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Evaluating Effective Spare-parts Inventory Management for Equipment Reliability in Manufacturing Industries

Nazim Baluch*; Che Sobry Abdullah; and Shahimi Mohtar
School of Technology Management & Logistics, COB, Universiti Utara Malaysia, 06010 -UUM Sintok, Kedah, Malaysia
* E-mail of the corresponding author: nazimbaluch@gmail.com & nazimbaluch@uum.edu.my

Abstract
The spare part management function is critical from an operational perspective especially in asset intensive industries such as refineries, chemical plants, paper mills, automotive manufacturing, and oil mills. Given the determinants like demand, unpredictability, part substitution, and tight control on spare parts inventory coupled with high service level expectations; the exigency of spare parts management in manufacturing operations cannot be underrated. In most organizations, a constant scrimmage persists over the stocking, ordering, and maintaining of products required by maintenance and operations. The Materials Management and Purchasing functions are often vied against Maintenance, Facilities, Engineering, and Operations with respect to; the number and types of stock keeping units, capital and critical spares, obsolete inventory, inventory investment, and turnover and program operation. This paper evaluates best practices in the Maintenance Repairs & Overhauls, discusses the ABC classification scheme, and elaborates on the role of maintenance storeroom as service provider.
Key Words: Spare Parts Management, ABC Classification, Maintenance Store Room

1. Introduction

In most organizations, a constant scrimmage persists over the stocking, ordering, and maintaining of products required by maintenance and operations. The Materials Management and Purchasing functions are often vied against Maintenance, Facilities, Engineering, and Operations with respect to; the number and types of stock keeping units (SKUs), capital and critical spares, obsolete inventory, inventory investment, and turnover and program operation.

Despite all branches of an organisation are pursuing the common goal to reduce costs, this strife behaviour prevails due mostly to; the fear of stock-outs, perception of inventory as "cheap Insurance," and the lack of knowledge with respect to the total cost of holding inventory. "Cheap insurance" is based on the thought process that inventory is typically expensed when received vs. issued and that cost is small compared to any potential loss of revenue that could occur if operations/production was halted for any measurable period of time due to non-availability of replacement parts. Spare parts management is a science: The trade off between managing parts inventory and meeting service levels construe into a need for forecasting accuracy, managing parts evolvement and high analytical capabilities. The availability of parts and making equipment fit for operation proclaims the maintenance as well as regular business operations; equipment downtime is lost production capacity.

Spare parts refer to the parts requirements for keeping owned equipment in healthy operating condition by meeting repair and replacement needs imposed by breakdown, preventive and predictive maintenance. The spare part management function is critical from an operational perspective especially in asset intensive industries such as refineries, chemical plants, paper mills, and oil mills etc., as well as organisations owning and operating costly assets such as airlines, and logistic companies, etc. Spare parts, in manufacturing, also include; consumables such as welding rods, or chemicals for the water treatment etc. Maintenance Tools & Equipment are often lumped with spare parts; they include hand tools, power tools, specific equipment such as, bearing installation kits, weld sets, portable lathes, band saws, grinders, pipe benders, electric diagnostic meters, and many more. Maintenance, Repair & Overhauls (MRO) spare parts are different from production parts whose demand is: production dependent and is predictable; easier to forecast because of more predictable movement patterns; and are typically input or output of a production process (such as weld tips in an auto robot assembly).

The exigency of spare parts management in manufacturing and service operations cannot be underrated. Given the determinants like demand, unpredictability, part substitution, and tight control on spare parts inventory coupled with high service level expectations; it is imperative to accurately forecast spare part requirement and to optimize on inventory, and it warrants significant decision support. Historically, the standard philosophy regarding MRO in many Maintenance organizations was that high inventory levels and large numbers of SKUs must be maintained on site in order to ensure that equipment could be serviced and repaired on a moment's notice. The actual cost to support this environment is very high but rarely is the total costs associated directly to this decision are considered exclusively and reviewed. Traditionally the perceived cost is deemed acceptable due to the concerns voiced by Maintenance and Operations for the need to have the necessary MRO materials and assets on hand at all times (Timme & Christine, 2003). Proper planning and control of spare parts inventory is a critical component of an effective asset management program. If the right parts are not on hand when needed for routine maintenance or repairs, downtime is prolonged. If too many parts are on hand, the enterprise absorbs excessive costs and the overhead of carrying the inventory.

