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MRO inventory reduction—challenges and management: a case study of the Tennessee Valley Authority

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Emphasis on maintenance, repair, and operations inventory (or MRO inventory) can lead to improved inventory control, reduced operational costs, enhanced productivity, and increased cost accounting accuracy. To review the benefits of MRO inventory reduction, as well as highlight the management challenges associated with the process, a case study of the Tennessee Valley Authority (TVA) is presented. TVA is a not-for-profit electric power generation entity. TVA standardised inventory policies and procedures. Their comprehensive five-year plan included employee training, changes in organisational structure and strategy, reduced MRO inventories and the establishment of new growth drivers. Net inventory reductions of $47 million were realised. Suggestions for future MRO inventory reductions as well as replication of the management involvement and improvement process in other organisations are included.

Keywords: Inventory, maintenance, repair and operations (MRO) inventory; Reduction; Improvement; Safety stock; Repair Parts; Utility

1. Spare parts inventory characteristics

Service parts are independent demand items needed to repair and maintain technical installations. Ghodrati and Kuman (2005) agree that with the continuous technological development in the twenty-first century, industrial systems have become more complex, and this makes service or spare parts control and availability even more critical. The lack of spare parts, when required, is likely to cause unexpected downtimes, which in turn lead to losses without compensation. These spare or service parts often have erratic demand patterns and while most are rarely used, they are, nevertheless, critical to maintaining production. Eaves and Kingsman (2004) recognised that a large portion of spare parts are known to have this intermittent or slow-moving demand pattern, and present unique problems for both forecasting and inventory control. Razi and Tam (2003) in their research on spare part inventory discovered that most enterprise resource planning (ERP) systems are ill-equipped to deal with the erratic demand patterns of slow moving spare parts. Policies covering spare parts inventories are also different from those governing work-in-process (WIP) or other inventories. Kennedy *et al*. (2002) also found spare parts inventories to be unique in relation to management issues, age-based replacement, multi-echelon decisions, obsolescence, and repairable spare parts.

Stratman (2005) agrees it requires hard work and discipline to keep inventories under control since spare parts inventories typically account for 5 to 10% of a firm's investment base (Mehrotra *et al*. 2001). This view is supported by Cardamone (1996) who found stocking optimal levels of critical spare parts to be one of the

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most difficult tasks faced by managers, particularly because the demand for the spare parts, other than those for planned or scheduled maintenance, is so unpredictable and results in conflicts for inventory managers who must minimise carrying costs while minimising down time due to stockouts. The situation is further complicated by the typically high-value of the repair critical spares, inventory constraints, cost of lost production, safety and environmental objectives, maintenance strategies adopted, and logistic aspects of spare parts (Braglia *et al.* 2004). Sleptchenko *et al.* (2003) agree that today's expensive technically advanced equipment, including computer systems, medical equipment, and defence systems, require a high availability and timely supply of spare parts to attain a high system availability. Their research found item prices, failure rates, and repair times vary considerably for these high value parts.

Research has proposed a number of less than perfect solutions for managing critical spares. Simulation software tools, simultaneous optimisation procedures, heuristics and mathematical models based on linear programming, dynamic programming, goal programming and simulation have been proposed and implemented to manage spare parts (see, for example, Cardamone 1996, 'Utility company saves...' 1996, Huiskonen 2001, Caglar *et al.* 2004, Sleptchenko *et al.* 2005, Wong *et al.* 2005).

Common inventory replenishment models including economic order quantity (EOQ), number of day's inventory, fixed-order quantities, fixed-time period models or price-break models are often inadequate for spare parts, primarily due to the limited historical use of the part. Other models too often fail to take into account the critical nature of service parts where stockouts and backorders are not allowed. MRO parts not used in scheduled maintenance are replaced due to random wear and tear. It is difficult to accurately or statistically predict or forecast when a unit's failure will happen (Vaughan 2005). Spare parts also may have long lead-times and must be stocked to prevent downtime.

