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Design of a 10-digit inventory codification system for a tube and pipe manufacturing company in Zimbabwe

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Abstract

Lack of proper inventory control usually leads to high stock-outs resulting in 'firefighting'. This paper looks at the engineering and technical services required to maintain smooth production with the aim of developing an inventory control system for the efficient utilization of resources. A work study was carried out at a tube and pipe manufacturing company in Zimbabwe followed by an analysis outlining the operations, limitations and process flows. An inventory audit provided some insights on the company's inventory control status. A 10-digit inventory codification system was designed based on 7 rules for generic application and capability for 'make or buy' decisions on spare parts. A cost benefit analysis revealed that although the project would initially be costly, a reduction in inventory can be realized through removal of slow moving and obsolete stock, realizing some annual savings in the long run, coupled with an improvement in record keeping and accountability.

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Keywords: Inventory control; manufacturing; maintenance; tubes and pipes; supply chain

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1. Introduction

With the rapid changes in technology globally, the importance of inventory control and management systems is steadily increasing with the resultant effect filtering through to small scale manufacturing companies [1]. Although the scope for inventory control has been limited to production, there has been a paradigm shift for using it in engineering management and technical services that support production. The engineering and technical services function is normally taken as a business unit whose thrust is to provide services to the production department. The ultimate objective of engineering control and management function is for the company to realize good profits through the maintenance and design of plant equipment at low cost. The control and management of inventory is critical to the smooth functioning of the plant [2]. Generally, companies with no proper systems in place for controlling inventory, risk a number of problems such as high capital investments for inventory, losses due to inventory deterioration, stock-outs resulting in crisis management, difficulties in tracking inventories and high maintenance costs which may ultimately affect their output [3]. The case study company manufactures steel tubes and pipes of various sizes as well as other related steel products using different methods and techniques depending on the required sizes and profiles. Various machine tools such as presses, welders and extruders are used to produce the steel tubes and pipes and these machines are maintained by the engineering and technical services department of the company. It was within this context that the engineering and technical services department occasionally have to order spares and parts for the machine tools to ensure continuous and smooth production. Quite a significant stock of the inventory at the company was in finished goods, an indication that it was not exactly what the customer wanted and cannot be changed to meet customer demands, hence the need for inventory profiling.

At the onset of the research, a work study of the tube and pipe manufacturing plant was carried out based in the plant but with frequent visits to the technical and engineering services to establish the relationship and how inventory was being managed and controlled in the provision of services to production. There was no material or spare parts planning before maintenance was carried out resulting in stock-outs. This was usually evident when the company was on planned shutdown maintenance. The machine history cards did not explain exactly where the part repaired or replaced was located and it was thus difficult to extrapolate data, let alone synthesize it. It was also difficult to analyse the behavior of the machines over long periods of time. There was evidently no proper description of the machines in terms of their serial numbers, manufacturer and other accessories. Changes done on machinery and equipment were also not recorded. The work study was followed by an analysis of the information and how the lack of proper inventory control resulted in problems similar to the ones highlighted above. It therefore became imperative to look further and assist the company to address the risks and costs involved in the absence of such an effective system and institute a proper management and control system that to manage inventories and define formal links between the inventory decisions and the company's strategic goals. In view of these challenges, the aim of the research was to develop an inventory control and management system for the engineering management and technical services function that would ensure the effective and efficient utilization and resource allocation of the inventory.

2. Background to inventory control

2.1. Introduction

Inventory is the core consideration of modern operation innovations and thus central to the operations of a business in that it comprises the stocks and goods for use in the operations [4], i.e. to support production (raw materials, work in process and machine spares), to support repair and maintenance or simply as finished goods or products for sale [5, 6]. In this paper, focus was mainly on those items that were required to support activities offered by the engineering and technical services department for repair, replenishment and maintenance of production machinery in the manufacture of the tubes and pipes or related products. Managing these spares is a science that involves maintaining a database of stocked goods for use in the various sections of the production plant or supply chain occurring before the scheduled production of the various sizes and shapes of the tubes and pipes. These have to be regularly checked and monitored and in the process the inventory must be controlled to ensure that the company does not hold unnecessary stocks or delay in procuring required stocks. Inventory control is thus often employed in logistics and supply chain management and the associated techniques and systems necessary for managing the inventory [7].

