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**eSCF Operations Practices:
Insights from Science**

Spare Parts Planning at ASML

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European Supply Chain Forum



Where innovation starts

Enhancing spare parts planning

The use of advanced planning methods to provide excellent services

Concise summary of this best practice

Key to successful provisioning of high tech spare parts is the use of advanced planning methods. This best practice discusses how ASML organized its global spare parts network, using a custom-made planning method. Doing so, ASML has further improved their service level, whilst simultaneously reducing total costs. Instead of being an organizational burden, providing service is now a distinguishing competitive factor.

Key terms

Service supply chains, high tech spare parts inventory, pooling, emergency and lateral transshipments.

Relevant for

Equipment vendors, moving into service level agreements (such as ASML, Océ, Vanderlande Industries, IBM, Stork, Thales, Airbus, Boeing, etc).



ASML: from technology leader to market and technology leader

ASML is a Dutch equipment manufacturer in the semiconductor industry. ASML designs, supplies and integrates advanced technological equipment, called lithography machinery. The customers of ASML (such as Intel, AMD or Samsung) have billion dollar plants that house and exploit the equipment to produce semiconductors. The lithography step is one of the many steps in the high tech production environment, but the lithography step is crucial in terms of throughput and in terms of 'chip generation'. On the newest chip generations, the IC pattern has been shrunk and therefore the chip will be smaller, more powerful and more valuable. Time to market is everything, since new generations earn exponentially more money than older generations.

Avoiding and decreasing down-time costs

In semiconductor plants, the ASML machines are the most capital intensive, which generally means that plants are developed such that ASML-machines are the bottleneck of the process. Customers therefore generally strive for high occupation rates of the machines in their production processes. If an ASML machine breaks down, this can cause the whole production process at the customer to go down, resulting in down-time cost of tens of thousands of Euros per hour! The incurred downtime costs can easily run into millions of Euros per failure. So, investments to decrease downtimes pay off. The expected performance of the service is agreed upon in the service level agreements (SLA's). At ASML, most customers require an availability of their systems that corresponds to a minimum aggregate mean waiting time of a few hours only.

Customer retention

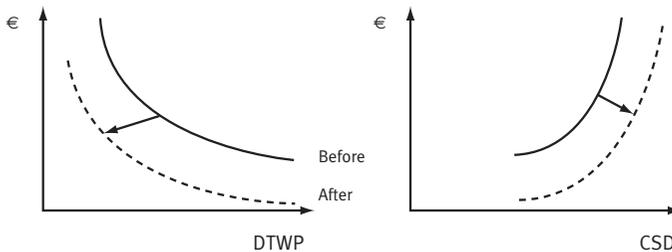
Customer retention is a very important value for ASML. The key element of satisfying and retaining customers is service performance (especially in demanding and capital intensive businesses, such as the semiconductor business). This implies that ASML needs to be determined to deliver customized service that solves the customer's problem. Therefore, ASML requires a reliable and flexible supply chain with a state-of-the-art planning, accurate part delivery and high part quality. Cost effectiveness is a secondary concern, but obviously, costs are solely acceptable when value is delivered to customers.

This best practice focuses on the performance of spare-parts networks. The performance of a spare-parts network can be measured in multiple ways. ASML uses the terms Down Time Waiting Parts (DTWP) en Customer Satisfaction Degree (CSD). DTWP is the fraction of time that equipment is not available due to waiting for spare-parts, and CSD is the fraction of parts that is available in the local warehouse. When the DTWP is low and the CSD is high, the system availability will increase.



The causal relation between service performance and customer retention.

Spare parts management is often considered as a special case of inventory management, because spare parts have characteristics that make inventory decisions more difficult: Spare parts are often very expensive, the demand volumes and rates are low, and the parts are often highly critical and specifically build for a certain system. Moreover, the objective of spare-part inventory management is not to so much to obtain a certain service level, but to contribute to a certain level of system availability for the customers.



To improve customer service at lower costs, ASML desires to shift the curve between costs and availability downwards via innovative projects.