2. Establishing re-order quantities

Because the replenishment heuristics may be based on erroneous assumptions or imperfect data, determining order quantities is a challenging, but often first step in reducing spare parts inventory investment. Lau *et al.* (2006) agree that assumptions inherent in popular inventory models can often introduce a serious underestimation of parts' availability when the failure rate is high, the repair time is long, or the number of working systems is small, as in many MRO environments.

Various ways to categorise spare parts may depend upon their reparability, the demand intensity, purchasing lead time, delivery time, the planning horizon, the price of the part, the criticality of the part, the cost of stock keeping, and re-ordering cost (Fortuin and Martin 1999). When a company only uses a part every 18 months, for example, some of the variables, such as demand during lead time and other model variables, lose their meaning. In a sense, the entire spare parts inventory is really safety stock.

Examining the largest demand during prior years' periods, three years for example, is often used by firms to estimate future part needs. By examining the largest quantity needed, management may feel confident in their ability to satisfy demand. However, the drawback to this approach is the amount of slow-moving inventory. Braglia *et al.* (2004) agree that with the complexity of the spare parts, few studies have adequately addressed the management of this inventory. Yet, the cost of not having a critical part when it is needed may outweigh any inventory carrying costs, particularly in critical industries like electric power generation. Utility companies have been the focus of several spare parts inventory studies due to their unique situations (see Pitts 1988, 'Utility company saves...' 1996, LeSueur and Dale 1997). In this paper, a case study of the Tennessee Valley Authority (TVA) is presented to highlight the process of developing an inventory plan and classification approach, optimise spare parts inventory and to standardise the inventory management processes among the entity's various power generation sites. The goal of this paper is to illustrate the use of and steps in such a classification approach. A criticality classification of spare parts, according to Braglia *et al.* (2004) is generally based on administrative efficiency considerations (i.e. inventory costs and usage rates), derived from historical data and is often the first step in inventory understanding and reducing spare parts inventory.

3. The case of TVA

The US Congress established the Tennessee Valley Authority (TVA) in 1933 to provide flood control, navigation, and electric power to the Tennessee Valley Region (see http://www.tva.gov/abouttva/history.htm), a service area covering 80 000 square miles in the southeastern United States including almost all of Tennessee and parts of Mississippi, Kentucky, Alabama, Georgia, North Carolina and Virginia. TVA is the largest public power company in the United States with 29 469 megawatts of generating capacity. Through its 158 locally owned distributors, TVA provides power for nearly eight million residents in 170 US counties. Power sales average more than \$6.6 billion a year. TVA is funded by selling electricity to its customers and by issuing debt and is not funded by tax dollars.

3.1 *TVA's production facilities and operations*

TVA's electricity is generated by eleven fossil or coal-burning plants which produce most of TVA's electricity. Four of the plants are powered by natural gas or fuel oil. TVA also generates power at three nuclear plants, 29 hydroelectric dams, and one pumped storage plant. TVA has 18 transmission service centres with 16 600 circuit miles of transmission line. TVA has five combustion turbine sites (four of which are at fossil plant sites) and three distribution centres. These facilities are spread across the seven states where power is supplied.

3.2 *Inventory challenges*

The company's MRO parts inventory to maintain these facilities and operations was valued at \$282 million at the beginning of this study. The inventory control system consisted of a re-order point (ROP) and re-order quantity (ROQ) system with daily re-orders for items at or below the ROP. For these MRO parts, the stocking goal was to have at least one part on the shelf. When the on-hand inventory reached one item, a replacement order would be triggered. The ROQ would typically estimate a year's supply and the ROP would be at half this amount.