2.2. Types of inventory systems

The Kanban or pull mechanism, tends to align inventory with actual consumption where production triggers decisions to purchase in a Just-In-Time (JIT) manufacturing environment [8]. This is quite common and applicable in highly repetitive environments with little business turbulence, but more variable situations require more flexible control systems [9]. Independent demand inventory systems assume that managers can consider the actual demand of each product in isolation. Material Requirement Planning (MRP) assist management to provide the right part at the right time to meet schedules for completed products while also providing formal plans for each part number, whether raw material, components or finished goods [10]. Accomplishing these plans without excess inventory, overtime, labour or other resources is also important [8]. Inventories require a great deal of capital and affect the delivery of goods to customers but sometimes there are unavoidable conflicts within the same organisation owing to the differences in focus and objectives of each department. At the micro level, item-by-item decisions need to be taken, i.e. how much, when and where to order? However at the macro level, it is much broader and deals with issues that have strong implications for both the types of value delivered by the system and the strategic stance of the company. At this level, concern is on the amount of overall inventory to have, its position and profile in the supply chain [11]. In order to develop a beneficial inventory control system, it is necessary at the onset to identify a number of key factors and challenges that will facilitate the smooth development of a robust system [11]. It was evident from the work study that there was a need for a better system of recording, keeping, storing and transmitting information.

2.3. Inventory control systems and behavior

Four typical inventory control systems can be employed in an organization [11]; the single-bin system (P system), where the bin or shelf is filled up periodically, the two-bin system consisting of two compartments, where the front compartment contains materials issued and the back compartment is sealed. When material in front is gone, the back compartment is opened for use and an order is placed (Q system). The card system usually contains one card for each inventory item kept and has decision rules for either the P or Q system. The computerized system records a computer readable storage which is maintained for each item [12]. In making any decision that affects inventory size, ordering, carrying, out of stock and capacity related costs must be considered [13]. Inventories exist to meet customer demands, where the customer can either be internal as a machine operator or external. In either case an essential determinant for an effective inventory is an accurate forecast of demand which can either be independent or dependent [13]. A supply chain encompasses all activities associated with the flow and transformation of goods and services from the raw materials stage through to the customer. Distorted information or the lack of it, from one end of the supply chain is one of the main causes of uncertainty, and it leads to excessive inventory, poor customer service, wrong capacity plans and high costs, a common result of the bullwhip effect [14]. This phenomenon occurs when slight to moderate demand uncertainties and variability become magnified from the manager's point of view at each link in the supply chain. Stock piling may occur resulting in excessive and idle inventory if each supply chain member makes ordering and inventory decisions with self-interest [15]. Because of supply and demand variability, inventory has to be balanced continuously and should not be reduced if there is likely to be a negative effect on customer service [16].

Forecasting is often used in inventory management to estimate the value of a variable at some point in time. This works on the basis that if the future can be predicted, then the company's practice of spending on spare parts can be adjusted accordingly [17]. Depending on the time span, forecasting can be categorised into short term, where decisions are made on inventory control and production planning, medium term, where tactical decisions such as whether to lease equipment or make employment changes and strategic decisions such as establishment of research and development or mergers with other strategic partners. Several techniques can be used for forecasting and these range from; qualitative, where there is no relevant past data to quantitative methods such as statistical analysis, regression, moving average or exponential smoothing can also be used to provide quantified estimates of the value of inventory [18]. Inventory or asset replacement frequently occurs with a new part that comes with new technology or even appearance owing to the rapid changes in technology, thus rendering existing spare parts inventories obsolete [19]. The replacement decisions under such circumstances can be quite complex, requiring that appropriate measures be taken when such replacements are made.

3. Work study and as-is-analysis at case study company

The case study company, located in Harare, Zimbabwe specializes in the production of tubes and pipes of various sizes and profiles. The company operates three in-line mills for Φ13.49-165mm pipes and one spiral mill for Φ140-535mm pipes. The production also includes galvanizing and coating with epoxy resins or red oxide. The piping can be supplied with a range of couplings where required, including flanges, sockets, tube lock rings and alvenius ends. The company also produces galvanized and corrugated inverted box rib (IBR) Chromadek roofing sheets (Fig. 1).

Fig. 1. The company's (a) steel tubes and pipes; (b) lock rings and couplings; (c) Chromadek sheets

The company employs a planned maintenance strategy and on a weekly basis, the maintenance planner checks the planned maintenance master schedule, to see which machines are due for maintenance. Artisans who carry out the maintenance use the check-lists but it was evident during work study that they needed to be reviewed, as they were no longer compatible with the new technological changes instituted on the machines [19]. Some of the problems observed in the procurement process included; bureaucracy and non-payment of accounts resulting in delays to get spares and inconsistent hand over during shift changes resulting in missing items that were sometimes difficult to account for. Both the engineering and production departments did not have much input in decisions to buy and the absence of a database and software to keep track of records resulted in stock-outs of strategic items.