2. Spare-parts Management & Equipment Reliability

Spare Parts Management dispensing an organized maintenance storeroom is one of the key processes which support effective maintenance planning and scheduling and equipment reliability improvement. Improved materials and spare parts management will free up time for maintenance planners, maintenance supervisors, and hourly maintenance personnel. It is not unusual to see an average of 20-30% of maintenance crafts people's time to be used for finding parts and material (Evans, 2008). The reliability and availability of industrial plants represents a critical aspect in many modern manufacturing and service organisations. Increased efficiency of production plants requires the minimisation of machines downtime. Spare parts availability and its prompt accessibility is among the major factors leading to a reduction of the protraction of downtime when a breakdown occurs. Thus, a logical approach to solving the issue of spare parts availability lies in preserving requisite sizes of inventories of spare parts for immediate disposition whenever needed. On the other hand, stocking is limited by space and cost; for these reasons, designing the reserve of spare parts in an optimal way represents a critical and important task for every parts inventory manager.

There are many aspects that must be considered when reviewing any MRO materials and asset management program. In those organizations where Purchasing and Materials management are not directly involved or empowered to impact the management and direction of these programs, significant opportunities exist for cost reductions and process improvements. Many times the responsibility for selecting items to be stocked, replenished, maintained and disposed of is the responsibility of departments other than Material Planning or Management. The question that is commonly raised regarding the management of assets and MRO by Maintenance and Operations is, "why shouldn't those departments that use and require these materials also order, stock, repair, and maintain these materials?" The fact is that many companies effectively "carve out" several of the fiscal duties and responsibilities from the Materials and Purchasing Management function, and make it the direct responsibility of Maintenance and Operations; the issue is not whether the required repairs and services are performed, but rather how can this process be managed and performed at the same or higher service level at a lower cost. The other major problem is increasing the awareness of why the change is necessary and implementing the change inside the organization is critical, once opportunities have been identified (Timme & Christine, 2003).

Two main approaches that have been followed to develop a possible spares provisioning decision model are: Mathematical models; and Classification approaches. The first approach concerns the development of mathematical models based on linear programming, dynamic programming, goal programming, and simulation (Kennedy *et al.,* 2002). Similar approaches have been examined extensively in the past and a vast number of inventory models have been developed during the last decades. Starting from the multi-echelon technique for recoverable item control (METRIC) model of Sherbrooke (1968), several researches have been conducted that deal with a variety of different aspects of the spare parts inventory management. These works are generally concentrated on the mathematical optimisation of the inventory costs and service levels associated with a potential spares inventory policy in terms of economic order quantity, reorder point, safety stocks, and so on (Kennedy *et al.,* 2002). Application of multi-attribute decision making (MADM) techniques and analytic hierarchy process (AHP) methodology for spares classification have also been considered in the literature (de Almeida, 2001; Sharaf & Helmy, 2001). Attributes such as usage rate, standard characteristics of spare, lead time of supply, spare cost are considered in their models (de Almeida, 2001). However, most of these methodologies are too complex, abstract or oversimplified, thus reducing their usefulness for maintenance managers working in low-tech low-risk industries such as palm oil mills.

Apart from new generation turbines and decanters whose maintenance is usually outsourced, most of the critical equipment in palm oil mills is low-tech (Sivasothy *et al.,* 2006); it does not warrant a finer spare parts management system that might be essential for, say, an automotive plant; as most of the mills still operate equipment that was designed in 1950's and 1960's (Sivasothy *et al.,* 2006). Given this level of sophistication, the classical ABC model is adequate to manage spare parts inventory in palm oil mills. The use of classification schemes as a spare parts management tool represents a popular approach in industrial world. ABC-classification according to the Pareto's principle is the most well known and used classification scheme to manage the spare parts inventory management problems. A criticality classification of spare parts is generally based on administrative efficiency considerations (such as inventory costs, usage rates, etc.) derived from historical data of the company. The modern production planning software packages, such as ERP, are able to obtain similar analyses easily and with a reduced time consuming operation. Based on these analyses, oversized inventories, obsolescence aspects or stock-out problems for the different items are recognised (Braglia *et al*., 2004).

