Why not stock one?

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ABSTRACT: *To make sure that a critical spare is always in stock when needed, why not stock one? Whenever a part is needed, just go and get the one in the storeroom. If you don't think it's quite that simple, you're right. This paper describes proven techniques that have been used to determine when one (or more or less) is the correct stocking quantity to protect availability at 300 locations with US$ 3 billion of operating and maintenance spares.*

KEYWORDS: *Decision making, evaluation, inventories, inventory control, management, mills <factories>, paper mills, plant departments, risk assessment, spare parts.*

An "inventory tree" approach (**Fig. 1**) was developed to divide the total operating and maintenance (O&M) inventory into manageable classifications *(1)*. This philosophy involves classifying inventory according to its characteristics, then applying the appropriate resources to manage each inventory class relative to those characteristics and the item's importance to production. This approach has several advantages.

First, it is uneconomical or inefficient to manage all inventory aggressively. By categorizing inventories and applying different management techniques to each, it's possible to maximize the value of the stocking decision with a minimum of effort.

Second, different tools to manage inventory are applicable to the different inventory classes. The stocking logic for an actively used, consumable item is quite different from that of a rarely used, highly critical spare.

Third, categorizing inventory permits material managers to spend the greatest amount of time improving stocking decisions of the most important spare parts, rather than giving equal attention to any item that crosses their desk.

Finally, the inventory tree sets quantifiable criteria for each inventory classification. By dividing the inventory into logical segments, realistic, achievable stock targets can be set with clearly identified "do differentlies" and organizational responsibilities for each segment.

For active items, parts used at least once a month, many good forecasting models exist which use historical monthly demand to predict future independent demand. Commonly used models include variations of linear regression, exponential smoothing, seasonality, and moving averages. Although properly applied forecasters work very well for active items, our experience in pulp and paper mills is that an average of over 90% of O&M stores inventory has been used too infrequently to use historical usage as the basis for accurately forecasting future demand. In pulp mills, 56% of the stock items in a typical O&M storeroom are used less than once per year.

The final step in classifying spare parts inventories is to separate the rarely used items into "key" and "nonkey" groups. This step is important because it will determine the number of items (and the amount of effort needed) that justify intensive management (key items) as opposed to those that can be managed with less stringent controls (nonkey items). It is also an opportunity to see the Pareto principle in action, where focusing on a small percentage of inventory items will address effectively the majority of inventory value.

To identify these rarely used key items (RUKIs), a key item criterion is chosen. This criterion is the value of on-hand inventory or the value of recent usage, or both. As the key item criteria are increased, the number of RUKIs to receive intensive management decreases much more rapidly than the inventory value of the RUKIs. Typically, less than 12% of the O&M stores items represent over two-thirds of the inventory value and are used too infrequently for the future usage to be forecasted. These RUKIs are the spares for which risk-based assessment provides the greatest benefits.