Spare parts inventory management

The key challenge of inventory management is balancing inventory costs and the value of service. Holding inventory entails costs (i.e. handling and disposal costs, lost capital opportunities, used storage space, etc) but inventory facilitates service by enabling the provision of parts demand without the delay of production and transportation.

The balance between inventory and service, in terms of low DTWP and high CSD rates, is depicted in Figure 2 with the solid curve. To improve service levels, one has to increase the stock levels. It is also possible to alter the balance, preferably to manage it downwards. This will improve service for the same or less costs. This requires improvements in part quality, part demand and part delivery. This best practice focuses on the latter.

The challenge

There are many methods to plan the stock levels of the spare parts inventory. In general, it can be stated that if one desires an accurate balance between costs and service, the model has to become more dedicated and will become more complex (see Figure 3). Qualitative methods, such as prescription or opinions, are outperformed by more complex, quantitative methods. Commercial spare part planning packages will (most likely) include multiple-item methods, to calculate the cost availability equilibriums.

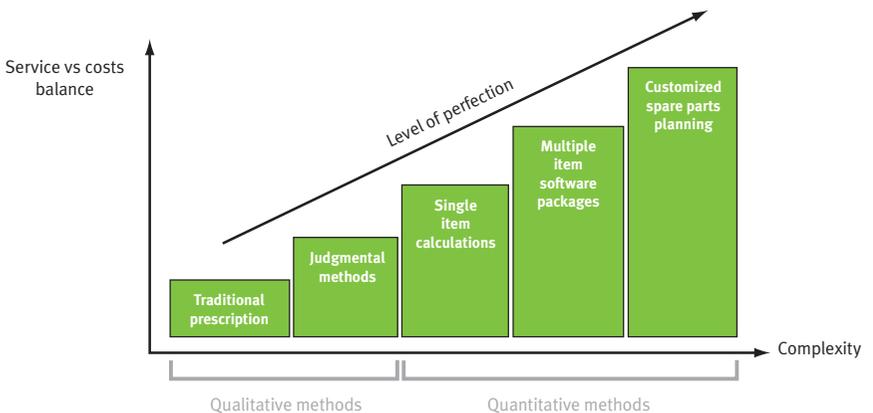


figure 3

ASML strives for a high level of perfection in its spare-parts delivery to meet customer's demands.

However, the requirements set by the management of ASML exceeded the capabilities of commercial spare-parts planning packages. The distribution network of ASML proved to be more flexible than the planning packages could handle. Moreover, these models did not take customer differentiation into account, which would allow a company to tailor the service levels for a specific customer. ASML required a planning method that integrates multi-item, multi-location, multi-transportation-options and customer differentiation simultaneously. Such a complex package did not exist yet. The management of ASML decided to develop the planning method in cooperation with the Technical university of Eindhoven.

ASML initiated the PhD project of Bram Kranenburg, to build a customized spare parts planning model. His tasks were to:

1. Customize the planning method to enable different customer contracts;
2. Simulate the real-time situation of the spare parts distribution network, and to model multi-location, multi-transportation options;
3. Develop a planning heuristic that was fast and accurate;
4. Investigate the potential business opportunities of ASML's spare part strategy;
5. Implement the improved planning methods in SAP.

Availability

Generally, companies that install complex technical systems require high availability, because their primary processes may depend on these systems and the capital investments are high. The downtime costs are therefore high, and the suppliers are expected to ensure their systems are operating smoothly. Not surprisingly, there is a direct relation between system availability and profit. Therefore, customers are more aware of the total costs of ownership, and their requirements for capital investments shift more towards serviceability, accountability, reliability and availability, as opposed to the products specs solely.

The multi-item service differentiation challenge was developed and implemented at ASML in a little over 18 months. This enabled ASML to provide the customized service levels that are offered in the Service Level Agreements (SLA), defined for each customer separately. The second task was tackled and implemented in the comparable pace. Let's take a more in-depth look into the multi-item, multi-location, multi-transportation modeling at ASML.