3. Spare-parts Inventory Management and ABC Analysis

The ABC analysis provides an apparatus for identifying items that have a significant impact on overall inventory cost, while providing a mechanism for identifying different categories of stock that will require different management and controls. The ABC analysis suggests that inventories of an organization are not of equal value. Thus, the inventory is grouped into three categories (A, B, and C) in order of their estimated importance (Cheng, 2010).

Primarily, a spare part inventory is generally analysed through a failure mode effects and criticality analysis or FMECA to obtain a first reduction of the problem dimensions; that is only the most critical spares are analysed. Thereafter, an ABC analysis according to Pareto's principle of the most critical spares is carried out to classify the different items. In this way a second reduction of the items is obtained (i.e. only the spare parts classified into the most critical class will be considered in the next step). The conventional ABC analysis adopted by many firms, classifies the plant components into three classes of criticality: very important (A-class), important (B-class), and less important (C-class); only the components belonging to class A require management attention. An accurate re-definition of the stock levels for the different spare parts is executed; thousands of items may be potentially held in inventory by a typical company, but only a small portion of them deserve management's close attention and accurate control (Sharaf & Helmy, 2001).

The classification of spare parts is frequently based on a single criterion; the most frequently adopted is the annual cost usage. Spares with low utilisation and low inventories are considered to be of low importance. Only obsolescence/deterioration problems must be carefully taken into account for this type of item. A careful revision of the safety stocks, reorder points and order quantities is generally required so as to attempt to reduce the stocks. In particular, for the items that are already characterised by low safety stocks, improvements can be obtained adopting the just-in-time paradigms. Besides quantifiable factors that are taken into account during these standard types of analysis, such as: item costs, usage rate, and historical inventory levels; other attributes concerning more intangible aspects such as safety objectives, provisioning characteristics, type of maintenance adopted, and loss of production, should also be considered.

4. The Maintenance Storeroom: Key to Efficient Maintenance Operation

Besides being the central hub for maintenance, the storeroom also provides functions that are absolutely critical to the maintenance operation. These functions are so important that when the storeroom is operating in a best practices mode, the rest of the maintenance operation can excel. Put another way, if the storeroom is run improperly (such as poor inventory accuracy, parts unavailable when needed due to poor replenishment and procurement practices, etc), the rest of the maintenance operation will not achieve high service levels of equipment availability and reliability.

The Storeroom as Service Provider **-** If you follow the flow of technicians and materials in a typical maintenance operation, a common pattern emerges. In general, you have a central hub and the spokes of a wheel - where the hub is the storeroom, and the spokes are the paths to the equipment or machinery in the facility or site that are undergoing maintenance. The number of work centers on the site multiplies the actual material flow. This correlation illustrates the crucial role of the maintenance storeroom; to provide parts quickly when needed. This function places the storeroom in the position of a service provider, with the rest of the maintenance organization (and by extension, manufacturing operations) as the customers. Perhaps one of the main integrants of success for a service provider, besides fundamentally delivering what is promised, is to manage expectations of the customers. This is done in a deliberate way through various forms of communications so that not only does to the customer understand what service they will receive; they also understand how the service will be performed. In the maintenance world, there is an implied expectation of parts availability. For many parts, that expectation can be easily met. But for some classifications of parts, that expectation is unrealistic either due to cost of the part, reliability profile MTBF and MTTR (Mean Time Between Failures and Mean Time To Repair), or other characteristics of the part. Those responsible for maintenance and the storeroom must communicate to the facilities and operations organizations the reasonable expectations of service from the storeroom. These expectations of parts availability are the result of analyzing the impact on downtime, the likelihood of failure, and the carrying costs of the parts. Ideally, the time to decide on whether parts should be stocked is when new equipment is placed in-service. Manufacturing and the parts suppliers can work with maintenance in recommending the spare parts to stock as the new equipment is being purchased. Thereafter, maintenance can use historical usage data in deciding adequate inventory levels, or even to discontinue carrying certain items. In a larger maintenance and parts organization, a parts inventory planner is the decision maker when it comes to the stocking level, timing of re-orders, and replenishment trigger levels of a part (York, 2003).

