Proactive Service Logistics for Advanced Capital Goods (ProSeLo):

Full Proposal-Project Plan

The project plan consists of six parts:
- Summary
- A. Orientation and Project Goals
- B. Activities/Work packages
- C. Consortium and Project organization
- D. Evaluation
- E. Valorization and implementation

Summary

The summary is a maximum of 1 A4 and will be used for communication purposes. Please include the following: 1. Motivation and goals (including links to innovation program 2. Activities / work packages 3. Expected results 4. Innovativeness 5. Valorization strategy and implementation strategy

Capital goods like lithography systems, large-scale computers, and baggage handling systems become more and more advanced. The primary processes of users are strongly dependent on the availability of these capital goods and they require very high availability levels. Realizing these very high availability levels is hardly possible (or very expensive) when maintenance is organized by individual users. Hence, more and more maintenance activities are shifted to the manufacturers, who, due to pooling effects and the value of collecting failure and degradation data at a central level, can organize this in a much better and much more efficient way. In some industries it is already common for users to close full service contracts when a new system is bought, and there it may even occur that users do not buy the system anymore but just its function. In other industries, one moves into the direction of having all systems under full service contracts. Under full service contracts, the manufacturer is responsible for all maintenance costs and realizing the Service Levels Agreements. Users then get a clear picture of their Total Cost of Ownership (TCO) at the moment that they buy a new system, which is an additional stimulating factor for the shift of maintenance activities to manufacturers.

A manufacturer needs to have a well functioning control tower under full service contracts. The task of a control tower is to control all maintenance activities at an operational, tactical, and strategic level. In this project, we focus on the strategic and tactical level. We study: (i) the sharing of spare parts that are owned by different companies or that belong to different service contracts; (ii) new concepts to deal with last-buy decisions and to facilitate the re-use of parts, modules, and systems; (iii) new predictive maintenance concepts that make use of the possibilities that are offered by remote monitoring and diagnostics. The first two topics aim to realize a much more efficient service supply chain under given failure levels of systems. By the third topic, we aim to prevent failures, and thus unscheduled downtimes, by

replacing components some time before they would fail. With these new concepts, we aim to get the best of two worlds, viz. an increase in availability levels and a decrease in TCO. Our new concepts will strongly contribute to the competitiveness of manufacturers, and thus they can increase their market shares. In addition, by establishing or extending their control towers in the Netherlands, there will be a strong increase in GNP and in jobs for highly-skilled people. Obviously, the Netherlands will increase its attractiveness by developing knowledge and educating people in the above areas.

The consortium for this project consist of 14 parties. Eight of them are manufacturers who all have one or more of the above topics on their own roadmaps: ASML, DAF, Fokker Services, IBM, Océ, Marel Stork, Thales, and Vanderlande. All these manufacturers are global players and they are top players in their markets. Next, Ceva Logistics is involved as a 4PL logistics service provider for studying the reducing effect of more preventive (i.e., scheduled) replacements of components on the costs of the service supply chain. Gordian Logistics, a leading consultancy firm in the area of service logistics, is involved to lead the valorization activities, for which we developed a valorization strategy and for which we reserve a significant part of our budget. The Service Logistics Forum (SLF), a leading Dutch knowledge platform for service logistics, plays an important role in the dissemination of the generated knowledge via their workshops and yearly congress with 150-200 participants from a broad scope of industries. At the scientific side, we have three universities that have a extensive track record in service logistics and maintenance management: Eindhoven University of Technology, Erasmus University, and the University of Twente. Apart from Ph.D. students and postdocs, a whole group of master thesis students will be involved to obtain to high level of a two-way knowledge transfer between the universities and the companies.

A. Orientation and Project Goals

Motivation

This section describes the motivation for initiating this project, the real and topical issues underlying the project and the urgency to address the issues.

Capital goods are machines or products that are used by manufacturers to produce their end-products or that are used by service organizations to deliver their services. Capital goods have a life cycle consisting of 5 phases; see Figure 1. In the first phase, based on feedback from the market and knowledge on technical possibilities, needs and requirements are defined. Next the system is completely designed. After that multiple units of the system are being produced. Then, in the exploitation phase, the systems are used, and finally the system is disposed of.

Figure 1: Life cycle of a capital good

The focus of this proposal is on *advanced capital goods* like lithography systems, large-scale computers, baggage handling systems, and so on. These capital goods are technically complex, they are expensive, users are completely dependent on their availability, downtimes may be very expensive, and they have long life times (20-40 years, say). For these advanced capital goods, there is a long-term trend that users are interested in getting a function rather than a product, and they look how expensive the function is per unit of product/service that they produce themselves (see Cohen et al. [2006] and Oliva and Kallenberg [2003]). E.g., an airport like Schiphol is interested in buying the function 'handling of baggage' rather than in buying a 'baggage handling system', and they are interested in the cost per handled bag. It is also known that for advanced capital goods, only a fraction of the Total Cost of Ownership (TCO) consists of the buying price of a new system. The largest part of the TCO consists of maintenance and downtime costs. Maintenance costs form often an equally large amount as the price of the new system, and direct and indirect costs of downtime can easily be higher (see e.g. Öner et al. [2007]).

The transition to function-oriented markets offers a great opportunity to Original Equipment Manufacturers (OEM-s) such as ASML, DAF, Fokker, IBM, Marel Stork, Océ, Thales, and Vanderlande, which are all involved in this proposed project. Via *full service contracts*, they can arrange that they become responsible for all maintenance activities ánd for managing the availability of their systems. They can establish or further extend the *control tower* for all maintenance activities, ánd possibly also for the systems produced by competitors. The objective of this control tower is to provide the best combination of system availability and TCO. This is equivalent to providing the lowest possible levels for downtime and TCO. The tradeoff between downtime and TCO is depicted by the solid line in Figure 2. This line shows that TCO will go to infinity if users require lower and lower downtimes and nothing is drastically changed.

