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Emissions included spare parts inventory planning

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Introduction

ASML's supply chain supports the uptime and reliability of their advanced lithography systems, which are used for semiconductor manufacturing worldwide. Traditionally, the planning of spare parts inventory at ASML has been driven by the objectives of minimizing operational costs and ensuring that strict service level agreements (SLAs) are consistently met for customers.

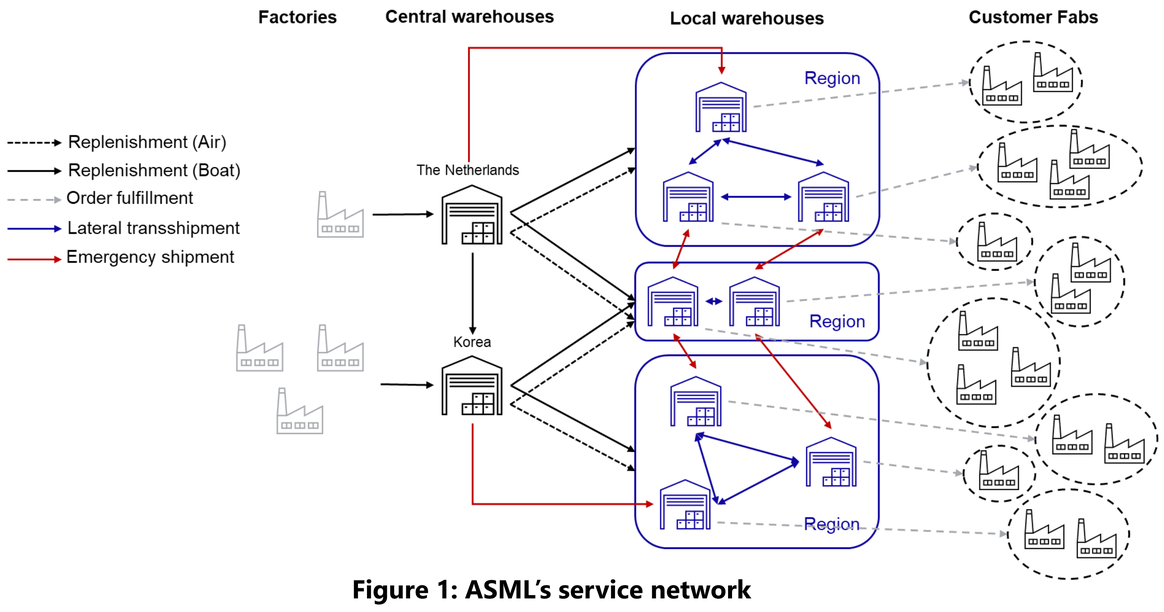

Figure 1: ASML's service network

Problem statement

As ASML becomes aware of the urgency to address climate change, the environmental impact of inventory decisions must now be considered as an integral part of the planning process. Meeting ASML's commitment to achieving net zero greenhouse gas (GHG) emissions by 2040 requires a fundamental rethinking of how inventory and logistics decisions are made, balancing the traditional imperatives of cost and service with the new lever of sustainability. Of ASML's upstream scope 3 emissions - about 98% are attributed to inventory and transportation, with the company's usage of air freight, a major contributor to the transportation emissions. While switching to greener modes of transport could reduce emissions, this change would increase lead times & risks breaching the service level agreements. This creates a fundamental trade-off: how can ASML reduce its environmental footprint without sacrificing reliability and responsiveness? This requires balancing of competing objectives through a new approach to supply chain planning.

Solution design

The research addresses the challenge by developing an approach with three incremental layers on top of the existing SPartAn (**S**pare **Part**s **An**alyzer) planning model, which determines near-optimal base stock levels for each item-location combinations. The first extension was to account for emissions generated by the inventory holding and transportation activities. Emissions are quantified using spend-based estimation for inventory holding, and distance-based estimation for transportation, in line with GHG Protocol Reporting Standards.

The second extension is the introduction of a dual base-stock policy. Here, each material at each location is assigned two inventory thresholds. The upper threshold triggers replenishment by boat, which is slower but low in emissions, while the lower threshold triggers replenishment by air, which is quicker but high in emission footprint.

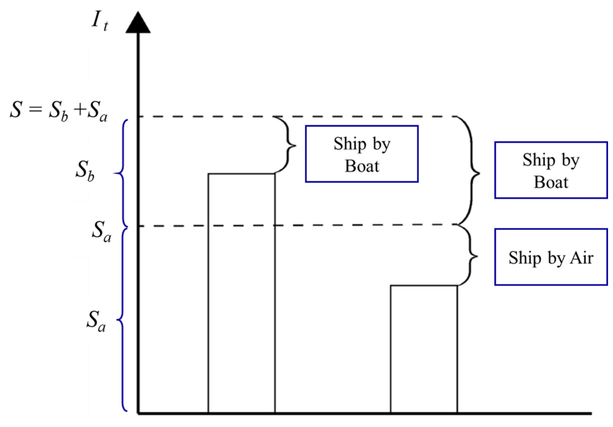

Figure 2: Dual base-stock policy

This allows the planning to explicitly control how much of the replenishment volume is allocated to each transport mode. By maintaining separate thresholds, the model can dynamically allocate inventory and transportation resources in response to changing demand patterns, lead times, and service targets.