Among the many challenges of managing the company's MRO inventory was an ingrained culture of excess at TVA by the maintenance groups—'if one was good, two was better'. This risk-averse approach meant maintenance managers avoided risks of stockouts rather than pursuing a strategy of managing known risks. Due to the difficulty of knowing the quantity needed or when a part might be needed, contingency buying was the norm and contributed to the continuing MRO inventory growth. The contingency buying was simply buying for the unexpected and maintenance typically ordered more than was suggested using the ROP and ROQ rules. This excess purchasing represented a 'just in case' approach to stocking spare parts inventory. Another issue with the inventory creed was the multiple storage locations of spare parts. In addition, there was no incentive for TVA's maintenance managers to minimise their inventory investment since they were evaluated on the actual part usage and work-order costs and were not assessed on the amount of on-hand MRO inventory in stock.

Production planners often resort to simplistic methods for determining safety stocks due to a lack of time and information (Sandvig 1998), and TVA managers typically ordered a year's supply of every spare part just for convenience. For new parts with no history, managers relied on the original equipment manufacturer's (OEM's) recommendation for which items and quantities to stock. OEMs are measured on sales; thus this method of ordering and stocking led to large inventory levels. At TVA, as a governmental entity, carrying costs were not an issue since the firm does not pay taxes. In for-profit firms, however, excess inventory, and their associated taxes do represent a significant cost to be reduced and avoided, if possible. TVA's carrying costs, averaging 7% per year, only represented a source of 'opportunity cost' of funds which were not available for other purposes. Using a standard EOQ model led to extremely large purchase orders and TVA managers carrying multiple-years' supplies of parts, particularly since carrying costs were low relative to ordering costs. Management, however, felt the EOQ model would tie up too much money in inventory as compared to other replenishment methods like the in-house algorithm the company developed.

TVA Maintenance Planners were blamed for all MRO parts shortages, so to avoid any stockout problems, they maintained extremely large safety stocks and there was a tendency for safety stock levels to steadily increase over time. When there was a shortage, the amount of safety stock was increased, and the new quantity was seldom, if ever, reduced to the original level, even after the temporary problem had been resolved. Thus after the initial panic of parts shortages, excessive safety stock often sat idle in storage rooms, tying up capital, using space, and in time becoming obsolete, damaged, or subject to shrinkage (theft). There were even parts for machines TVA no longer used or maintained.

While TVA did refurbish and re-stock numerous repairable items, when a part failed they typically ordered a new part as well. The company feared the consequences of not having some parts; they would need to run a power generation unit at a lower level of output, generating fewer megawatts of electricity or take down a power generation unit entirely, driving electricity sales to zero. In the case of a public utility, the loss of power is more than just an inconvenience. Unlike a supermarket being out of a favourite item and the consumer substituting a competitor's product, lack of electricity leaves the customer with no power alternatives. In an outage situation, TVA would have to operate other less economical power generation units to fill the shortage or purchase higher cost power from another competition utility company. For this reason, spare parts inventories grew to prevent downtime and to ensure the company did not encounter the costly situations resulting from lack of spare parts. Yet this excess inventory was often unnoticed by TVA management.

Each TVA site owned their own inventory and was responsible for their inventory personnel. Unlike suggestions for pooling spare parts, particularly those with low trans-shipment time (see Wong *et al*. 2005), TVA did not pool significant amounts of MRO spare parts stock, other than a minimal inventory of fossil steam turbine parts. In addition, there was no consistency in the inventory stocking philosophies among the multiple TVA sites, even though inventory management literature suggests an optimal spare parts order replacement policy should be established (Giri *et al*. 2005). Chang *et al*. (2005) agree the demand for spare parts should be classified into critical and non-critical demand, depending on the criticality of the equipment for production.

TVA's culture was to stock everything, including convenience items like mops, brooms, dustpans – items readily available at any area 'big box' retail store, even though these items be could bought as needed, eliminating much unnecessary inventory. Maintenance preferred to stock these 'convenience' consumable items in house. With the TVA accounting system, inventory costs were free to maintenance departments until the maintenance personnel issued the parts or supplies to unique work orders, so there remained no incentive for maintenance to reduce inventories, even of common cleaning supplies. Because TVA lacked a proper understanding of their total inventory investment, they did not track their inventory investment over time, and they lacked an established goal for inventory levels; the inventory, as expected, continue to grow as various strategies and philosophies throughout the organisation drove purchases.