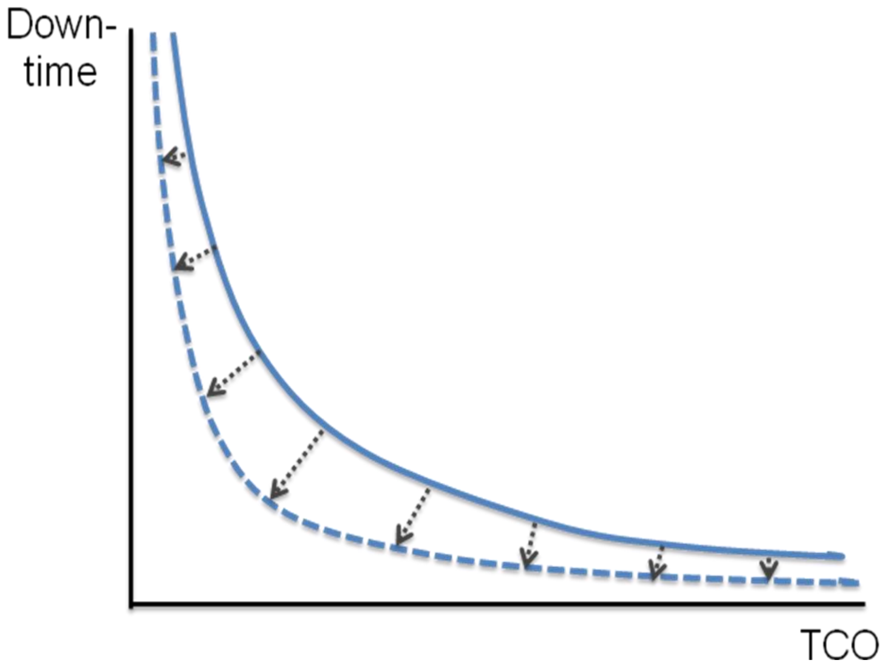


Figure 2: Downtime versus TCO

In this proposed project, we aim to investigate innovations that move the solid tradeoff line in Figure 2 into the direction of the axes; see the arrows and the dashed line in Figure 2. I.e., we aim at finding opportunities to reduce both downtime and TCO significantly.

We distinguish three research areas, also referred to as Work Packages (WP-s), to realize the shift of the curve in Figure 2:

I. Shared parts for performance-based contracts
II. Last buy and re-use
III. Proactive Maintenance via remote monitoring

Below we give a further explanation and motivation for these work packages.

WP I: Shared parts for performance-based contracts

As stated above, increasingly, service logistics of capital goods is outsourced to the OEM-s using service contracts in which well-defined Service Levels Agreements (SLA's) are specified. The OEMs face many uncertainties when they sell service contracts, for example about the system failure behavior due to limited information on component failure rates and system use by the customer. Furthermore, sales of service contracts and logistics fulfillment are usually organizationally separated in practice, such that a proper coordination is lacking. OEMs have several means to influence its service contract performance, such as

- choosing the right amount of spare parts at the right locations in the network,
- influencing throughput times in the service process, such as repair of modules and components, transportation times to the operating sites and return times of failed parts; for example, this can be achieved by adjusting resource capacities (tools for diagnosis and repair, service engineers) or by priority setting of specific jobs in the service processes.

Apart from optimizing the service logistics between the OEM and one customer, the OEM can also improve his service by sharing parts. This is especially the case if the service chain is not fully controlled by one player (like the OEM), or in case an outside party wants to act as control tower. The first case occurs if the OEM applies consignment stocks at customers, or when he takes care of customer owned stocks. The second case is when the company acts as an intermediary between several companies which have own stocks. Sharing parts has advantages, because due to pooling lower safety inventories can be maintained. Yet it raises questions on the way to execute it in such a way so that the costs and benefits are balanced over the parties involved. Moreover, companies want to assess the consequences of sharing beforehand and also want to have an insight into the risks involved, similarly as stated before. These problems get specific issues in case the OEM faces an end-of-life phase of her systems (as is the case with Fokker Services).

OEMs often have insufficient knowledge on how to attain the SLA's in service contracts, both initially (when service contracts are sold) and during service contract execution when information on failure behavior and system use is revealed. A complicating factor is that SLA's are measured in a finite time window (like one year), which means that an SLA can easily be missed because of common statistical fluctuations in the failure and service processes, even if the average performance is conform target.

WP II: Last buy and re-use
Spare parts are important to service capital goods throughout the whole system life cycle. In general, spare parts can be sourced from:

1. failed parts that are returned from the field and that are technically and economically repairable (parts that have been replaced by a spare during corrective maintenance);
2. complete systems that are returned from the field (for example, at the end of a lease period) and that cannot be sold or leased anymore to a new customer; these systems can be disassembled and useable parts may become available as spares ("asset recovery")
3. new parts as manufactured by the own production department or external suppliers.

Unfortunately, the timing and/or quantity of spare parts from the first two sources is usually not adequate and highly uncertain. Therefore, an OEM buys new spare parts for servicing its systems at the start of and during the system life cycle. At a certain point in time, production may be discontinued, and then the OEM has to decide about a so-called "last buy", such that sufficient spare parts are available to cover the total demand over the remaining life cycle with high probability. This decision is generally hard, because the length of the remaining life cycle ("final phase") tends to be long (5-20 years).

Because a stock-out of a spare part may have serious consequences (expensive alternative solutions, long downtimes at customer, service contract violation), it is common for companies to buy an excessive amount of spare parts at the "last buy" opportunity with the goal to have a low out-of-stock risk. Usually they succeed, but that comes with a price: Each year companies like Océ and IBM scrap spare parts with a total value of many millions of Euros, representing an enormous waste from both a financial and an environmental perspective. Furthermore, reusable parts are often not repaired and re-used anymore in the last years of the system life cycle, even though this could be technically and economically feasible. Clearly, there are ample opportunities to take more advantage of re-use, which will save costs for OEMs and reduces waste for the society (more sustainable service supply chain).

WP III: Proactive Maintenance via remote monitoring
Unexpected failures are the main source of unscheduled downtime of a capital good. The yearly unscheduled downtime is equal to the product of the number of unexpected failures and the average downtime per failure. While in earlier research, and also in the Work Packages I and II, the focus was/is to reduce the average downtime per failure, this work package aims to reduce the number of unexpected failures.

Reducing unexpected failures of capital goods can be achieved through the following two steps:

1. Accurately predicting their failure times: During operation, critical components of a capital good typically undergo a gradual and irreversible damage, known as a "degradation process". These degradation processes have a high degree of randomness due to the different operational and environmental conditions of each individual capital good. Consequently, predicting the failure time is a very challenging task. But, doing this accurately is necessary to get reliable predictions and thus to be efficient in the second step.
2. Performing preventive maintenance actions: When the evolution of the degradation state of a critical component is estimated well, we can accurately predict the time at which it will cross some pre-determined critical/alarming level or failure threshold. Some time before that we can execute a preventive replacement (or repair).

The above two steps result into proactive maintenance (a form of condition-based maintenance), which leads to scheduled downtimes at predetermined times instead of unscheduled downtimes at very inconvenient times. In addition, one can take some extra time for the provisioning of maintenance resources (service engineers and spare parts), while those resources have to be made available against the highest possible speed when an unexpected failure occurs. So, both downtimes and maintenance costs (and thus TCO) will be reduced significantly.