Situation description

The customers of ASML are clustered in certain areas over the world. To keep DTWP to a minimum, ASML has set up a network of warehouses, with a local warehouse in each of these clusters. The local warehouses are replenished from the global warehouse in Korea, with a lead-time of approximately two weeks. When a customer requires a spare part, it is preferred to deliver from the nearest local warehouse. When the part is not available in the local warehouse, ASML uses two transportation options to minimize the DTWP:

1. **An emergency shipment** (from the global warehouse in Korea)

An emergency shipment will be carried out from the central warehouse to the local warehouse, which requires about 36 hours if the local warehouse is in North-America or in Europe, and up to 18 hours when the customer is situated in Asia. This is shorter than the regular replenishment time, but still quite long compared to the expected repair time of a few hours as guaranteed in the SLA.

2. **A lateral transshipment** (from a neighboring local warehouse)

The second option to quickly provide the customer with the required part is the so-called lateral transshipment, where the part is provided from another neighboring local warehouse. The main advantage of this strategy is the lead-time reduction to just 5 to 10 hours, thus it drastically reduces the mean waiting times compared to an emergency replenishment. The drawback of this strategy is the increased likelihood that the neighboring warehouse go out-of-stock, potentially harming other customers.

In daily operation, ASML has been using lateral transshipments for years, because it is faster and cheaper than emergency replenishments. However, during the assignment of base stock levels to each warehouse, the actual usage of lateral transshipments has not been taken into consideration. This leads to imbalances in stock levels: either the stock levels at regular local warehouses are too high, or the stock levels at main local warehouses are too low. These imbalances lead to large mean waiting times, low satisfaction rates (CSD), and high transportation costs.

The network structure to provide spare parts

The network structure that is used in the research of Kranenburg matches the situation observed in the practice of ASML. It distinguishes two types of local warehouses: *main* and *regular* local warehouses. Main local warehouses are allowed to supply lateral transshipments, whereas regular warehouses are not allowed to do that. Both main and regular local warehouses can receive a lateral transshipment (see Figure 4).

Obviously, it is desirable that the warehouses that provide lateral transshipments are capable to provide these parts quickly. These warehouses are generally larger, they supply more customers, they observe higher demand rates, and they are closely located to airports.