4. Methodology

TVA's inventory grew to a high of \$323 million in 1991 from \$182 million in 1980. With some success, TVA began reviewing and revising re-order rules with the approval of various sites. Slower-moving inventory was reviewed and obsolete materials were scrapped and written off. The efforts by various business groups contributed to the reduction of the inventory to \$282 million at the end of 1995. Still there was no corporate-level centralised materials management functions at TVA; rather, there remained different materials management efforts by the Nuclear group, the Fossil/Hydro group, and the Transmission group.

Using the four-step methodology proposed by Duchessi *et al*. (1988), TVA first developed a set of categories for classifying spare parts into homogenous classes and next associated controls for each category based on their criticality. They then implemented the specific controls for each category with unique cost-criticality traits. They created four inventory categories:

1. Critical spares.
2. Spare parts.
3. Consumables.
4. Bulk commodities.

All parts were classified into one of the four categories. The 'critical spares' were determined by the maintenance and operating groups. These were selected based on the potential for loss of electric power generation for the company if these parts were not readily available. The regular 'spare parts' classification included repair parts and replacement parts whose function was required in the organisation, in structures, systems, or equipment, but did not affect the company's core mission of power generation. The parts were largely necessary to ensure the operation of the facilities. The 'consumables' included non-spare part items which were used over a period of time, and readily available. Examples included electric lamps, chain, wire rope, and cleaning supplies. Finally the 'bulk commodities' category included non-spare part items that became part of the facility and were also readily available including pipe, conduit, fittings, and steel.

The categories of parts were managed differently based on availability, usage characteristics, and criticality to TVA's operations. Spares are rarely used items, but must be available in the quantities used for each job, just in case they were needed. Typically, a 'critical spare' should always be on hand whereas normal 'spares' might be replaced as used. The 'consumables' and 'bulk consumable' commodities were readily available with higher usage items managed individually, based on their unique usage characteristics.

To assess and work towards improving inventory levels, TVA established a new position, the Senior Vice President of Procurement, as well as a General Manager of Materials Management as part of the Procurement Group. There was now a TVA Materials Management Group as opposed to each separate business unit having their own materials management group. The first initiative from the new Procurement organisation was to develop a TVA-wide inventory management policy for all business units, ensuring a consistent methodology for establishing stocking levels, and achieving significant long term inventory reductions. The plan was to enable the transition from a 'business unit unique inventory' to a 'TVA-wide virtual inventory'.

The Senior Vice President of Procurement challenged the new Materials Management organisation to achieve significant inventory reductions. In addition to promoting consistency, the new strategic inventory question was—'What should the inventory level be and how do we reach this level?'

To address these objectives, a team was established to develop a five-year inventory plan to reduce the large inventory investments and promote consistency within TVA. Teams were established to represent the different business groups at the company. Their charge was to identify the inventory investment in TVA in terms of 'what', 'where' and any 'unique characteristics' of the part or item. Teams were also asked to identify the TVA inventory management policy and to identify opportunities for inventory reduction. Final steps were to establish inventory targets and to implement the plan and measure the results relative to the targets.

The team was led by the Nuclear Power Materials Manager who was selected due to his expertise in materials management and experience at other public utilities prior to joining TVA. He selected the team members. The multifunctional team was made up of representatives from Procurement and Materials Management from the various electricity generation functions and included the Manager of Inventory for Nuclear, the Manager of Inventory for Fossil/Hydro, inventory analysts from the transmission and distribution centre groups, and materials catalogue personnel from Materials Management. Their new goal was to control inventory growth and stock the parts necessary to maintain the power system at the lowest overall cost.