The approach discussed above can be highly enhanced via the current possibilities to do remote monitoring. In remote monitoring, some quantifiable measure that characterizes the degradation of capital goods is monitored in real time, using techniques (e.g. sensors) that can be applied remotely. This may lead to highly accurate predictions against very low costs.

Many OEM's have already remote monitoring technology built into their systems. For example, Vanderlande Industries is currently implementing their Business Process Intelligence (BPI) systems that capture measures from their systems installed at the customers' cites. For instance, this includes the percentage success rate of scanners in parcel sorting systems. This success rate starts at a high value close to 100% for a new system, and then gradually decreases as degradation progresses. Numerous other measurements are made in real-time and logged into a central database or control tower. Marel Stork also makes real-time measurements from their poultry production lines that produce up to 12,000 products per hour. Measurements from the systems installed at different customers of Marel Stork are logged into a central database that can be used to provide maintenance support for these customers.

So far, OEM's do not yet really use their remote measurements for proactive maintenance, and their measurements were not designed for the purpose of proactive maintenance. But, the technology is there, and we want to investigate its great potential for proactive maintenance.

Relation to Dinalog innovation themes

This section describes the relationship to the innovation program and specifically to the focus areas (Cross Chain Control Centers, Service Logistics or Transport Hubs in Control). (For more details, see www.dinalog.nl; download "Rapport Commissie van Laarhoven")

This project is directly linked to the subprogram "Service Logistics"; see the report of the Commissie van Laarhoven [2008]. In particular, via the above three work packages, we aim to develop knowledge and tools that contribute to an excellent functioning of control towers for the service supply chains of OEM-s of advanced capital goods. The topics of the three work packages are all incorporated in the description of the subprogam "Service Logistics".

Objectives and goals

This section describes the project objectives and goals in terms of SMART: Specific, Measurable, Acceptable, Realistic and Timing.
The goals have to be linked to the goals as described in the innovation program (For more details, see www.dinalog.nl; download "Rapport Commissie van Laarhoven")

The *main objective* of this project is to further develop the control tower function of an OEM. With the three WP-s as described above, we develop those parts that are seen as most innovative and most promising to decrease both downtimes and TCO and to create a strong competitive advantage. The covered topics fit in a higher-level framework that was developed with a large group of companies in June-December 2009; see Rustenburg [2010].

Below, we give the objectives at a more detailed level, together with the research questions.

WP I: Shared parts for performance-based contracts

In this work package, we aim to answer the following research questions:

a) How should an OEM effectively manage variability in customer service levels to create a stable and predictable performance of equipment for the customers?
b) How can the OEM take care of the risks for the customer in contracts and in which situations is that appropriate?
c) How should part sharing agreements between parties be set-up and how should costs and benefits be allocated between the various parties.
d) Can we evaluate the costs, benefits, and risks of these agreements beforehand in order to convince parties to close such agreements?

Sub-questions:

1. Which measures (like additional spare parts, throughput time reduction) should be taken *in the initial phase* to ensure that an OEM satisfies SLA's with high probability?
2. When should the OEM pro-actively intervene to prevent that SLA's are missed *during service contract execution*, and which measures are most effective and efficient?
3. How do the part sharing agreements depend on the different roles and cases, e.g. in case the OEM faces the out-of-production systems and in case the OEM works together with a user.
4. What contract forms are attractive under which conditions to which users? Pay per part, or pay per operating hour?
5. How can we evaluate the risks of using these part sharing agreements, and how can operational flexibility options, like stock reservation, repair/replace mitigate these risks?

This will lead us to fulfill the following objectives:

1. Develop decision support models to support logistics fulfillment of service contracts both at the initial phase (service contract sales) and during contract execution to enhance service contract performance, taking various operational flexibility options into account.
2. Develop guidelines for pooling contracts in various situations and give advice to companies about them.
3. Develop a decision support system to evaluate various cost allocation mechanisms in various pooling situations.

WP II: Last buy and re-use

The main objective is to develop models and methods that help OEM-s to achieve a better balance between system uptime and cost of servicing systems by more re-use of parts and thus less waste.

For this objective, the following research questions are relevant:

1. How can installed base information be exploited to generate better forecasts for the timing and quantity of reusable parts in the remaining service period (both initially and throughout the service period)?
2. What is the value of the various types of installed base information, i.e., which kind of information is worthwhile to collect and to maintain and which information not?
3. How can the trade-off between reuse of spare parts and procurement of new spare parts during the part production period be improved in order to reduce service costs and to increase service supply chain sustainability?
4. Under which conditions should returned parts be disposed, kept on stock as failed part to be repaired, or be repaired and kept on stock as reusable parts?
5. When should reusable parts be repaired locally and when should they be repaired at a central location (e.g., one per continent)?
6. Are there any other ways to influence the return flow of reusable parts (e.g. from systems in the field at or close to the end of their economic life), and how does this influence the last buy and reuse?

WP III: Proactive Maintenance via remote monitoring

The main objective is to develop a mathematical framework that integrates lower level information from the remote monitoring of capital goods with higher level decision models for performing optimal proactive maintenance. In particular, the following research questions are relevant:

1. Which quantifiable measure best provides a comprehensive assessment of the underlying degradation state of a capital good?
2. What is the suitable tool to model the evolution of this measure in order to predict failure? And what is the appropriate failure threshold for the capital good under consideration?
3. What is the optimal time to perform a maintenance action that achieves a balance between the lost-opportunity cost resulting from unnecessary maintenance and the high downtime cost resulting from unexpected failures?
4. What is the optimal time and quantity to order spare parts that minimizes inventory holding costs while preventing expensive stock-outs?
5. What is the optimal allocation of maintenance resources (labor and spare parts) given the acquired optimal maintenance policy?
6. For capital goods that do not already have remote monitoring capabilities built in, how should the decision be made regarding whether or not to invest in it? In other words, what are the cost savings and/or increased system uptime resulting from deploying maintenance using remote monitoring?

Expected results

This section describes the targeted final results to be expected by executing the project, both project results for the project partners, but also the contribution to Dinalog economic goals (long term and timing to achieve these goals). Indicate what your project as a business case will contribute to the ambition to increase the Dutch added value (GDP) in supply chain control and logistics from € 3 billion in 2007 to over € 10 billion in 2020. What possible concrete tools and instruments can be expected from the project?

Our project aims to contribute to the development of control towers for OEM-s, both the OEM-s involved in this project and OEM-s in general. In Appendix II, key information of all consortium partners is given. The involved OEM-s denote their roadmaps and ambition. Without exception, they all plan to further develop their control towers and to increase their maintenance services business significantly.