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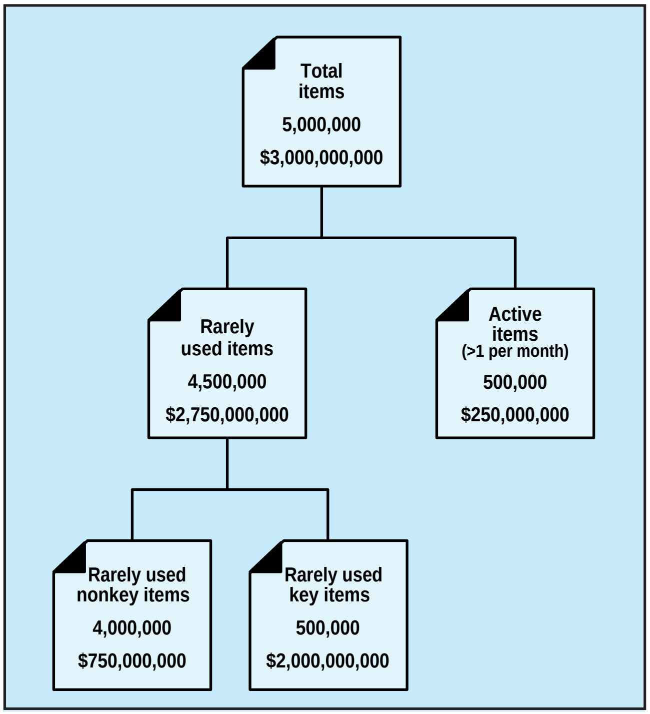
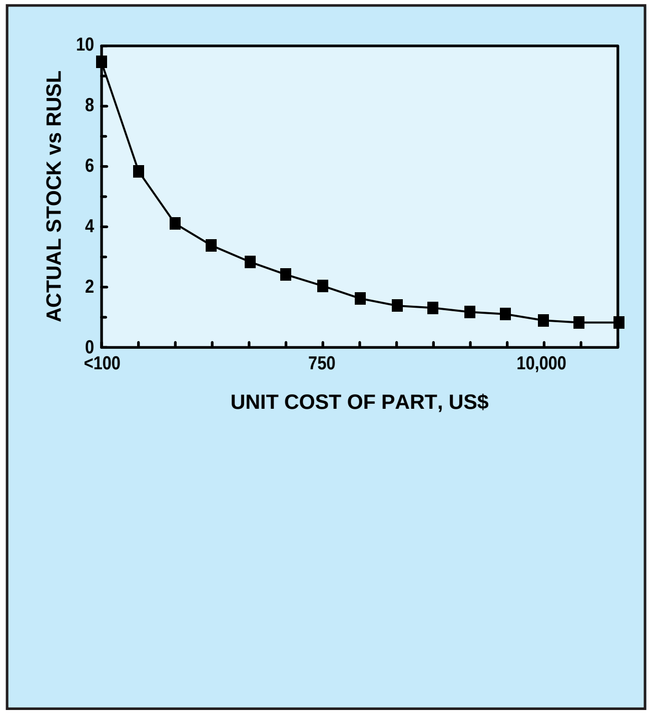
1. Summary of 300 sites at 100 companies. Rarely used key items (RUKIs) comprise only 10% of the items but 56% of the value.



2. Cost bias



Alternatives to risk-based assessment

Prior to the development of the risk-based technique, a variety of methods were used to attempt to manage the rarely used spares. Asking vendors how much to stock results in 20–40% overstocks. Asking maintenance results in 25–50% overstocks with several biases, including cost and lead time. Asking the materials management function to guesstimate the required stock commonly results in understocks compounded by the biases.

Statistical techniques that have been tried include lumpy demand, sometimes called stuttering Poisson. Lumpy demand requires two or three demands in recent years, and more than half of the RUKIs have not been used this often. Other techniques use a number of months, supply or fraction of the prior years' demand. Such techniques ignore at least several of the fundamentals that determine proper stock levels: criticality, number in service (applications), lead time to replenish after a usage, and that inventory cannot be managed in the aggregate; each item must be managed on its own merits.

Many companies have installed new computer hardware, on-line, real-time material systems, common sense rule-of-thumb guidelines, complex mathematical algorithms, etc. Despite all this, the result is inevitably the same: continued increases in inventory or a degradation in the availability of items for operations and maintenance, or both.

A million dollars of inventory exists only in the mind of a finance department. Over the years, we have reviewed inventory valued in the billions of dollars in hundreds of storerooms, and we have never seen a million dollars of inventory. In storerooms, there are only pieces and parts. And, each part has its own story or reason for needing to be in stock. Proven, unbiased, statistical techniques should be used for each segment, and the largest segment (90%) is the rarely used, *'nonfore0-castable'* stocks.

The bias(es)

Manual, best-judgment determination of stock levels without the assistance of statistical techniques invariably results in a counterproductive cost bias. Inexpensive parts tend to be grossly overstocked while the expensive parts tend to be understocked. **Figure 2** illustrates the actual average cost bias found in billions of dollars of inventory in a factor of almost 10 times the quantity required to support desired availability.

As parts become more expensive, the tendency to overstock decreases. For parts with a unit cost of more than US$ 5000, over half are stocked in quantities too low to support availability. The overall result is an unbalanced inventory with substantially too much total inventory combined with poor parts availability because at least one-third of all items are not being reordered soon enough *(2)*.