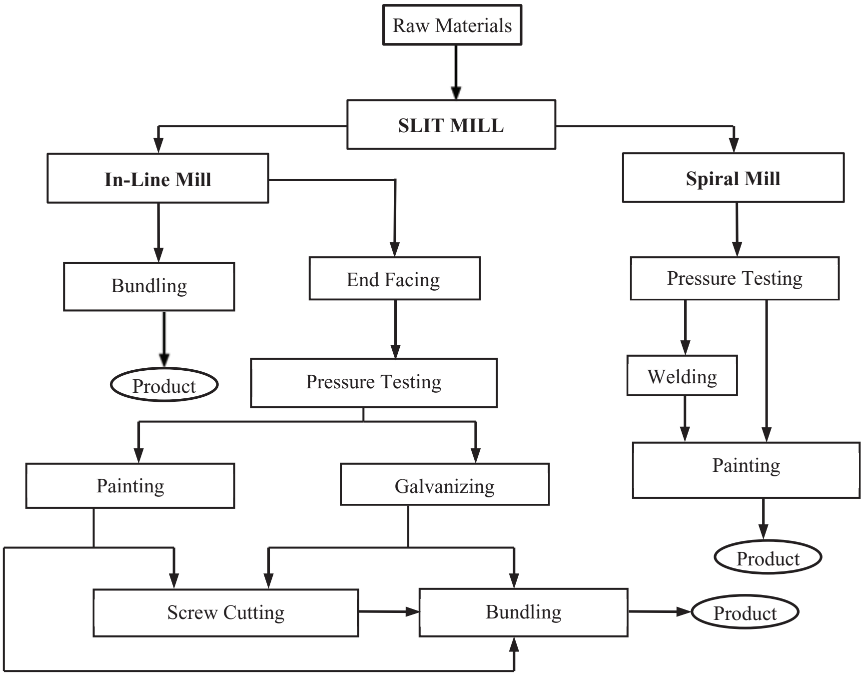

Fig. 2. The company's general production flow

The company's general production flow is shown in Fig. 2. Sheets are passed through the slit mill to produce various strips depending on the outer diameter of the required pipes. All the tubes and pipes follow the same production line except for pipe fittings. The square pipes from the mills are bundled but the round pipes undergo pressure testing. Depending on the customer needs the pipes are galvanized before being painted. There were a number of problems observed in the plant operations such as; stock-outs affecting maintenance planning, spare parts and raw materials and no Materials Requirements Planning (MRP), which resulted in bottlenecks in the system. An outline of the current processes and activities at the company with a view to analyse and further explore their manufacturing systems and processes gave an insight to the purposes of the research. It also identified factors which directly or indirectly affect the development of a suitable and effective maintenance strategy of the plant.

4. Research methodology, data collection and analysis

There were generally 3 classes of inventory observed at the company based on company records; slow moving – 19%, i.e. inventory on hand, in excess of one year's requirements or inventory on hand that had not moved in six months, obsolete – 24%, i.e. all inventory items, purchased or produced, that had not been moved into production or sold within a twelve-month period and the rest – 57% were inventories that were classified as both slow moving and obsolete. Following the work study and interviews with personnel in the various departments, it was established that some of the causes of obsolete and slow moving inventory were; inaccurate forecasting and/or irregular supply, requiring large safety stock to cover uncertainties, large batch sizes, long machine setups, requiring high levels of Work in Process (WIP), management pressure to keep workers busy, design and specification changes in the product or component, changes in methods of production or excess purchase or production. Thus, removal of such excess inventory meant a reduction in the unnecessary holding costs and an increase in the investment by taking care of the opportunity costs.