In general, we will see that much more work will be moved to control towers and we will get much leaner maintenance operations by local support organizations all over the world. The Netherlands has a large capital goods industry. In 2008, the size of the export of capital goods was 117 billion Euro (see the size of the export of “Machines en apparaten”, “Elektrotechnische machines en apparaten”, en “Transportmiddelen” in Table 12.22 of the Statistisch Jaarboek [2009]). The maintenance costs during the 20-40 years of the exploitation phase are often of the same size as the price of a new system. Hence, the maintenance activities for the capital goods exported from the Netherlands form already a market of the same size! With the trend to move work, and thus added value, to the control tower, in principle it should be able to increase the added value in The Netherlands by service logistics by 1 billion Euro’s per year, say, which would correspond to 10 billion Euro’s over a period of 10 years.

The type of work in control towers of OEM-s requires highly skilled people, with PhD, MSc and BSc degrees. The above potential increase in added value by service logistics will lead to thousands of extra fte-s over a period of 10 years. Our project will contribute to the supply of people with skills in service logistics. Notice that the availability of well trained people plays an important role when an OEM chooses its location for his control tower. This is an important aspect in keeping the current control towers in The Netherlands and in attracting new control towers.

The more concrete tools and results that we plan to generate are described below.

WP I: Shared parts for performance-based contracts

1. A decision support system to support logistics fulfillment of service contracts.
2. Cost and profit allocation schemes when sharing parts between several companies. these will be specified for three cases
   - comparable companies (in size and role)
   - different companies: an OEM and a user have own parts
   - in case of outphasing systems
3. Inventory control policies that guarantee individual company service levels while allowing parts sharing
4. An overall framework for the decision of whether or not to engage in parts sharing. This will relate the business environment, product environment with contract options.
5. Efficient solution algorithms with which the allocation schemes and inventory control policies can be evaluated in terms of costs, service levels and risks.
6. Advice to participating companies (esp. Fokker Services) on their move to become manager of shared parts
7. One Ph.D. thesis and five M.Sc. theses
8. 6-7 ISI journal publications, and 3 publications in professional journals.
9. Average of six presentations in international scientific conferences (Target conferences: INFORMS, MSOM and ISIR). About two presentations at professional conferences / seminars, like RLA Trends.

WP II: Last buy and re-use

1. Insight in the installed base information that has added value to improve forecasts of the spare part requirements over the remaining life cycle of a system.
2. Tested forecasting models for spare part requirements over the system life cycle, taking into account relevant installed base information
3. Tested decision support models for integral last buy and re-use decisions of parts, focusing on reducing costs and increasing service supply chain sustainability. These methods will be implemented in prototype software that is suitable for case studies at the participating companies.

4. Case studies at Océ and IBM for model constriction and assessment of model results. For these case studies, at least four master thesis projects at the two leading companies Océ and IBM will be conducted. We aim to test the methods as developed based on these case studies at other companies for their generality, particularly at Vanderlande Industries who also participates in this work package.
5. One Ph.D. thesis and five M.Sc. theses
6. 4-5 ISI journal publications, and a few publications in professional journals
7. Three presentations at relevant professional conferences or international scientific conferences such as INFORMS, MSOM and ISIR

WP III: Proactive Maintenance via remote monitoring

1. Degradation models that use real-time remote monitoring data to predict and update the remaining life of a capital good during operation under varying operating and environmental conditions.
2. Mathematical decision models to determine optimal proactive maintenance policies based on remote monitoring information. Special emphasis will be put on models to determine:
   - Optimal replacement and repair policies
   - Optimal spare parts provisioning policies

   The models described in (1) and (2) will all be validated using both hypothetical and real-world data, and compared to existing benchmarks in the literature.
3. A decision support framework for the decision of whether or not to invest in remote monitoring systems. This is of crucial importance to OEM's that do not currently have remote monitoring capability in their systems, and are considering modifying the design to include this capability.
4. Efficient solution algorithms for the models described above that are expected to be large in size.
5. User-friendly interfaces for the easy implementation of the developed sophisticated mathematical models. These interfaces will take remote monitoring data as input, and use it to solve the relevant model for the decision maker. The output decisions will be displayed in an easy-to-interpret form (e.g. flashing LED's, Dial Indicators, and Expected Failure Time of the Capital Good). This will make it more feasible for the operator to interpret the outcomes of the model.
6. One Ph.D. thesis and eight M.Sc. theses
7. 8 ISI journal publications, and multiple publications in professional journals.
8. Average of six presentations in international scientific and professional conferences (Target conferences: INFORMS, MSOM and ISIR).

Relation to government policy

If applicable, this section describes the relation to government policy and how interaction between the project and government bodies (which?) is pertained before and during the project.

This project is linked to government policy in four ways. First, we strengthen the control tower function of service supply chains, thereby improving the *competitiveness* of the service logistics sector in the Netherlands. Second, the control tower function will be fulfilled by a large percentage of highly-skilled employees, which contributes to the development of a knowledge economy. Third, we contribute to the goal of The Netherlands to become leading in maintenance. Fourth, we contribute to the *sustainability* of service supply chains by a more efficient use of resources, less parts obsolescence, and less emergency maintenance actions.

We plan to have an extensive valorization program; see “E. Valorization and implementation strategy”. In our valorization strategy, we distinguish value creation, implementation, and dissemination. For the value creation, regional development enterprises (BOM, REWIN, NV Oost, LIOF) and branch associations (EVO, NDL, Scheepsbouw Nederland, BWMT) will be involved. For the dissemination, we plan to make use of multiple national forums and associations.

Orientation

This section describes how the consortium oriented on similar projects and the state of the art on the subject. It clearly states what makes this project new, unique and innovative compared to existing research and other projects. State the relation of the proposed scientific research work in the proposal to the international state of the art.

WP I: Shared parts for performance-based contracts

Research on contracts and risks deviations is rather scarce. The operations research literature mainly concerns evaluations of inventory control policies. Selective throughput time reductions as alternative to improve service contract performance has not been addressed as far as we know, Related research can be found in the application of emergency supply and lateral shipments (Wong et al [2007]) and repair shop priority setting within spare parts management (Sleptchenko et al [2005]).

