A TOOL TO ACHIEVE A SPECIFIC AVAILABILITY AT THE GROUP LEVEL, AT MINIMUM TOTAL COSTS OVER THE GROUP OF ALL SPARE PARTS NEEDED FOR THE MAINTENANCE OF CAPITAL GOODS

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Introduction

This report describes a generic tool that supports in deciding how many of each spare part to put to stock in order to minimize total stock keeping costs, while achieving a specific availability of spare parts at the group level. Spare parts within a group differ with respect to purchase price and demand rate. The disruption of a maintenance process caused by a lacking spare is most of the time independent of the purchase value of the part. This tool allows taking advantage of these differences in purchase price, and of the differences in demand rate. The tool takes a specific required availability at the group level as input, and determines how many of each of the parts within the group should be put to stock in order to achieve that availability at minimal stock keeping costs.
This tool has been developed for a company delivering services for ground support equipment to handle planes at airports.

Scope

The tool considers the spare parts needed for a group of capital goods (vehicles or machines) that are used in operational processes, and that are repaired upon failure in a repair shop. Upon failure of a system, one or more spare parts may be needed. Non-availability of such a spare part disrupts the repair process and increases the repair time, resulting in lower availability of the system for the operational process. The repair process of course also requires other resources, such as a repair dock, repair engineers, and tooling. This tool only considers spare part availability, and it is assumed that the management of the repair shop balances availability and costs of all resources needed, resulting in a target value for the availability of spare parts at the group level. This means that a target is set for the fraction of times that a spare part needed for a repair process can be directly supplied out of stock.

The tool only considers availability and costs of spare parts. The user of the tool should link the spare parts availability with the other resources to estimate the resulting system availability. For the spare parts, the tool considers demand resulting from system failures and/or system inspections. The tool assumes for each spare part a stationary Poisson demand process, which parameter can be estimated with sufficient reliability, and which is independent of the demand process of the other spare parts.

The spare part availability is measured as the aggregate fill-rate, which is calculated by adding up the weighted fill-rates for each spare part in the group. As weighting factors, the spare part demand rates are used. In formulae:

- Let I be the set of spare parts numbered $i = 1,2,3,\ldots$
- Let β_i be the fill rate of spare part i,
- Let λ_i be the demand rate of spare part i,
- Let D be the sum over i of all demand rates,
- Then $\sum_{i\in I}\frac{\beta_i\lambda_i}{D}$ is the aggregate fill rate for the group.

Besides stock keeping costs, also ordering costs are involved in managing spare parts, for some items resulting in ordering batch sizes larger than one. The tool assumes that an (R,Q) inventory policy, i =1,2,3,… , is used to manage the individual spare parts. Thus, whenever the stock on hand plus all items on order minus the backordered demand is less than or equal to R, an integer number of Q spare parts is ordered.

The tool assumes that R_i and Q_i are determined sequentially. First, Q_i is determined for each spare part. Next, in the optimization, the reorder levels R_i for each spare part are set, taking the ordering batch sizes as given.

Optimizing the R_i in order to minimize total stock keeping costs while achieving a specific aggregate fill rate is computationally difficult. Therefore, the tool used an approximation technique that splits up the group of spare parts in subgroups, with each subgroup containing spare parts that have similar demand rate and spare part costs characteristics. Each spare part in a subgroup has the same target fill rate, but target fill rates can differ between subgroups. The tool searches for subgroup fill rate targets that minimize total stock keeping costs while achieving the target aggregate fill rate.

The tool assumes that the user splits up the spare part in nine subgroups, combining parts with low, medium, and high demand rate, with parts with low, medium, and high prize, (see the classification in Figure 1), such that each subgroup contains about the same number of spare parts.
Once the subgroups are formed, a subgroup fill rate target is set for each subgroup.