5. The Importance of Inventory Accuracy

One of the critical success factors for the storeroom is achieving a high level of inventory accuracy. Accurate inventory is defined as the correct part and the correct quantity physically in a storeroom location being the same as that shown on the inventory control system or computerised maintenance management system (CMMS). Minor variances between actual and system counts are tolerated, such as with nuts and bolts. However, if the part, quantity, or location is not correct when matched against the system, then that location is counted as an “error” for purposes of tabulating inventory accuracy. The consequences of inaccurate inventory include: high risk of an stock-out condition as parts will not be ordered on-time; parts will be flagged for re-ordering by the system even if not needed; maintenance technicians and machine operators will lose confidence in the inventory control system or CMMS, and benefits from using other functionality in the system will be lost; and encourage proliferation of bench stock (stock held on the floor or in cabinets/shelves outside the storeroom). It is critical that not only the storeroom operators understand the importance of inventory accuracy, maintenance technicians, maintenance planners, operations personnel, and plant management also understands the importance of inventory accuracy since these groups will be impacted adversely by inaccuracy of inventory. Achieving high levels of inventory accuracy requires recording of: all parts receipts against purchase orders or outside repair orders; receipts of parts returned to the storeroom that were previously issued to a work order but not actually used; parts serial numbers, lots, or other important information at the time of receipt; parts put away in locations; all parts issued to a work order, employee number, or other account; and routine and accurate cycle counts.

6. Storeroom Organization for Productivity

The storeroom is like any other business area when it comes to productive operation – the area must be organized in a physical sense:

I. The parts storage area is sized and equipped aptly for the types and volumes of parts to be handled by maintenance;
II. Lighting in the area must be sufficient to permit counting of parts in the aisles – whether for parts issue to a work order or for cycle counting and the area must be free of debris and clutter in the aisles to permit personnel quick access to the locations;
III. The locations must be labelled so that time searching for parts is minimized; stepladders, stools, and carts must be parked in an area that is out of the main flow;
IV. The area needs to be physically separated from the main plant, either by walls or with a secured cage, this separation is to discourage theft and to enforce recording of parts receipts / issues for inventory accuracy purposes, and monitored controlled access procedures must be in-place for normal business hours and after-hours needs for parts;
V. There are distinct work elements within the storeroom, and they should be combined into jobs that make the most productive use of staff’s time; combining too many different work elements into a job is counterproductive.

7. Slotting Inventory Correctly

Slotting of inventory is the assigning of a part to a location based on the part's movement, amount of inventory to hold on-hand, and physical characteristics (such as size and weight); real productivity savings in the storeroom can be gained from the correct slotting of parts. Parts that are slow movers should be stored near the back of the storeroom, and fast movers near the front of the storeroom for quicker access. For example, a motor that is a critical spare and needed once a year should be slotted in the rear of the storeroom, while filters and gaskets that may be needed for frequent preventive maintenance tasks should be located near the front of the storeroom. There are many different storage and retrieval methods that can be employed to handle parts, each can be befitting depending on the volumes and characteristics of the parts. For example, dense storage narrow aisle man-up vehicles may be appropriate for either heavy parts on shelves, or for small parts on shelves. Other alternatives for parts storage in the storeroom include a vertical lift module, which is a vertical carousel. The distinct feature of this technology is that it provides for parts coming to the operator, significantly reducing travel time to locate parts; Common in automotive plants for stamping presses.

The less mechanized (but still very efficient) options for parts storage and slotting include case flow lanes, static shelves, and small parts bins. No matter which storage technology is chosen, the important issue is that parts history must be analyzed to determine the movement. There will be different payback points for each alternative as labour and productivity savings offsets the capital investment.

Finally, another common element of slotting, regardless of which storage and retrieval methods or technology used, is that each location is unique and is referenced in the inventory control system or CMMS. Using unique locations enables the use of an automatic identification system to streamline parts handling. The introduction of automatic identification (auto ID), using barcode technology into the storeroom has resulted in a significant contribution to storeroom productivity, inventory accuracy, and error elimination. Whether for parts put away, parts picking, or cycle counting, using auto ID is now a best practice.

8. Preventive Maintenance (PM) Kit Building

One of the functions of the storeroom is to provide parts, tools, and supplies for the technicians to perform preventive maintenance tasks. As a way to level out the storeroom workload and provide better service (higher availability of parts) to the technicians, the storeroom can build PM kits in advance of the scheduled PM time. This requires access to the PM schedule by the storeroom, and a way to track and hold parts inventory prior to issuing them to the PM work order.