The third extension is made to systematically explore the trade-offs between cost and emissions. An epsilon-constrained approach is used to construct the pareto frontier between operational costs and emissions. By solving the model under progressively tighter emissions budgets, it is possible to identify the cost of incremental emissions reductions and to reveal the points at which further reductions become disproportionately expensive. This provides valuable insights for decision-makers, allowing them to understand the relationship between cost and emissions, highlighting the opportunities and limitations inherent in different strategies.

Results

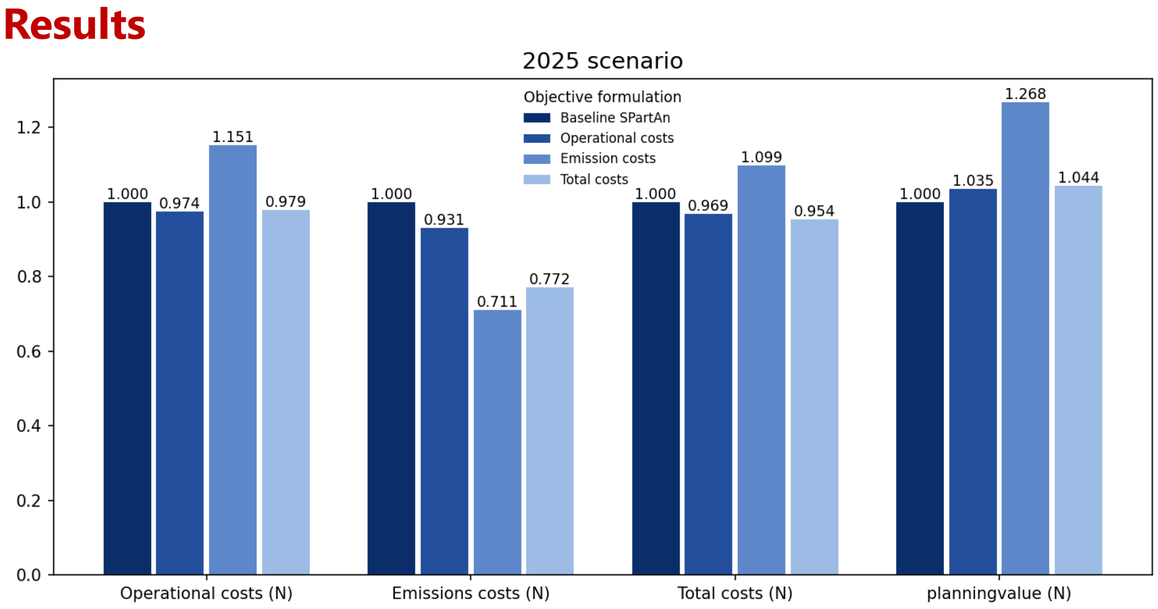

Figure 3: Results for 2025 demand scenario

A case study based on an ASML region for the current & future scenario was made, with the full assortment of spare parts and demand patterns preserved to ensure practical relevance. The results demonstrate that it is possible to achieve substantial reductions in GHG emissions while also reducing or maintaining operational costs. In the 2025 scenario, optimization across both cost and emissions enables a reduction in emissions of approximately 22.8% and a reduction in operational costs of about 2.1%, compared to a baseline scenario in which all replenishment is performed by air. Allocating half the replenishment volume to boat brings emission savings while maintaining service. Comparing the 2025 baseline with 2030 scenario brings in 67% increase in demand – Here the extended model achieves only 6.8% increase in emissions at optimal costs formulation and 4.1% reductions in emissions when optimizing for emission costs, against 24% allowed increase in gross emissions.

Practically, ASML can achieve significant GHG benefits without incurring costs, when the right balance is struck between inventory, transport and service. Aggressive emissions reduction requires higher inventory to buffer against the longer lead times but enables compliance with ambitious & stricter sustainability targets.

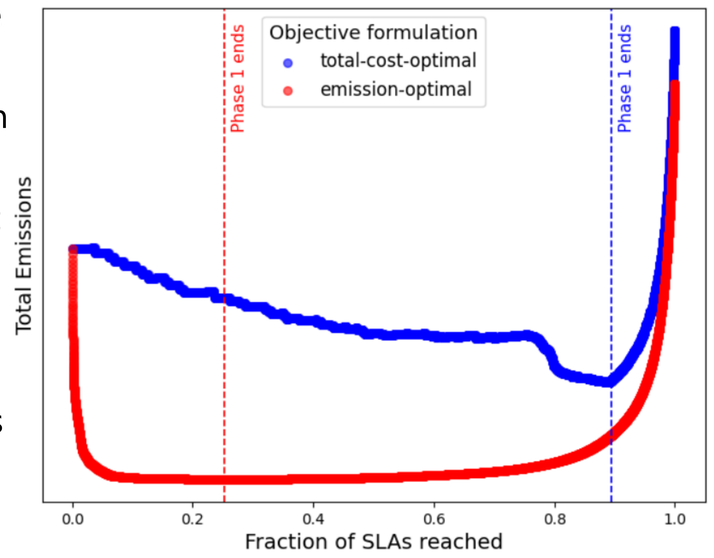

Figure 4: Emissions distance between cost & emission-optimal solutions as fraction of SLAs met

References

van Houtum, G.-J., & Kranenburg, B. (2015). Multi-location system with lateral transshipments. Spare Parts Inventory Control under System Availability Constraints, 97–125.

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