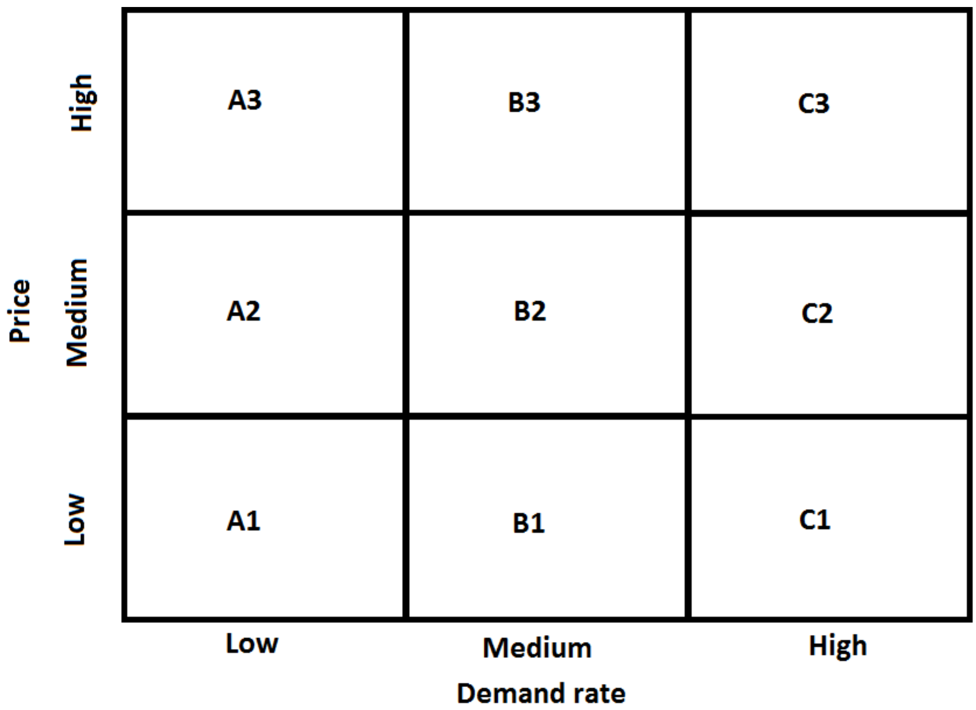

Figure 1 Example of classification used in the tool

The fill-rate targets for each subgroup within the classification to achieve the aggregate fill-rate target are determined by a greedy algorithm. In the next section we describe the working of the tool that has been developed to do this.

Tool description
The tool consists of three modules that are used consecutively and iteratively.

Module 1 calculates for each spare part the order quantity, Q_i, which is done independent of the reorder point. The tool applies the classical Economic Order Quantity formula: $EQ_i = \sqrt{\frac{2*C_i^o*\lambda_i}{C_i^m*h}}$.
The outcome is rounded to an integer number, excluding 0. Inputs to this module are the demand rates, λ_i, the prizes, C_i^m, the ordering costs C_i^o, and the stock keeping costs rate h. Stock keeping costs should include the risk of obsolescence. However, the obsolescence risk of a spare part is difficult to estimate and express in a cost figure. Therefore we use a different approach and specify a parameter, T^{Max} , that indicates the maximum period of average demand for which for that spare part items can be ordered at once. After the economic order quantity has been determined, the module sets the order quantity, Q_i, equal to the minimum of EQ_i and $\lfloor T^{Max} \lambda_i \rfloor$.

Module 2 operates on the spare parts in a subgroup. It takes a specified subgroup fill rate target as an input, and then calculates for each spare part in the subgroup the smallest integer re-order level, R_i, that given the order batch size Q_i, the demand rate λ_i, and the replenishment lead time L_i, results in a fill rate that is larger or equal to the specified target fill rate target. Since both the order quantity and the re-order level must be integer values, the actual fill rate resulting from this re-order level may be larger than the specified fill rate target. Therefore, after the calculation of the reorder points, the actual fill-rates are calculated, as are the stock keeping costs for each spare part in the subgroup. Thus, the input to this module is the subgroup fill rate target, and the outputs are the re-order levels, the actual fill rates and the stock keeping costs.

After this procedure has been applied to all nine subgroups, the resulting actual fill rates per spare part are input to Module 3 which calculates the aggregate fill rate and the aggregate stock keeping costs.

Module 2 is used in an iterative process to determine the re-order levels that satisfy the aggregate fill rate targets. The iterations start with setting (low) initial fill rate target for each subgroup, and then apply Module 2 to calculate first round values for reorder levels, actual fill rates and stock keeping costs. Then module 3 is applied to determine the first round aggregate fill rate.