One of the ways to do this is to use a mobile cart with multiple kitting bins (locations) on-board. The parts listed on the PM work order are picked from the storage locations, and are placed into one of the kit bins. These kit bin locations are an extension of the static storage locations, and the inventory control system or CMMS will track these kit bin locations with a "staged" status. When picking is completed, the entire cart is moved to a kitting hold area, and scanned into the hold location.

When a PM is scheduled for work, the technician presents the PM work order to the storeroom. The system will show that the inventory has already been picked is in the kitting hold location. The kitting bin can be scanned to the work order, and the technician can take the PM kit to the job. The entire process of retrieving the parts for the PM, from the technician's perspective, is very fast. In the event that an emergency work order situation arises, and the only part in stock has been picked to the kit bin, the system can locate the part and remove the part from the PM kit through a move transaction.

9. Parts Transactions

Parts receipts should be recorded to offset either a purchase order or a work order for outside services, while parts issues should be used to tie a part to a work order, technician identification, or an account code. Failure to record these transactions will waste the efforts set forth at increasing storeroom efficiency, productivity, and accuracy. The maintenance organization must embrace the inventory control system or CMMS, use the transactions that are provided, and view it as the tool to a successful operation. In many storerooms, the discipline of entering these transactions breaks down under the pressures of the day, especially if there are emergencies that need to be addressed. Also, there can be a culture of "take what you need" that can undermine the efforts of increasing inventory accuracy and accountability. Management, through education, effort, and enforcement, can overcome these obstacles; cultural change is an ongoing process and not a one-time program.

10. Measures and Key Performance Indicators (KPIs)

There are several measures and KPIs to gauge performance of storeroom operation, the major indicators are: Inventory accuracy (cycle count adjustment / total cycle counts); Percentage of stock-outs (number of stock-outs / total parts issues); Percentage of inactive inventory (parts inactive in the past year / total parts); Parts to labour ratio (parts inventory value / maintenance labour cost). When measures and indicators are recorded over time, these become a benchmark for the organization. Continuous improvement efforts can then be launched to improve upon these standards, with the desired result of cost reduction and higher productivity. Without tracking performance, it is not possible for the storeroom to know whether improvements have indeed been worth the effort. JIT inventory management have only a limited ability to assist the efficiency of the maintenance process. Issues such as just-in-case inventory management are far more important. This has implications not only within the area of operations, but throughout the entire supply chain. Often the improvement of a supply chain is based on "how we buy," the probabilistic nature of asset maintenance means also that we need to be thinking about "why we buy" (Mather, 2008).

11. Conclusion

The spare parts inventories management in industrial plants represents a very complex problem due to the difficulties concerning data collection, the number of factors to be considered, and the large amount of the items involved. Maintenance spare parts store room is a service provider; to dispense efficient and effective services it needs to focus on the best practices of spare parts management. In order to accomplish best practices the maintenance store room ought to: adopt the idea that the storeroom is a service provider; organize the storeroom and staff for efficiency; ensure inventory accuracy - it is of utmost importance; perform routine and daily cycle counting as part of the storeroom duties; properly slot parts depending on part volume and characteristics; use auto ID and/or barcodes to streamline data entry and reduce errors; build PM kits in advance to enable quick PM of equipment; record all parts moves, receipts, and issues on time; and create, track, and use measurements and KPIs. As each company is unique, so too are the storerooms – different storerooms will require their own combination of solutions. When the storeroom operates in a best practices mode, then it is easy to see productivity gains not only in the storeroom, but also throughout the organization.

References

Braglia, M., Grassi, A., Montanari, R., 2004, "Multi-attribute classification method for spare parts inventory management", *Journal of quality in maintenance engineering,* Vol. 10, Issue: 1, pp. 55-65.

Cheng, L. L., 2010, "Shipping and Logistics Management", Springer London Dordrecht Heidelberg New York, p. 158

de Almeida, A.T., 2001, "Multicriteria decision making on maintenance: spares and contracts planning", European Journal of Operational Research, Vol. 129, pp. 235-41.