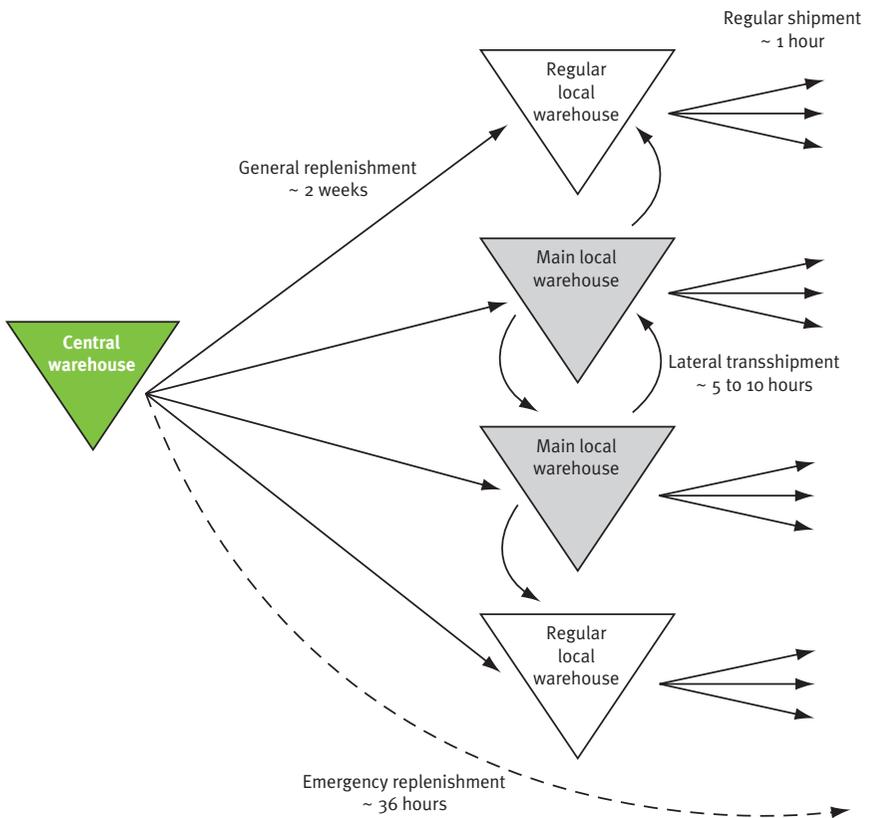


figure 4

The service supply chain at ASML.

The beauty of this method is that it is generally applicable, and many service distribution networks (if not any) can be simulated. When there are only regular local warehouses, no lateral transshipments are allowed, hence, this is a no pooling¹ situation. When there are only main local warehouses, this is a so-called full-pooling situation. It is also possible to model distribution warehouses, that solely supply lateral transshipments. In this case, the main local warehouse receives no direct demand. This is the so-called quick response stock or regional warehouses, which are being used by several companies (for example Océ).

Modeling the service network

In his research, Kranenburg modeled the service network structure of ASML in America. ASML America uses 19 warehouses to service 27 customers. Four warehouses are indicated as main local warehouses, which are allowed to provide lateral transshipments (partial pooling). The dataset for the 19 warehouses in the United States is as follow: there are 1.451 SKU's, with prices ranging from 1 € to 1.000.000 €. The costs for an emergency shipment and a lateral transshipment are respectively 1.000 € and 500 €. The holding cost rate is set to 25 % per year, and the target average waiting time for a part is set to 0.15 days. The demand rates for the parts are very low for most parts. The highest value occurring in the dataset is 36 items per year per customer. Concerning the lateral transshipments, two business questions arose. Firstly, ASML desired to understand the benefits of using lateral transshipments, and secondly, ASML desired to know the additional benefits from including lateral transshipments in de spare-parts planning.

Business opportunity 1: the benefits of using lateral transshipments

The benefit of using lateral transshipment can be seen in Table 1, where the number of main local warehouses is varied. The current situation with four main local warehouses is normalized to 100 %. It can be seen that without the use of lateral transshipments, the total yearly costs (virtually) would have been 93 % higher. It can be concluded that the use of lateral transshipment has improved the efficiency considerably. It can also be seen that *upgrading* the other 15 regular warehouses to main warehouses is less useful, because the cost reduction is relatively low. The cost reduction would be less than four percent.

¹ Risk pooling is one of the most powerful tools to address variability in the supply chain. When demand is aggregated, the coefficient of variation (the relative standard deviation) becomes smaller, which means that the demand can be supplied from a common pool of inventory. Therefore, the total required safety stock can be decreased, reducing total inventory costs. There are a few types of pooling, including location pooling, virtual pooling, product pooling.

So, this is interesting: the major of the benefits is obtained from upgrading the first couple of local warehouses to main local warehouses, so there is little value to upgrading all local warehouses to main local warehouses.

Number of main local warehouses	Total yearly costs (normalized)
0 (no pooling)	193.0 %
4 (the current situation)	100 %
19 (full pooling)	96.1 %

table 1

The use of lateral transshipments.

Business opportunity 2: the additional benefits of planning lateral transshipments

As stated before, prior to this research, ASML did not take lateral transshipments into account in the planning phase, i.e. the inventory in each local warehouse was planned separately. Nevertheless, lateral transshipments were used as soon as a warehouse ran out-of-stock. It can be seen that there is quite a gap between the targeted waiting time and the realized waiting time, which means the target average waiting time was over-satisfied (see observation A).

To assure that the same objective was realized with the new planning model, 0.1007 was set as target waiting time for the new method. It can be seen that an additional yearly efficiency improvement of 31.5 % is achieved (see observation B) when the use of lateral transshipments is taken into account in the planning method. This means that the use of lateral transshipments indeed decreases both costs and waiting times. Moreover, the realized waiting times is just slightly better than the target waiting time, so it can be concluded that the planning method has become much more accurate.