In addition to the cost bias, stock levels decided without statistical support tools also have a lead-time bias. Simply stated, a lead-time bias means that readily available parts tend to be substantially overstocked. Items with lead times of less than six weeks are overstocked by two to three times the amount required to support operations and maintenance. Items with lead times greater than 20 weeks have an average of only one-half the required quantities.

Hence, Murphy's Law: the part that is backordered is always the most difficult to expedite because it probably has the longest lead time, and easily procured parts are almost never needed in a hurry!

The stocking logic for rarely used items is designed specifically for the risk-based assessment of the 90% of the O&M spare parts for which other inventory management techniques have been proven to be either nonapplicable, suboptimal, useless, or counterproductive. Risk-based assessment "listens" to each RUKIs reasons for needing to be stocked and then quantifies the probable on-hand inventory and probable backorder implications of alternative stock levels.

The nonkey items do not warrant aggressive effort; they tend to be inexpensive, overstocked (great for availability; remember the cost bias?), and comprise such a small portion of the inventory investment that the overstocks are of little concern to materials and finance.

The technique

Conceptually, the RUSL (rarely used inventory stocking logic) calculation begins by calculating the probability that a specific part will require replacement on any given day. Some of the inputs into this calculation include historical usage and the implications of early failures after replacement (bathtub-shaped curve). Multiplying that probability by the quantity of this part in service determines the overall likelihood that a request for an issue from (or a demand on) the storeroom inventory may occur on any given day. Multiplying this result by the lead time to replenish a storeroom issue facilitates the calculation of the probability of multiple demands during the lead time to replenish. The final calculation is to factor in the degree to which getting caught short is unacceptable.

Fortunately, all this complex logic has been designed into an easy to use, risk-based decision support tool.

For each stock level being considered, RUSL calculates the two risks inherent in any stock level decision. One is the risk of getting caught long. This risk is quantified by determining the average inventory value that will be on the shelf waiting for a potential demand that does not occur times the annual inventory carrying cost. The other is the risk of getting caught short. To quantify this risk, RUSL calculates the probable amount of time each year one or more parts will be needed while no stock is on the shelf times the cost implication of this unavailability.

The sum of the two risks is the likely total annual risk cost of any given stock level decision.

The first stock level decision evaluated is the decision to set the maximum to zero (do not stock the item) and only order the item after a demand has occurred. The annual inventory risk cost for this decision is very easy to calculate because there will never be any inventory of this item. However, as shown in **Table I**, the annual back order risk cost is a very high US$ 4.7 million. With a zero stock decision, the duration of a back order is always equal to the lead time. Next, RUSL evaluates the consequences of stocking one unit. For stock levels of one or greater, backorder durations are less than a full lead time because one or more units have been ordered already when a prior demand occurred.

As stock levels increase, the likely resulting backorder costs decrease but the inventory carrying costs increase. At some stock level, the sum of these two costs is at a minimum; this is the economically optimum stock level. In Table I, the optimum level is to stock two units and reorder when the stock level drops to one unit.

The initial review determines the minimums and maximums that are to be used for the RUKIs until the next time a requisition is created to replenish the item. Before a future requisition becomes a purchase order, the item is again reviewed to see if the minimum should be adjusted up or down. Following the simple policy of reviewing requisitions before major (above the key item value) purchase orders are issued eliminates the replenishment of excess stock as used and the creation of new overstocked items: "By not replenishing excess stocks as they are used and reinvesting the savings in understocked items, potential availability problems are eliminated without increasing total inventory investment" *(3)*.

For items that have a grossly high value of overstocks and a low expected usage rate, RUSL includes an econometric model which is used to evaluate investment recovery alternatives under various market conditions *(4)*.

First-time purchases

Risk-based assessment techniques not only are highly effective in managing existing spare parts but are equally effective for setting the initial stocking levels of items being purchased for the first time *(5)*. Problems frequently arise in setting inventory levels for brand-new items. Because there is no history of usage and because of plant management's reliance on "judgment" or supplier recommendations to set initial spares stocking levels, there is a strong tendency to spend excessively (40% overstock is common). If the item is rarely used, this results in excessive levels of inventory for many years.