We may expect the first round aggregate fill rate to be lower than the aggregate fill rate target. If this is the case, we then increase the subgroup fill rate targets by a certain step size (which is an input to Module 2), and determine for each subgroup the re-order levels, the actual fill rates, and the stock keeping costs resulting from this increase.
We next apply Module 3 to determine for which subgroup, the increase in fill rate target gives the largest ratio of increase in aggregate fill rate over increase in stock keeping costs. For this subgroup, the fill rate target is definitely increased with the step size (The biggest bang for the buck). For the other subgroups, the old fill rate targets are restored.

Finally, Module 3 is used to calculate the aggregate fill rate resulting from these subgroup fill rate targets. If this aggregate fill rate is still smaller than the aggregate fill rate target, the next round in the iteration process is started. For each of the subgroups, the fill rate target is again increased with the step size, and the whole process is repeated until the aggregate fill rate is equal to or larger than the aggregate fill rate target.

The outputs of the tool are the aggregate fill-rate, the aggregate stock keeping costs per year, and the aggregate ordering costs per year. Besides, the tool gives the stock keeping costs and ordering costs per subgroup. Also the control inputs, being the aggregate fill rate target and the subgroup fill rate targets, are shown. Figure 2 gives a screenshot of the graphical user interface of the tool.

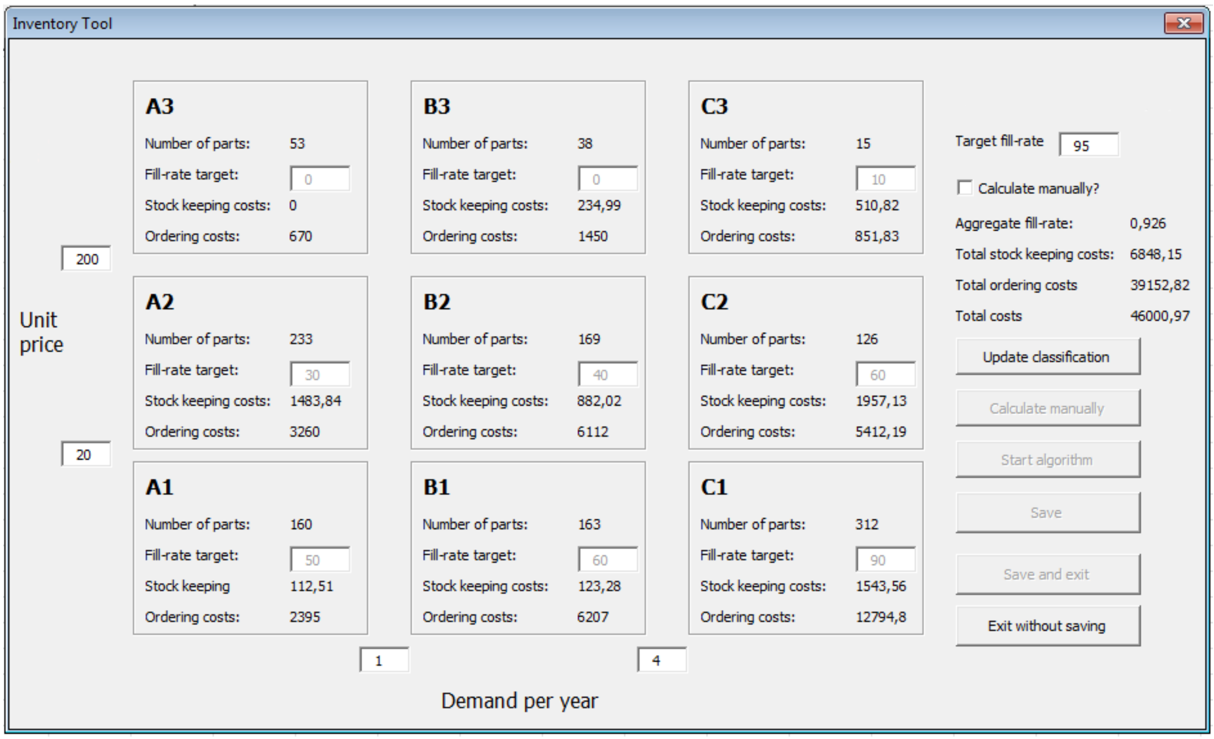

Figure 2 Example of tool result

On a more detailed level, the tool provides information at the spare part level about the re-order points, the order quantities, stock keeping costs, the ordering costs, and the fill rates.