Also, most literature focuses on long-run system behavior, whereas service contracts always have a finite horizon which tends to be short. This means that steady-state performance characteristics are less suitable. In the area of system reliability theory, results for the system behavior on finite time intervals have been developed a few decades ago, see the literature on interval availability (e.g. Carrasco [2004]). However, the focus in this stream of literature is on the relation between component reliability and system availability in a finite time interval (intrinsic availability). Preventive maintenance and spare part provisioning is not included. On the other hand, some papers on the behavior of simple inventory systems in finite time intervals have been published in the last years, which started with the paper by Chen et al [2003]. For a simple single-item inventory system, Banarjee and Paul [2005] show that the average fill rate is a decreasing function of the interval length, Thomas [2005] conducted an extensive simulation experiment on the fill rate behavior of a single item in a simple inventory system. Katok et al. [2008] analyze human behavior for inventory control in finite time intervals in a laboratory setting. These results show that research on the behavior of service contract performance in relatively short service contract interval is still in its infancy. This also means that, next to analytical results, we will also have to rely upon simulation for the analysis of large systems as encountered in practice.

Shared parts reflects also spare parts pooling. That is the business process where companies share each other’s spares. Pooling inventories in general has been studied already for some time, albeit much less for spare parts. One major research issue has been the study of lateral transshipments, where depots helps each other in case of stockouts. Wong et al. [2006] gave an excellent review of the area. In general the conclusion is that lateral transshipments are beneficial (although Yang and Dekker [2010] remark that that is no longer the case if the lateral transshipment times are long). Much effort has gone into calculating either heuristically or through exact methods the effect of lateral transshipments under various demand allocation schemes. The research on cost allocation in such systems has been scarce, according to Wong [2007]. Most lateral transshipments papers assume that the service chain is controlled and owned by one party only. A few papers, Kilpi et al. [2004] and [2009] have been particularly devoted to the airline industry, showing that it is a promising phenomenon in that area.

In the cost allocation studies we can distinguish two approaches. In the first group there is a central decision maker who has to allocate costs over all parties. In the second group decentralized inventory systems are considered where all parties optimize their own interest. The standard approach is game theory. Researchers study various allocation schemes and investigate whether the outcomes are in the core of the game. In case of decentralized systems, the authors consider Nash-equilibria. One main problem with the studies however, is that the models are high level and lack many practical aspects. Moreover, they consider similar parties and typically only one component, while in practice different parties may be involved and parties may have different assortments. Moreover, parties may not always reveal their true costs. One important cost element is the costing of the parts, because parties may have paid different prices for them. This may be especially a problem if a demand can be satisfied from several sources. Furthermore, if the systems are in an out-of-production there is a substantial obsolescence risk and demands may decrease or drop dead in time. So the aim of the project is to extend the present approaches and make them workable for the industry. Moreover, we hope to benefit from the other work package on end-of-life problems.

WP II: Last buy and re-use

Regarding forecasting of spare part demand, there is quite some literature available. An early paper is by Moore [1971], who uses time series analysis to estimate the so-called all-time requirement for spare parts. Later on, significant contributions in this area have been made by Ritchie and Wilcox [1977], Foote [1995] and Wasserman and Sudjianto [1996]. Next to time series data, some authors try to include installed base information in spare part demand prediction. The most advanced as far as we know is Hong et al [2008], who include the number of product sales, the product discard rate, the failure rate of service parts, and the replacement probability of the failed part. The authors solely focus on the forecasting procedures and do not include the *integration with last buy decisions*. Still, this paper is a good starting point for our research. Next to forecasting models for spare part demand, however, we also need to develop models to forecast for *supply* of spare parts from the field and from asset recovery, taking into account installed base information like the age of the systems (for asset recovery) and the repair history of items.

In the area of last-buy decisions, most literature is based on rather simple spare part forecasting models. As is common in inventory theory, the models available in the literature can be divided in cost-oriented and service-oriented models. Service-oriented models focus on attaining some target service level, cost-driven models assign costs to out-of-stock situations. The first service-oriented models have been developed by Fortuin [1980, 1981]. He derived formulas for the final order quantity (Last buy) in order to achieve a certain service level of the remainder of system life cycle for use by Philips Electronics. The most recent contribution in this stream of research is by van Kooten and Tan [2009], who develop a decision model for the final order quantity under the risk of condemnation. In the area of cost-oriented methods, major contributions are by Teunter and Fortuin [1998, 1999], Teunter and Klein Haneveld [1998, 2002] , Cattani and Souza [2003] and Bradley and Guerrero [2009]. In none of these methods, alternative supply options for spare parts are taken into account.

As alternatives to the last buy of spare parts, two approaches have been considered. First, Pourakbar et al [2010] recently developed a model for last-buy decisions for consumer electronic products where alternative repair strategies are considered, such as swapping of products or offering a discount on a new model. Next to the last buy decision, the authors also develop a dynamic strategy to update decisions when demand information is revealed during the product life cycle. Clearly, such an approach is less suitable for advanced, and thus expensive, capital goods. Second, Krikke and van der Laan [2009] include phase-out returns of customers replacing systems and consider both push and pull policies for repair of failed parts (push = repair upon arrival of the failed part, pull = repair upon demand). This paper is closely related to our problem setting, and actually the only paper that we found in this area. However, the scope of the optimization problem is limited to a single customer, single item model where the timing of phase-out returns is deterministic and known in advance. In the area of advanced capital gods, we have to deal with multi-item, multi-customer problems where the timing of system returns for asset recovery is uncertain.

Our scientific contribution consists of the following main parts:
1. Adapting forecasting models for spare part demand using relevant installed base information to the information that can be made available in the advanced capital good industry.
2. Development of forecasting models for spare part supply, consisting of repairable parts returned from the field and parts that come available from asset recovery, taking into account installed base information like part repair history.
3. Extension of last-buy models to include the re-use options as alternative spare part supply option, focusing on multi-item, multi-customer models and uncertain system returns.
4. Integration of spare demand forecasting, spare part supply forecasting and last buy and reuse decisions.

WP III: Proactive Maintenance via remote monitoring
Remote/condition monitoring is the process of collecting real-time sensory information from a functioning device to determine its state of health. Remote monitoring is used in numerous applications including a wide variety of different components such as bearings (see Wang and Kootsookos [1998]), machine tools (Sick [2002]), engines (Zhou and Clelland [2005]), and generators (Loyd et al. [1999]), among others. In remote monitoring, various condition phenomena such as temperature (Garcia et al. [2006]), degree of wear (Ghosh et al. [2007]), and vibration (Yang and Kwang [2006]) that are directly or indirectly associated with degradation are captured using sensors.

