the costs incurred in manual inventory management and also increase productivity since forecasting is easily done. The software is also recommended for big-scale merchandising industries, and since the basics of inventory are the same, the algorithm could be employed for both the manufacturing and merchandising industries.

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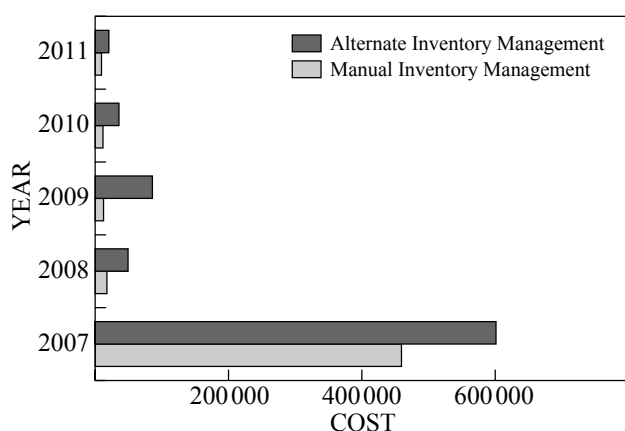


Figure 3: Chart showing the relationships between the costs incurred using the manual and the alternative inventory management (manInvent) systems