When setting initial quantities for new spares items, experienced maintenance personnel are asked two questions which they are eminently qualified to answer. One of the questions is not, "How many do you think we ought to buy?" The first is, "If you need one of these parts and one is not available in the storeroom, how bad does it hurt?" The second is, "When you install one of these parts, how long do you expect it to last?" In other words, estimate the mean time before failure for the item, provided reliable

I. Risk based assessment

Stock level decision Min.	Max.	EOQ	Avg. inventory, units	Total annual risk cost, US$
–1	0	1	0.0	4,753,951
0	1	1	0.8	469,785
1	2	1	1.8	89,491
2	3	1	2.8	96,732
3	4	1	3.8	129,432
4	5	1	4.8	163,382
5	6	1	5.8	197,380

II. Percent of inventory rarely used at 25 pulp and paper mills

Inventory value, US$	Rarely used, % total
19,009,081	96.8
22,215,211	96.6
10,479,986	96.1
1,623,487	94.6
12,168,845	94.2
20,525,703	93.2
5,508,695	93.1
25,150,292	92.3
11,685,520	91.8
4,508,861	91.6
10,385,114	91.5
3,049,710	91.3
15,364,842	91.0
5,516,601	90.8
6,775,785	90.8
1,384,417	90.7
10,682,677	90.1
5,151,896	89.0
2,193,572	88.3
6,872,467	88.1
6,250,406	86.6
11,015,298	86.0
6,039,899	84.9
8,690,706	83.5
5,357,919	82.8
237,606,990	91.7

values are not available from the supplier.

For new spares, RUSL calculates the stocking levels that correspond to a range of operating lives for the part (usually from less than six months to 20–30 years mean time before failure). This results in an excellent initial stocking decision because the experienced judgment of maintenance is combined with the proven, unbiased logic of the risk-based assessment techniques to set initial stocking levels *(6)*.

Obviously, the best time to eliminate excess and potentially obsolete inventory is before the first unit is purchased. RUSL's new spares methodology has accomplished this objective successfully for tens of thousands of new items.

Conclusions and recommendation

RUSL's risk-based techniques have been used to evaluate the O&M stores inventory at more than 300 sites with US$ 3 billion of inventory. The sites are a mix of nuclear power plants, refineries, pulp mills, offshore oil platforms, mines, and other process operations.

Twenty-five of these sites are pulp and paper mills with US$ 237 million of inventory. **Table II** shows the total inventory and percent rarely used found at each mill.

Because all of these sites previously had been using one or more of the various techniques described earlier in this article, the benefits of the risk-based assessment of spare parts techniques have been dramatic.

Oh yes, why not stock one? In our mega-database of US$ 3 billion of inventory, stocking one is the correct answer for 42% of the items. Stocking none is recommended for 3% of the items (very infrequent failures combined with short lead times and low criticalities). Stocking two or more is necessary for more than half of the items (55%) to avoid excessive disruptions to production.

Despite having the majority of the recommendations being for stocking more than one unit, 40% of the inventory we analyzed has been determined to be stock in excess of the level required to minimize total risk. In these same 300 storerooms, 30% of the items had a reorder level too low to minimize total risk. High cost (and often highly critical) and long lead time (and therefore most difficult to expedite) items were the items most commonly understocked. Maintenance and operating personnel agree with 90% of RUSL's recommendations for stock reductions and 95% of the recommendations for stock increases. Because the value of overstocks outweigh the understocks by a factor of four to one, the net effect is often a 30% reduction in inventory combined with an increase in availability.

In addition to the two risks of getting caught long and getting caught short, a third and most annoying risk exists when setting stock levels. This is the risk that you may recommend exactly the correct stock level for a new or existing spare but are unable to defend the decision. A logical, defendable technique that balances spare parts inventory by eliminating both overstocks and understocks, RUSL's risk-based assessment of spare parts technique has proven to significantly improve availability with substantially reduced total inventory investment at hundreds of locations. TJ

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