While there were no external pressures for inventory reduction, the executive simply wanted to assess more accurately inventory levels. The team's first task was to draft a TVA Inventory Management Policy and to identify potential inventory reductions. Assignments were made to team members based on their resources and expertise. Some members worked to draft an inventory policy while others collected preliminary inventory data by generating reports and accessing the current total parts inventory from their computer system. At weekly team meetings, the group reviewed data from the previous weeks' assignments. Each meeting generated additional ideas for inventory analyses. Sixteen weeks into the project, the team reached conclusions and presented their recommendations.

4.1 *The improvement plan*

The first task of the team was to establish the current inventory value and stratify the inventory based on location, material type, usage characteristics, and other criteria. The baseline inventory was $282 million. The generating facilities held the majority of the inventory followed by the transmission group and distribution centres:

Business unit	Inventory
Fossil/hydro	$132.4 million
Nuclear	$121.5 million
Transmission	$24.4 million
Distribution	$3.4 million

The inventory investment was primarily in the spare parts category:

Material type	Inventory
Spare parts	$236.9 million
Bulk commodities	$32.4 million
Consumables	$12.4 million

In addition to identifying material type and location, further analysis identified the usage characteristics and the inventory levels relative to the defined stock levels (re-order point and re-order quantity). The analysis found $75.3 million of the inventory was over the maximum stocking level as defined by the existing re-order point rules and $89.0 million of the MRO inventory had not been used in more than three years. The initial team findings described the current inventory situation and highlighted for top management the lack of consistency in spare part stocking policies. No conclusions were made regarding the appropriateness of various levels of inventory at this stage of the analysis.

After the initial stratification of current inventory, the team was charged with identifying opportunities for improvement and establishing appropriate inventory targets for the next 5 years. Top management agreed the 5-year time frame was necessary to change the ingrained culture of the MRO inventory policies. In addition, since some MRO items were very rarely needed, the 5-year time span was necessary to reflect any significant changes in the levels of some inventoried items.

Further analysis was conducted to identify opportunities to optimise inventory. Eleven areas were identified for potential inventory reductions. These areas were presented and discussed at the weekly team meetings and a consensus was reached for specific opportunities to pursue. These opportunities included increased inventory sharing among sites and business units, consistent reviews of spare part re-orders, disposal of inventory with more than 10 years supply on hand, and disposal of overstocked items that had not been used in

3 years or more. TVA established a supplier managed inventory for the low cost, high turn items. The vendor managed items were consumable, low cost but high usage items and included nuts, bolts, and screws. These could be stocked closer to point of use, increasing productivity and reducing issue-and-receipt transactions, plus would minimise additional handling by storeroom personnel. Using the time value of money and inflation levels to identify when it would be more appropriate to surplus and sell items and buy again, when needed, if excess quantities existed, the 10-year threshold was established with the CFO.

Individual assignments were made to the team members and each of the opportunities were reviewed in detail with reduction targets established. The targets were determined by applying reduction percentages to each inventory item based on analysis and the teams experience and knowledge of the unique inventory. For example, $9.7 million of inventory represented a supply of 10 years or more based on historical data. It was estimated this could be reduced by 25% or $2.4 million over 5 years through increased inventory sharing and immediate write-offs. Common inventory items represented $27.5 million and it was estimated this could be reduced by 50% over 5 years by increased sharing and transfers among the sites. Eleven unique opportunities were grouped into five major strategies to optimise the inventory investment with a total reduction potential of

Strategy	Potential in millions
1. Surplus inventory not needed	$52.5
2. Establish supplier managed inventory	$1.3
3. Establish consignment with suppliers	$19.3
4. Share inventory (transfer versus buy)	$12.1
5. Review planned replenishments	$14.8
	$100.0

$100 million over 5 years.