The ABC classification system is a method of classifying inventory according to several criteria including its monetary value to the firm [9, 18]. Typically thousands of independent demand items are held in inventory by a company but a small percentage is of such high value to warrant close inventory control. In general, 5-15% of all inventory account for 70 – 80% of the total value (class A), 15-30% account for 15 – 20 % of total value (class B) and 50 – 60% of inventory account for 5 – 10 % of total value (class C). The classification of items into A, B and C categories at the company was performed by first listing all items, their unit cost and estimated consumption. If the product had a stable demand, historical consumption was used. The total value of the item was calculated by multiplying the unit cost by the demand and then sorting of the list in the total value order, with the highest value items at the top. The cumulative value was determined by adding the total value in sequence. After setting about 10-20% of the total number of items and starting from the top, the quantities of the cumulative total value covered by these items was found. The cumulative value was from 70-80% and the number of items were adjusted to get the class A. Another 15-20% of these items was taken and it was noted that they covered about 15-20% of the cumulative total value, over and above the class A items total value. The cumulative value was found to be from 70-90% to get the class B items. Finally the class C items accounted for the balance and these covered about 10% of the total extended value. The list of items critical for production or for characteristics such as erratic demand, long lead times and short shelf life were reviewed and upgraded to Class A or B items. The following deductions were made from the analysis:

- Class A: 26% of the total number of items in stock and accounted for 49% of the total cost of the items in stock.
- Class B: 29% of the total items in stock but accounted for 29% of the total value of the inventory in stock.
- Class C: 45% of the total quantities of inventory but constituting 22% of the total value of items in stock.

In this analysis, the raw materials and components with WIP and finished goods were not mixed since they should be controlled with a separate ABC classification. Thus, the analysis done was for the consumables and spares only. The determination of key performance indicators critical for the design of the inventory management and control system, processes and functional areas was performed first to avoid data overload by considering every bit of data as a key performance indicator. The operators close to the equipment and processes were also engaged in the collection and analysis of the data. Effort was also made to ensure that operators understood how the data was to be collected and how its analysis was going to improve their work performance and benefit the company at large. The moving average for time series forecasting was used, taking the moving average *MA(n)* for the forecast period into the future using equation (1).

$$MA_{(n)} = \frac{(D_t + D_{t-1} + \cdots + D_{t-n+1})}{n} \tag{1}$$

where n is the number of observations made in the forecast calculation and D is the actual demand observed for the historical period up to the time period t. Data for a 2 year period was collected from the material demands and recorded for each product and plotted, from which it was noted that bolts and nuts had the largest volume of quantities movement. A sample demand behavior plot for hexagonal nuts is shown in Fig. 3.

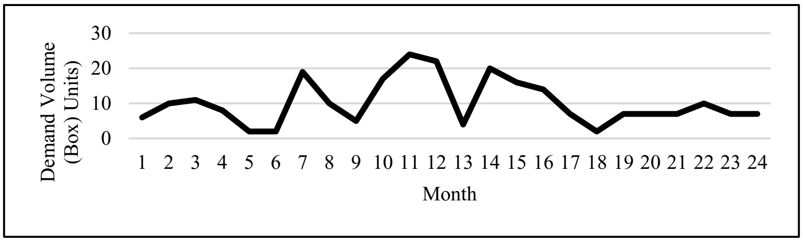

Fig. 3. Demand behaviour for 6mm hex nuts.

5. Design of the inventory management system

The design of a system to manage inventories must define formal links between inventory decisions and the firm's stated strategic goals [6, 16]. This requires a clear understanding of the firm's market, expectations of the customers in those markets, and the inherent characteristics of the items in inventories throughout the value chain. The codification system was designed to apply a disciplined approach or process by which all items of service supply can be identified and recorded in a uniform manner. The codes were designed to give information pertaining to the actual location of the item on the machine and it was based on the following principles:

- Establishment of a common language to ensure there is one unique stock number for each item of supply.
- Where the source of data is coming from, i.e., whether technical information is required including a drawing, specification or standards from the manufacturer.

Based on the company's operations, preferred information gathered from the technical services and production division of the company, Table 1 shows the rules/guidelines used in coming up with the codes of the inventory:

Table 1. Guidelines used in developing the codification system

Rule/Guideline	Details
1. Each part must have a unique number	Important in making sure that each part is uniquely identified and there is no identity number that is assigned to two parts even if they are from the same manufacturer, same design or same type
2. Number must follow the progression of the product flow line	This made it easier to generate the numbers and easy to understand e.g. initial components are represented by lower numbers and these increase along the production line
3. Number must follow the progression from bottom, then up and operator side to drive side	Helps in identifying parts of the same type located in the same place
4. Number must follow the progression right to left, taking the position where the operator stands while facing the machine	Identifies parts of the same type located in the same place when its's difficult to give a number when Rule 4 fails to give a unique identification
5. Description of items should be as per manufacturer	To avoid confusion on which item is being referred to
6. The codification of all the hand tools always started with two zeros e.g. 0001208805	This was just an arbitrary value that distinguishes hand tools from machinery
7. Each part shall maintain its Stores Number	This was to ensure compatibility of the proposed system to the old Stores Number identification system.