In degradation modeling, the main focus is on modeling the evolutionary paths of the measures captured by remote monitoring to predict failure. For example, Lu and Meeker [1993] develop a random coefficients model to estimate the failure time distribution based on degradation data from a population of components. Very few works in the literature focus on integrating real-time condition-based information from remote monitoring to accurately predict failure. In Gebraeel et al. [2005], the authors develop stochastic degradation models that utilize condition monitoring data to predict and update the remaining life distributions of degraded components. However, only approximate expressions for the remaining life distribution are obtained.

There is a large body of literature on maintenance optimization models. Excellent reviews are provided by Wang [2002], Dekker [1996], and Jardine [2006]. For the sake of relevance to the current work package, we categorize the works on maintenance optimization into; (1) Reliability-based models that use the failure time distribution of components and systems to determine optimal maintenance strategies (see for example Armstrong and Atkins [1996]), (2) State models that characterize degrading systems using a set of states and model the transition between these states using tools such as Markov processes and semi-Markov processes (Benyamini and Yechiali [1999] and Elwany et al. [2010]), and (3) Condition-based maintenance that determines optimal maintenance policies based on the condition of the system (Mann et al. [1995]). None of the works in the literature focuses on integrating the powerful mathematical tools used in state models with remote monitoring techniques to derive optimal structured maintenance policies according to the underlying state of health of degraded systems.

In this work package, we fill in this existing gap in the literature by establishing a missing linkage between lower level real-time information acquired from the remote monitoring of capital goods with higher level decision models to obtain structured policies. These condition-based maintenance policies are expected to achieve reduced costs and increased system availability due to the fact they are based on the actual condition of the capital good.

We also extend our study to provide decision support for spare parts inventory management and service logistics. Since unexpected failures can be predicted accurately using remote monitoring, advance information on the demand of spare parts becomes available. There are many works in the literature on inventory control models under advance demand information, such as the work by Tan et al. [2007]. In most of the literature, advance demand information is obtained using sales forecast, or using assumptions about the demand distribution. By using remote monitoring techniques, more accurate information about the demand of spare parts can be available. In Elwany and Gebraeel [2008], the authors present a renewal-theoretic based decision model for ordering spare parts using remote monitoring. However, only heuristic approximations of the decision policy are derived. We plan to extend this study by providing exact decision policies for ordering spare parts under advance demand information.

B. Activities and Work Packages

WP I: Shared parts for performance-based contracts

Involved partners:

- WP-leader: Prof. Rommert Dekker, Erasmus University Rotterdam.
- Leading companies: Fokker Services, Thales
- Other strongly involved partners: Marel Stork Poultry Processing, University of Twente
- Involved full-time researchers: 1 PhD student for 4 years (to be appointed at Erasmus University), 1 postdoc for 1 year (to be appointed at the University of Twente)
- Number of master thesis projects: 5

Phases of WP I	
Phase 1	Activity 1: Investigate business situations of the companies involved and inventarise all possible business situations. Start of an advisory trajectory on shared parts at Fokker. Activity 2: Set-up a first model for shared parts, analyze it, develop algorithms and evaluate them. Activity 3: 2 master thesis projects at Thales and Fokker and definition of a case as inspiration for model construction (at Thales). Furthermore, construction of conceptual models, describing the relations between decision options and SLA performance: o initial phase o service contract execution phase
Duration:	1 year
Deliverables/ Milestones:	• Completion of a report on business cases (EUR). • Completion of 1 master thesis project (UT). • Completion of research plan for PostDoc on performance-based service contract fulfillment
Phase 2	Activity 4: Set-up of a model for parts sharing in case of out-of-production systems. Activity 5: 2 master projects at Fokker and Thales Activity 6: Construction of mathematical models based on the conceptual models for service execution, collection of case data, model testing and validation Activity 7: Writing two journal articles in preparation for submission to ISI journals and present the preliminary findings at INFORMS and/or MSOM conference.
Duration:	1 year
Deliverables/ Milestones:	• Model formulation performance-based service contracts ready, along with test instances. • First drafts of 2 journal articles on parts sharing and performance-based service contract fulfillment. • Completion of 2 master thesis projects.
Phase 3	Activity 8: Develop outlines of a prototype DSS on fulfillment of service contracts. Activity 9: Set-up of a framework on parts sharing Activity 10: Develop solution algorithms with different allocation mechanism for parts sharing. Activity 11: Write 2 journal articles (postdoctoral project) and 1 journal article (Ph.D. project) and 1 professional article.
Duration:	1 year

Deliverables/ Milestones:	• Internal report on outlines prototype DSS • Internal report on framework • Algorithms for parts sharing • 3 journal articles and 1 professional article
Phase 4	Activity 12: Finalise the prototype DSS from activity 8. Activity 13: 1 master thesis project to disseminate results to other companies. Activity 14: Write 2 journal articles for submission in ISI journals and 2 professional articles. Activity 15: Writing and defense of PhD thesis.
Duration:	1 year
Deliverables/ Milestones:	• Prototype decision support system for service contract fulfillment. • Two journals articles, at least one submitted to top ISI journal. • PhD thesis. • Completion of 1 master thesis project

Activity 1: Inventarise business situations for parts sharing
Description: The PhD student will study the various examples of parts sharing in practice, by investigating the various company and allocation roles. This will provide insight into company preferences and to unique selling points for parts sharing contracts. We will pool over all information available within the project.
Planning: To be completed in the first year.
Work distribution: PhD student under supervision of Dekker and Gabor and supported by Rustenburg and Van der Laan
Expected results/deliverables/milestones: Internal report

Activity 2: A first model for shared parts
Description: We will set-up a model for shared parts, using information from activity 1 to gain insight in solution methods and possible outcomes.
Planning: To be completed in first year.
Work distribution: PhD student under supervision of Dekker and Gabor
Expected results/deliverables/milestones: A simple model for parts sharing with evaluation algorithm

Activity 3: First master thesis projects at Fokker and Thales
Description: We will start first project with master thesis student Industrial Engineering and Management (IEM) and one in Management Science as soon as possible after the start of the project. The goal is to inventarise the business environment and all operational restrictions. Next to advise on improvements and help in setting-up formal models. Do an analysis of the model

and present results.
Planning: Start as soon as possible after project start; completion within the first year
Work distribution: Master student, in cooperation with (1) University supervisors Van der Heijden, Dekker, Gabor and the PhD student (2) company supervisors of Thales and Fokker.
Expected results/deliverables/milestones: 2 master theses; definition of first model and first case definition.