The strategies developed address two different components of inventory. The first strategy addressed the 'unnecessary inventory' and the second strategy addressed managing the 'needed inventory'. The surplus strategy addressed the slow moving inventory items resulting from equipment changes and modifications.

The 'supplier managed inventory' strategy recognised the high cost associated with managing low cost, high-activity items and expensed these items upon receipt, moved them closer to the user with the external supplier restocking the parts bins. The consignment strategy was an effort to further partner with suppliers. The suppliers shared more of the inventory cost and TVA assumed ownership on a just-in-time basis, thus reducing inventory costs while ensuring inventory availability. The shared inventory strategy recognised excess inventories should be reviewed in an attempt to satisfy the needs of other units. Individual sites that were overstocked due to changes in work plans had these stocks reallocated to other sites. A favourite saying emerged from the process—'the best buy is no buy'. Consistent with a more standard inventory stocking policy, the replenishment review strategy identified and revised re-order points and re-order quantities due to changes in lead times and demand.

To achieve the consistency in stocking policy, the team established guidelines for stocking inventory items based on the material classification (critical spare, spare or non-spare) and lead times. In general, the less critical the part and the shorter the lead time, the fewer units would be stocked as compared to critical and long lead time items. In this way, stockout costs were less and the item was readily available, driving the lower stock levels. The more critical and longer lead time safety stock items were maintained at higher levels with defaults to the largest one time issue (largest quantity issued to satisfy a repair) over a 3-year period. For critical spares, a quantity used may be four on one issue ticket and six on another ticket. In this case, the quantity of six would be the default since for these two tickets it was the largest, one-time issue of the item. This rubric provided a degree of safety and was a guard against calculation averaging to quantities too low to satisfy a need. The re-order quantity (ROQ) was 12 months' supply for spares and 6 months' supply for non-spares if the lead time was greater than 30 days. The ROQ defaulted to the average one time demand, if larger, to prevent rounding at a level lower than was typically used for a job for the rarely used item. For lead times less than 30 days, the ROQ for non-critical items was 3 months' supply with the one time use default as the order quantity, if larger. The re-order point (ROP) was the typical lead time demand plus a safety multiplier depending on the criticality of the item. The largest one time issue over the past 3 years was used as the ROP default for criticality spares. This involved items that were currently over their identified stock levels and had not been used in 3 years or more. The overstock was subject to review and removal. A third party software provider was selected to review spare parts greater than $500 in value, with an emphasis on the criticality of the item as opposed to the lead times or demand.

While these guidelines are straightforward, they represented a significant improvement and consistency over existing stocking strategies. The emphasis was to provide replacement parts in the quantity typically used for a given job, if the parts were not on-hand. These stocking guidelines also provided the ability to anticipate what inventory levels *should* be as opposed to using the previous, varying philosophies that generated unpredictable and excess inventory levels.

To provide consistent analysis and reporting for all TVA operations and to drive the implementation of the inventory strategies across all business units, an Inventory Analysis and Reporting (IA&R) group was next established in the Materials Management organisation. A major effort of the IA&R group was to report consistently TVA's inventory investment by business unit and facility on a weekly and monthly basis. IA&R tracked the results of the five major strategies relative to the targets established and performed gap analysis as needed to identify improvement opportunities. The results of the strategies relative to the targets were reported in monthly meetings with the Senior Vice President of Procurement. The IA&R group reviewed daily replenishments, identified potential transfers from other facilities, and recommended revisions to the re-order rules using consistent inventory analysis tools and algorithms. TVA also provided APICS (The Association for Operations Management) CPIM (Certified in Production and Inventory Management) certification review classes to selected Materials Management personnel, on company time, to enhance skills and understanding of inventory management as well as educate the employees on a common production vocabulary (see http://www.apics.org/certification/CPIM/default.htm for course details).

