Robust Data-Driven Sparse Parts Inventory Management Under Uncertain Demand

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We consider the problem faced by spare parts inventory that demand intensity for components is unclear at the beginning of a product life cycle and typically fluctuates over time. We present a robust optimization (RO) approach in spare parts inventory with demand uncertainties. Then, we develop a more time-efficient algorithm capable of finding solutions in case of a large number of items in the model. Furthermore, we conduct extensive experiments to compare the performance of our ARO model with the conventional Poisson-based model. According to the experimental results, the ARO model exhibits remarkable efficacy in case of limited information on the demand distribution, while the conventional one performs better if the demand distribution is close to a Poisson distribution, and there is enough data to determine the parameters of the distribution.

Introduction

This project is in collaboration with ASML. As an innovation leader in the semiconductor industry, ASML focuses on proactively managing spare parts to guarantee their availability. In recent years, the company reported increased sales of the new generation of machines, which are in the early stage of their life cycle. The life cycle research for these new machines is not mature, resulting in challenges in spare parts inventory control systems.

In the conventional spare parts inventory models, it is assumed that demand follows a (compound) Poisson distribution, which requires the availability of a large amount of data to extract the essential information for the distribution. Such assumptions are simple and impractical, especially when the demand for spare parts is sporadic. This project focuses on the situation with limited information and much uncertainty on demand, especially in the initial stage of a product life cycle.

Methods and Approach

We propose a robust optimization (RO) approach in spare parts inventory control and investigate the

applicability of RO for spare parts inventory in this project. The investigation starts with the theoretical comparison between two spare parts inventory models: the traditional spare parts inventory model and the RO ones. The traditional model is under a single-location, multi-item spare parts inventory and extended to consider the emergency shipment (Van Houtum Kranenburg, 2015). A simulation-based comparison is carried out under given historical demand data with different demand characteristics. This investigation helps us understand the most suitable environment for using RO in spare parts inventory.

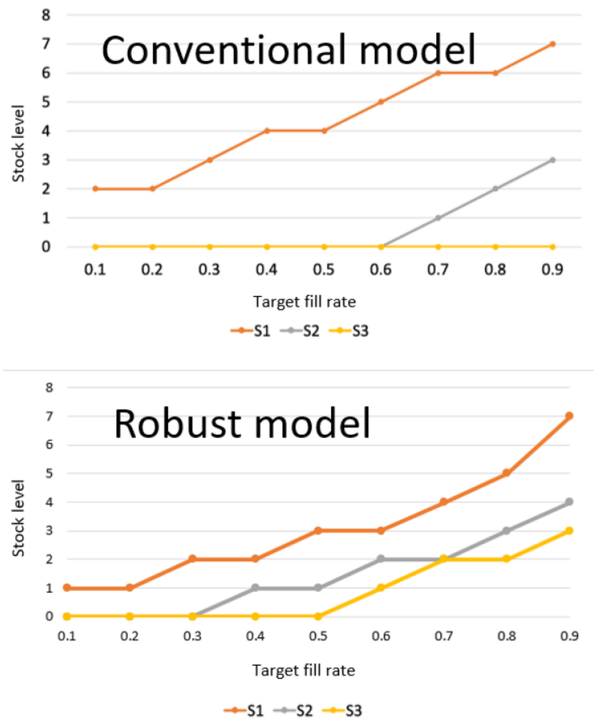

Figure 1: Solutions to conventional and robust models for the illustrative example.

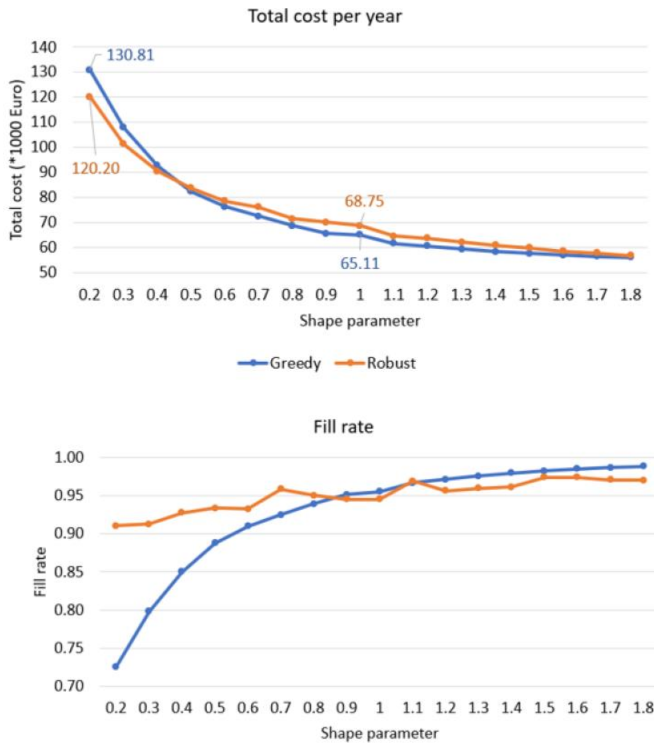

Figure 2: Total costs and fill rates under Weibull distribution.

Results and Observations

We use an illustrative example for three SKUs. The average number of failures per year is 15 for SKU 1, 5 for SKU 2 and 1 for SKU 3. The average repair lead-times are equal to 2 months for all three SKU's. The price of SKU 1 is 1,000 Euros, the price of SKU 2 is 3,000 Euros and the price of SKU 3 is 20,000 Euros. Figure 1 shows the solution of the conventional model obtained by the greedy algorithm and the exact solution of the robust model. We find that the conventional model prefers to store more spare parts at lower prices for SKUs. When the target fill rate grows, the lower-priced spare parts have priority to reach a higher stock level. In contrast, the robust model's solution is not sensitive to the price of spare parts.

Now we consider a situation that the arrival interval of spare parts demand is not an exponential distribution, but Weibull distributed. This consideration stems from the fact that ASML test their spare parts demand with a Weibull arrival process and finds that the shape parameters are normally distributed with a mean of one. We vary the shape parameters from 0.2 to 1.8 of Weibull distributions with a target fill rate of 0.9. When the shape parameter is greater than one, i.e., more lead-time demands converge to the average, the results of both models can reach the target, and the conventional model costs less. The robust model performs better when extremely high demand occurs more frequently.

Discussion and implication

Our investigation of spare parts inventory models in a less complex environment: we assume that the failure predictability can only be based on historical demand data. We will further investigate at a more complicated situation. We consider incorporating sensor data and the opinion of reliability engineers to improve the predictability of failures, especially in the initial phase of the product life cycle.

References

Van Houtum GJ, Kranenburg B (2015) Spare parts inventory control under system availability constraints, volume 227 (Springer).

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