The set of rules in Table 1 were used to derive inventory codes for different items following the production flow. The 10-digit inventory codification for the inventory management and control system was proposed to have 5 levels where every two consecutive digits represented one level as shown in Table 2 and schematic in Fig. 4.

Table 2. Description of levels for the 10-digit codification system

Level	Description
1	Describes the machine on which the item is located, where the numbering of machines follow the production flow line
2	When considering the various sections on the machine, the production flow from one section to another is taken
3	All the machine assemblies and different mechanisms present on a machine e.g. All the electrical equipment and pneumatic systems before breakup, starts to be codified at this stage
4	Itemization of components starts at this stage, i.e. shafts, sprockets, pinion etc.
5	This represents the final part of the sub-assembly which includes bolts, washers, nuts, brushes etc.

00	/	00	/	00	/	00	/	00
Level 1		**Level 2**		**Level 3**		**Level 4**		**Level 5**
Machine		**Machine Section**		**Machine Section Assembly**		**Machine Sub Assembly**		**Machine Part**

Fig. 4. 10-Digit codification levels.

6. Discussion and recommendations

The control of inventory varies from one item to another depending on the importance of each item. Generally, there should be control mechanisms instituted for the control of slow moving and obsolete inventory. This was achieved by defining slow moving, excess and obsolete materials, ensuring that there were reports that identified and measured these. There must also be ways to determine the disposition of excess or obsolete inventories such as returning such items to suppliers even at a discount or reworking items to usable states. The appropriate usage of the designed 10-digit codification system simplifies the identification of parts for an effective planning for spare parts and is useful in avoiding duplicate parts that may already be in stock as well as ensuring proper items are issued as requested. The inventory database was designed using Microsoft Access because of its compatibility, user friendliness and it was also readily available on most computers at the company. The system identifies equipment spare parts and job plan records as well as all pieces of equipment that a part can be used for at the inventory record level. It also has the capability to prompt Stores to automatically reorder stock when necessary, based on the production plan. Categories for quick location of inventory parts and printing of the catalogues for required reports are also provided in the system. Critical analysis of every component's behavior on the machine can be done through the reports generated by the database. A hybrid system, combining the two techniques of Kanban (pull) and MRP (push) may be the most ideal because of the complementary nature that results in an optimum manufacturing system.

Control mechanisms were also put in place to ensure that inventory is properly managed in terms of making decisions on whether a part has to be machined in-house or bought externally as well as keeping up-to-date company records. Processes for developing supplier partnerships were recommended and this included the rating of suppliers based on their quality of service delivery. Other recommendations included maintenance work simplification, engineering change management and hybrid shop floor control techniques. Each replacement of spare parts is recorded in a database for individual machines. Such databases ultimately provide information to quantify the average requirements for spares. The use of standard spares was also recommended as such practice ensures the reliability of fitting and good operation and on the other hand, easy procurement. The purchasing department should be in control of inventories unlike the situation at the company where the stores and the purchasing department work as different entities. In today's global environment, participative and productive relationships with key suppliers must be established to improve competitiveness. Furthermore, to sustain competitiveness, this relationship must be strengthened.

7. Conclusions

This paper focused on the development and design of a 10-digit inventory codification system coupled with a Microsoft Access database for the control of inventory, mainly spare parts and other consumables such as oil and lubricants for the engineering and technical services of a company specializing in the manufacture of tubes and pipes or related steel products. The demand behavior for most of the inventory items in stock was found to be a seasonal variation. However, the variation periods differed from one item to another. A lot of unproductive inventories were found to be in stock, amounting to more than 51% of the stock items, which were either slow moving or obsolete and their removal from the system reduced the stock holding costs as well as the company getting some revenue through their disposal. The 10-digit inventory codification system was designed to provide identification numbers to all parts on the machines and their exact locations. Guidelines were set to enable users to allocate codes to new spare parts in conjunction with the old numbering system for continuity. A cost benefit analysis revealed that, although the project would initially be costly, at approximately $20,000, a reduction in inventory can be realized through removal of slow moving and obsolete stock, resulting in some annual savings of almost twice the implementation cost, coupled with an improvement in record keeping and accountability and decrease in maintenance downtime. Such a system provides simplification in maintenance, enhancement of quality and a reduction in the lead-times thereby increasing profitability and viability of the company, an important aspect of lean manufacturing.

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