5. Results

The results of the strategies through the first four years (fiscal years 1998–2001) were:

Strategy	Results in millions
Surplus inventory not needed	\$69.3
Supplier managed inventory	\$1.3
Consignment with suppliers	\$1.2
Shared inventory	\$11.1
Review replenishments	\$17.2
	\$100.1

TVA identified inventory reduction drivers and implemented the strategies to achieve significant inventory reductions, meeting the 5-year target in only 4 years. While TVA implemented the reduction strategies and reduced inventory over \$100 million, the net inventory reduction after 4 years was about \$47 million after accounting for new stock and major additions due to expansions and new electric generating capacity. The major differences, in addition to normal fluctuation within the defined stock level (ROP to max), were the growth drivers. TVA recognised that in addition to implementing the reduction strategies, inventory growth drivers must also be identified and managed.

TVA identified these growth drivers and began monthly reporting along with a detailed review and disposition schedule. The major growth drivers were planned work receipts not used and returns that created overstocked conditions. For example, some planned work receipts contained items that were normally not stocked or for item quantities above normal stocking levels. Often these work receipts lead to more inventory. Drivers contributed from \$35 million to \$40 million to inventory growth over the 4 years of the plan. TVA learned not to concentrate solely on inventory reduction while ignoring growth drivers. To successfully manage inventory, growth as well as reduction must be managed.

6. Future inventory reduction and improvement plans

In their MRO inventory analysis project, TVA managers realised they needed a plan for better inventory management. From their initial study of the inventory data they realised inventory should not 'just happen'. Without a plan and reporting, too much inventory is unnoticed and the only time the inventory was initially a concern was when a part was needed, but unavailable. But, even in a not-for-profit environment, inventory represents capital utilisation. By following a formal inventory procedure, the organisation was able to reduce their inventory investment. Reducing the funds locked in extra inventory, the organisation found financial resources for new projects and debt reduction.

TVA's issues with MRO inventory were not attributable to lack of centralised management oversight but from a situation of several people in charge of inventories, each with a different inventory management philosophies. Without a company-wide inventory policy, the policies used differed from site to site and from manager to manager based on their individual priorities. Changing the organisation structure with more inventory accountability led to a new philosophy for inventory. The new goal was to avoid excessive MRO inventory growth while storing minimal levels of spare parts inventory. Central control is important and critical to define the inventory policy and to have standard reports that allow company leaders to track inventory reduction performance.

Future TVA plans are to continue to implement the inventory optimisation strategies and continuously improve the decision rules for each spare part classification. This supports the findings of

Strijbosch *et al*. (2002) who agree that firms must find an inventory control procedure to outperform the existing one in both improved service and lower cost and that switching from an intuitive control to a more elaborate, computerised, decision rule using a forecasting/replenishment approach results in substantial improvements.

TVA's IA&R group will also be more involved in the order process, reviewing all material requests and not just those for inventory replenishments. Standardisation is another reduction driver being aggressively implemented. Standard items like gloves, safety glasses, and ear plugs are identified, approved, and will be used by all the business units rather than each site having their favourite. Standardisation should also improve sharing or polling among the different sites. This supports the findings of Pitts (1988) in his study of nuclear electric utility providers who pooled their spare parts network and realised dramatic cost-reduction and risk-reduction benefits.

Costs for standardisation at TVA will vary based on the number of different users and subunits of the organisation that must agree to the policy. The degree of complexity of the item being considered will also influence the cost. Deciding on a standard light bulb for the company would be easy compared with deciding which valve or pump to use. For more complex parts, key decision makers must meet and discuss product features and benefits and agree to the best valued item for the company. Time must be allocated to these review sessions. The larger the degree of standardisation, the more sharing can occur across the company, and the lower the overall inventory investment can be. Swist (1994) similarly found that promoting spare part commonality can improve the odds of quick repair when breakdowns occur. At TVA, as a new item is requested, a search for existing items to satisfy the use is the first step of the new ordering process.