Activity 4: First model construction for shared parts in an out-of-production setting.
Description: Construction of first model to analyse parts sharing in case of an out-of-production setting using the insights obtained in activity 1, 2 and 3
Planning: Second year
Work distribution: PhD student in close cooperation with Dekker and Gabor and with company representatives of Fokker
Expected results/deliverables/milestones: First model and solution method, programmed in (simple) prototype software

Activity 5: 2 master thesis projects
Description: 2 master thesis projects will be executed at two of the three companies Fokker and Thales, and Marel Stork. This project aims for testing and evaluation of the first models. Probably, we will find that the models should be adjusted to cope with the specific business situation at the company where the project will be executed.
Planning: Second year
Work distribution: Master students, in cooperation with (1) University supervisors Dekker, Gabor and PhD student and Van der Heijden (2) company supervisors from Fokker or Thales / Stork.
Expected results/deliverables/milestones: 2 master theses; tested version of first model; analysis of first case study.

Activity 6: Construction of mathematical models for service execution.
Description: Construction of improved models for parts sharing and contract evaluations. Thereby, we take into account the experiences that we had during the previous master thesis projects (Activities 3 and 5).
Planning: Second year

Work distribution: Postdoc under supervision of Van der Heijden and Zijm and with company representatives of Thales
Expected results/deliverables/milestones: Improved model for parts sharing and contract evaluations.

Activity 7: First papers on parts sharing and contracts evaluations.
Description: Writing of first scientific papers on the results of activities 4, 5 and 6 and submitting them to ISI journals. Presentation of results at a relevant scientific or professional conference (e.g. ISIR 2012)
Planning: Second year
Work distribution: PhD student in close cooperation with Dekker and Gabor and the postdoc under supervision of van der Heijden.
Expected results/deliverables/milestones: Scientific paper, submitted to journal; conference presentation.

Activity 8: Develop outlines of a prototype DSS on fulfillment of service contracts
Description: Develop outlines of a prototype DSS on fulfillment of service contracts using all information and algorithms developed in previous activities (5, 6)
Planning: Third year
Work distribution: Postdoc in cooperation with (1) University supervisors Van der Heijden (2) company supervisor of Thales and/or Marel Stork
Expected results/deliverables/milestones: Internal report

Activity 9: Set up of a framework on parts sharing
Description: Combining all foregoing information and results a framework will be formulated about which allocation rules and evaluation rules to use under which circumstances.
Planning: Third year
Work distribution: PhD student under supervision of Dekker and Gabor
Expected results/deliverables/milestones: Internal report

Activity 10: Develop solution algorithms in case of different allocation mechanisms for parts sharing
Description: In this phase the main results should be obtained: inventory control policies and evaluation algorithms for the costs, benefits and risk of various parts sharing arrangements will be obtained. It will be based on the conceptual results of activity 9.
Planning: Third year
Work distribution: PhD student under supervision of Dekker and Gabor and with company representatives of Fokker
Expected results/deliverables/milestones: Algorithms and implementation. Tests.

Activity 11: Write scientific and professional papers.
Description: Write scientific paper and submit it to ISI journal; presentation of results at a relevant scientific or professional conference. Present professional paper at national fora.
Planning: Third year
Work distribution: Ph D student, in cooperation with university supervisors Dekker and Gabor
Expected results/deliverables/milestones: Scientific and professional papers, submitted to journals; conference presentation.

Activity 12: Finalise the framework and with detailed allocation rules and evaluation algorithms.
Description: All results so far will be combined in a framework. Tests of the allocation mechanisms can be done.Implementation of results in contracts.
Planning: Fourth year
Work distribution: PhD student in cooperation with (1) University supervisors Dekker and Gabor and (2) company supervisor of Fokker
Expected results/deliverables/milestones: Report with the framework and implementation of the algorithms.

Activity 13: Fifth master thesis project
Description: Fifth master project to disseminate models to other companies.

Planning: Fourth year
Work distribution: Master thesis student, in cooperation with (1) University supervisors Dekker and PhD student (2) company supervisor.
Expected results/deliverables/milestones: Master thesis

Activity 14: Write one scientific and two professional papers
Description: Write scientific paper and submit it to an ISI journal; presentation of results at a relevant scientific or professional conference. Present professional paper at national fora.
Planning: Fourth year
Work distribution: PhD student, Dekker and Gabor
Expected results/deliverables/milestones: Scientific and professional papers, submitted to journals; conference presentation.

Activity 15: PhD thesis
Description: writing of PhD thesis and defense. Integration of all written papers so far in a coherent PhD thesis.
Planning: Fourth year
Work distribution: PhD student under supervision of Dekker and Gabor
Expected results/deliverables/milestones: PhD thesis

WP II: Last buy and re-use

Involved partners:

- WP-leader: Dr. Matthieu van der Heijden, University of Twente
- Leading companies: IBM, Océ Technologies
- Other strongly involved partners: Vanderlande Industries
- Involved full-time researchers: 1 PhD student for 4 years (to be appointed at the University of Twente)
- Number of master thesis projects: 5

Phases of WP II	
Phase 1	**Start-up phase** Activity 1: Writing a detailed research plan Activity 2: PhD educational program within the BETA research school Activity 3: First master thesis project at Océ and/or IBM
Duration:	1 year (with the exception of Activity 2, which continues in year 2)
Deliverables/ Milestones:	• Detailed research plan • Completion of 60% of the BETA PhD program • First master thesis project completed and first case study defined. The master thesis project provides input from the practical side to the research plan of the PhD student
Phase 2	**Construction and testing of first model** Activity 4: Construction of first model for last buy and re-use decisions, using standard forecasting models Activity 5: Second master thesis project for testing and evaluation of the first model Activity 6: Writing a first scientific paper and submitting it to an ISI journal; presentation of results at a relevant scientific or professional conference.
Duration:	1 year
Deliverables/ Milestones:	• First model for integrated last buy and re-use decisions • Completion of the PhD educational program within BETA research school
Phase 3	**Construction and testing of second model** Activity 7: Construction of improved model for last buy and re-use decisions and a more advanced forecasting model (not integrated yet) Activity 8: Third master thesis project for testing and evaluation of the second model Activity 9: Writing a second scientific paper and submitting it to an ISI journal; presentation of results at a relevant scientific or professional conference.
Duration:	1 year
Deliverables/ Milestones:	• Improved model for integrated last buy and re-use decisions • Improved model for spare part demand forecasting • Model for spare part supply forecasting • Second scientific paper
Phase 4	**Model integration for last buy and re-use decisions with suitable forecasting procedures for spare parts demand and supply** Activity 10: Construction of an integrated model for last buy and re-use decisions, using standard forecasting models Activity 11: Fourth master thesis project for testing and evaluation of the integrated model Activity 12: Writing two scientific paper and submitting them to ISI journals; presentation of results at a relevant scientific or professional conference. Activity 13: writing of PhD thesis and defense
Duration:	1 year
Deliverables/ Milestones:	• Tested integrated model first model for last buy and re-use decisions, using standard forecasting models • Two scientific papers, submitted to ISI journals • PhD thesis