Method to assign base stock levels	Targeted waiting time in days	Realized waiting time in days	Total yearly cost (normalized)
Old method	0.1500	0.1007 [A]	100 %
New method taking lateral transshipment into account	0.1007	0.0975	68 % [B]

table 2

The additional benefit from including lateral transshipments in the planning.

Conclusions and recommendations

The aim of the dissertation of Kranenburg was to further enhance multi-item spare parts inventory control models, and to model the situation at ASML with a high accuracy. An important feature of this algorithm is the fact that spare part provisioning is not an aim in itself, but a means to realize high availability of the equipment. The new planning method deliberately increases the right stocks at the main local warehouses to enhance the total service at lower total costs. Generally, a higher number of different SKU's are stocked in the main local warehouses, which improves the total solution.

Kranenburg's dissertation shows that, for datasets obtained from ASML, substantial yearly savings (in the order of 30 % on the total costs) are realized when lateral transshipments are taken into account in the spare parts inventory planning method. Based on Kranenburg's work, ASML decided to implement his greedy heuristic into their spare parts inventory planning method. Nowadays, the method is completely integrated in the customized SAP system.

ASML is using the algorithm since early 2006 and succeeded in reducing both waiting times and cost considerably. Obviously, this dissertation is not a stand-alone project, and the results have to be seen in the light of a combination of projects. Other projects to improve customer service include:

- Transparency of real-time material movement in SAP;
- Part quality improvement to eliminate fast movers
- Active removal of slow-movers and non-movers;
- Move of the global warehouse from Netherlands to Korea.

The results are stunning! ASML has been measuring the performance of an older generation machines. In the last four years, the service rates have improved by a factor 10, and the total inventory decreased by a factor two! The savings, using the spare-part planning algorithm of Kranenburg², have been used to reallocate the inventories and this has led to an improved customer service. Now, in 2010, services and spare part provision have become value drivers and distinguishing competitive factors. This makes this research at ASML a true supply chain best practice!

² It is difficult to precisely assign the impact of a certain project to this total results, because these projects have been executed simultaneously.

Concluding, it can be stated that the implementation of Kranenburg's research has shown the enormous potential of applications of supply chain theories. One of the key factors to success, besides the devotion of Kranenburg and the employees of ASML, was the intense working relation between ASML and the Eindhoven University of Technology. Now, after multiple PhD and master thesis projects, this relation has become a strategic partnership.

Service in the capital goods industry

Customer intimacy and customer retention are becoming increasingly important for capital goods manufacturers. A number of trends explain why it has become more difficult to compete on the traditional marketing mix and product leadership: competition has further escalated, markets have further globalized, and the customers have become more demanding. These trends created conditions and incentives for equipment manufacturers to increase their responsibility and (by moving downwards in the value stream) increase their share in the service market.

The potential benefits of developing services for a manufacturing company are:

- **Building customer loyalty:** Customizing service, to meet each buyer's unique needs, provides the basis for a prospering cooperation and customer loyalty. The higher margins and recurring revenue streams easily pay back the investments done to offer customized service packages.
- **Differentiation from the competitors:** High-tech companies should focus on service because they cannot survive only on their 'competitive edge'. Technical advantages disappear too quickly, whereas services are more difficult to copy.
- **Increasing and stabilizing turnover:** The high-cost capital goods tend to be bought at irregular intervals, making suppliers vulnerable to periods when the volume of work declines and their revenues and operating margins shrink. Services potentially increase turnover (and margin on that turnover), and the revenue streams of services are predictable and continuous throughout the life-cycle.
- **Corporate image:** Providing adequate services that hugely impact (or break) the corporate image. Royce Rolls, for example, is so keen on ensuring their corporate image that they will do whatever it takes to repair your car. They will fly-in engineers to Africa to help a stuck 'rolls' driver.

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Editorial

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