Growth drivers will be assessed to identify opportunities for reducing contingency buying and more accurately satisfying material needs. Another phase of the inventory plan is to determine the proper mix of inventory. Inventory not needed has been addressed, the remaining needed inventory is being managed better, and now an effort is underway to identify spare parts critical to the operation of the power system to identify and correct any gaps that may still exist.

7. Discussion and suggestion for replication in other environments

Strijbosch *et al*. (2002) found demand for spare parts to be intermittent leading to some 40% of all spare parts having no usage during a 2-year review period. Their study found companies prefer well-defined control procedure to be used for all spare parts regardless of their demand characteristics.

TVA defined such procedures. Several inventory management suggestions from the TVA example are applicable to managers in a myriad of manufacturing and service settings and are not unique to utility providers. First, know exactly what inventory is stocked as well as its value, its location, and its unique usage characteristics including events triggering parts usage. Determine too the level of inventory you are trying to reach or maintain. Identify the inventory policies supporting the plan. Review and improve the policies and follow standardised inventory management practices throughout the company. These practices include identifying key inventory drivers, establishing consistent methodologies for both MRO inventory points and re-order quantities, and establishing supplier relationships which reduce the need to maintain inventory. Cohen and Lee (1990) agree that developing a supplier sourcing policy is key to management control of spare parts along with the grouping of parts and lateral supplying or stock pooling from neighbouring sites if the site is closer or has access to faster transportation.

Improved planning is also necessary. Firms must establish both an inventory growth control plan as well as an inventory reduction plan. Reducing contingency buying, particularly of readily available items a firm could purchase at a local retailer, is another tool. On-going identification and reviews of material purchased but never used is critical to controlling inventory growth. Reviewing these items with the end users can result in reallocations and a reduction of future contingency buying. As new needs are identified, firms should promote inventory sharing rather than stocking at multiple sites. To decide when to share inventory, cost thresholds must be established. First typical transportation costs for trans-shipment should be identified. If the cost of the item exceeds these transportation costs, it generally makes sense to transfer the item among locations. However, if the item's value is less than the transportation cost, the item should be purchased and shipped directly to the point of need. Guidelines for trans-shipment and stocking need not be complex to produce significant results. However, when fuel costs are rising, the guidelines must be re-established to reflect increasing costs. Stock levels should be validated based on criticality and expected use. Firms should ensure new item requests are reviewed and approved by management. Identify only what must be stocked and buy other items as needed. Efficient safety stock management can also aid planners in identifying and reducing inflated safety stock levels.

Manage the entire corporate inventory (spread over multiple site or stock-keeping locations) online as a 'virtual inventory' or a shared inventory among sites to satisfy any requests from the entire organisation. It is important, however, to note that with rising fuel costs, transportation costs for distributing intra-company inventory must be taken into account and compared with the costs of purchasing inventory from outside vendors. Inventory is as dynamic as the work activities that drive an MRO inventory. As plans change, overstocks can be used to satisfy the needs of other sites. Check for overstock to satisfy a need prior to buying additional inventory.

As with any plan, have targets, measure the results, and take corrective actions as necessary. If you report it and measure it, it will typically get done. Have all the involved units or employees involved in inventory analysis. Future inventory projects at TVA include partnering with suppliers to reduce lead times and inventory levels, supplier stocking of inventory for major equipment, and improved parts standardisation.

As in any inventory management, TVA found obsolete spare parts need to be identified and removed from inventory as new equipment additions or modifications are made. TVA's process for integrating managerial logic to control its spare parts inventory is supported by Duchessi *et al*. (1988) who found this top-down method classifies spares into distinct categories and links appropriate controls with each category. Cohen and Lee (1990) also found that once managers improve the logistics performance, they can devote more time to strategy and policy issues and can even leverage their large investment in parts distribution to contribute to their competitive advantage.

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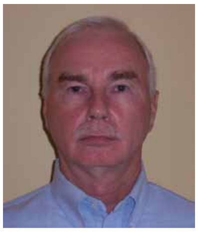

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