Evans, 2008, MRO Spares Optimization, Marcus Evans Malaysia *Location: Malaysia Kuala Lumpur* http://www.gulfoilandgas.com/WEBPRO1/Events/Event_Details.asp?id=752

Kennedy, W.J., Patterson, J.W. and Fredendall, L.D. (2002), "An overview of recent literature on spare parts inventories", International Journal of Production Economics, Vol. 76, No. 2, pp. 201-15.

Mather, D. (2008). *Asset resource planning*. New York, NY: Industrial Press Inc.

Sharaf, M.A. and Helmy, H.A. (2001), "A classification model for inventory management of spare parts", Proceedings of 7th International Conference on Production, Industrial Engineering, Design and Control (PEDAC 2001), Alexandria, Egypt, 13-15 February, Vol. 1, pp. 375-82.

Sherbrooke, C.C. (1968), "METRIC: a multi-echelon technique for recoverable item control", Operation Research, Vol. 16, pp. 122-41.

Sivasothy, K; Basiron, Y; Anhar, S; Ramli, T; Tan, H; and Mohammad, S. (2006), Continuous Sterilization: The new Paradigm for modernizing palm oil milling. Journal of Oil Palm Research (Special Issue - April 2006), p. 144-152.

Timme, S. G., and Christine, T., 2003, "The Real Cost of Holding Inventory," *Supply Chain Management Review*, (July/August 2003), pp.31-37

York C., 2003, paper Presented at IMC-2003 the 18th International Maintenance Conference, Netexpress Inc., York, PA, 17402, USA

1. First Author: Dr. Nazim Baluch

Dr. Nazim Baluch, a visiting senior lecturer from Canada, is currently attached to the School of Technology Management, College Of Business - Universiti Utara Malaysia (UUM). He earned his MBA in 2004 from the University of Guelph, Guelph, Ontario, Canada; and PhD in the field of Technology Management from UUM in 2012. As an academician, he teaches 'Operations and Technology Management' subjects. In his undergraduate studies at Mohawk College of Applied Arts and Technology (a degree granting institution), Hamilton, Ontario, Canada (1996-2002); he specialized in Mechanical Engineering Technology; Maintenance Engineering Technology; and Automation in Manufacturing. He has been active in the Canadian Automotive Industry and Supply Chain Management (warehousing) with hands on experience in 'Manufacturing and Operations Management' for the last several years. His recent assignment was at Magna International's plant in Canada (Magna is the most diversified automotive manufacturer in the world); there, he was a key member of the "Operations Management Committee" that monitored company: Product Quality Assurance; Equipment Reliability; Production & Material Handling; Maintenance &Tooling; and Human Resource Development. He has trained personnel in various management and technology fields, in corporate setting, in Canada. He is a member of the Malaysian Institute of Management.

2. Second Author: Prof. Ir. Dr. Che Sobry Abdullah

Professor Ir. Dr. Che Sobry Abdullah is currently attached to the School of Technology Management and Logistics, UUM College of Business, Universiti Utara Malaysia. He holds a PhD in the field of Civil Engineering (1989) and MSc in Construction Engineering (1982), both from the University of Leeds, UK. As an academician he teaches construction technology, project management, and engineering management subjects. He has been active in research and consultation works relating to the areas of concrete technology and brick construction, engineering forensics, and project management. He holds the MS Project 2007 and Oracle Primavera P6 certificates. He has been a member of the Technical Committee and Chairman of the WG of various Malaysian Standards documentation on bricks and blocks. He was a member of the British Masonry Society and had become the founding member of three national level associations, namely the Concrete Society of Malaysia, Institution of Engineers Malaysia Kedah-Perlis Branch, and the Technology Management Society of Malaysia.

3. Third Author: Assoc. Prof. Dr. Shahimi Mohtar

Dr. Shahimi Mohtar is an author, lecturer and researcher who has studied the operations management since 1997. He holds a Doctor of Business Administration from the University of South Australia (2005), Master of Business Administration from the Ohio University (1992) and Bachelor of Science in Mechanical Engineering from the University of Nevada at Reno (1986). He has more than fifteen years of working experience in electronic and maritime industries. He is an associate professor currently attached to the School of Technology Management, UUM College of Business, Universiti Utara Malaysia. He is also the co-author of Introduction to Operation Management book.