Activity 1: Writing a detailed research plan
Description: The PhD student has to study the relevant scientific literature, explore the problem area from a practical perspective and to construct a detailed research plan for the four-year period. Writing this proposal is related to the BETA course “Research Perspectives on Operational Processes”, at the end of which the research plan should be completed and presented to BETA staff and fellow PhD’s.
Planning: To be completed in the first year.
Work distribution: PhD student under supervision of Van der Heijden and Zijm
Expected results/deliverables/milestones: Detailed research plan

Activity 2: BETA educational PhD program
Description: PhD educational program within the BETA research school. The PhD student has to complete an educational program at post-graduate level in the area of operations management. This educational program has a size of at least 960 hours and will be completed after two years
Planning: To be completed after two years.
Work distribution: • Constructing an educational plan: PhD in close cooperation with Van der Heijden and Zijm. • Following courses and completion of educational program by PhD student
Expected results/deliverables/milestones: Completed BETA educational PhD program

Activity 3: First master thesis project(s) at Océ and/or IBM
Description: We will start a first project with a Master student Industrial Engineering and management (IEM) as soon as possible after the start of the project. This project should be a feasibility study in the area of last buy and re-use. The goal is to explore the problem in more detail from the practical side, to support the model definition, to define decision options and their mutual relation, to define a first case study, to examine data availability and to collect a first set of case data that can be used for a first analysis using some simple models that are already known.
Planning: Start as soon as possible after project start; completion within the first year
Work distribution: Master thesis student, in cooperation with (1) University supervisors Van der Heijden and the PhD student (2) company supervisor of Océ and/or IBM.
Expected results/deliverables/milestones: Master thesis; definition of first model and first case definition.

Activity 4: First model construction
Description: Construction of first model and solution method for last buy and re-use decisions, using standard forecasting models. This model is based on the definition as found in activity 3.
Planning: Second year
Work distribution: PhD student in close cooperation with Van der Heijden and Zijm and with company representatives of Océ and IBM
Expected results/deliverables/milestones: First model and solution method, programmed in (simple) prototype software

Activity 5: Second master thesis project
Description: The second master thesis project will be executed at one of the leading companies Océ and IBM. This project aims for testing and evaluation of the first model. Probably, we will find that the models should be adjusted to cope with the specific business situation at the company where the project will be executed.
Planning: Second year+
Work distribution: Master thesis student, in cooperation with (1) University supervisors Van der Heijden and the PhD student (2) company supervisor of Océ and/or IBM.
Expected results/deliverables/milestones: Master thesis; tested version of first model; analysis of first case study.

Activity 6: First paper
Description: Writing a first scientific paper on the results of activities 4 and 5 and submitting it to an ISI journal. This paper will be written while following a course on "scientific writing and editing" within the BETA PhD course program. Presentation of results at a relevant scientific or professional conference (e.g. ISIR 2012)
Planning: Second year
Work distribution: PhD student in close cooperation with Van der Heijden and Zijm
Expected results/deliverables/milestones: Scientific paper, submitted to ISI journal; conference presentation.

Activity 7: Second model construction
Description: Construction of improved model for last buy and re-use decisions and a more advanced forecasting model (not integrated yet). Thereby we take into account the experiences that we had during the previous master thesis projects (Activities 3 and 6).

Planning: Third year
Work distribution: PhD student under supervision of Van der Heijden and Zijm and with company representatives of Océ and IBM
Expected results/deliverables/milestones: Improved model for last buy and reuse. Improved Forecasting model for spare part demand. Model for spare part supply forecasting.

Activity 8: Third master thesis project
Description: Third master thesis project for testing and evaluation of the second model
Planning: Third year
Work distribution: Master thesis student, in cooperation with (1) University supervisors Van der Heijden and the PhD student (2) company supervisor of Océ and/or IBM.
Expected results/deliverables/milestones: Master thesis; tested version of second set of models; analysis of second case study.

Activity 9: Second scientific paper
Description: Writing a second scientific paper and submitting it to an ISI journal; presentation of results at a relevant scientific or professional conference (e.g. MSOM 2013).
Planning: Third year
Work distribution: PhD student under supervision of Van der Heijden and Zijm
Expected results/deliverables/milestones: Scientific paper, submitted to journal; conference presentation.

Activity 10: Integrated model construction
Description: Construction of an integrated model first model for last buy and re-use decisions, using advanced forecasting models for spare part demand and spare part supply from the field
Planning: Fourth year
Work distribution: PhD student under supervision of Van der Heijden and Zijm and with company representatives of Océ and IBM

Expected results/deliverables/milestones: Integrated model for forecasting of spare part demand and supply with last buy and re-use decisions.

Activity 11: Fourth master thesis project
Description: Fourth master thesis project for testing and evaluation of the integrated model.
Planning: Fourth year
Work distribution: Master thesis student, in cooperation with (1) University supervisors Van der Heijden and the PhD student (2) company supervisor of Océ and/or IBM.
Expected results/deliverables/milestones: Master thesis; tested version of integrated model;

Activity 12: Writing third and fourth paper
Description: Writing two scientific paper and submitting them to ISI; presentation of results at a relevant scientific or professional conference.
Planning: Fourth year
Work distribution: PhD student under supervision of Van der Heijden and Zijm
Expected results/deliverables/milestones: Scientific papers, submitted to journals; conference presentation.

Activity 13: PhD thesis
Description: writing of PhD thesis and defense. Integration of all written papers so far in a coherent PhD thesis.
Planning: Fourth year
Work distribution: PhD student under supervision of Van der Heijden and Zijm
Expected results/deliverables/milestones: PhD thesis

WP III: Proactive Maintenance via remote monitoring

Involved partners:

- WP-leader: Dr. Alaa Elwany/Prof. Geert-Jan van Houtum, Eindhoven University of Technology
- Leading companies: ASML, Vanderlande Industries
- Other strongly involved partners: Ceva Logistics, DAF Trucks, Marel Stork Poultry Processing, Thales, Erasmus University
- Involved full-time researchers: 1 PhD student for 4 years (to be appointed at Eindhoven University of Technology), 1 postdoc for 2 years (to be appointed at both the Erasmus University and Eindhoven University of Technology)
- Number of master thesis projects: 8

Phases of WP III	
Phase 1	Activity 1: Ph.D. educational program within the BETA research school Activity 2: Literature survey and preliminary problem definition for 1 Ph.D. project Activity 3: 3 master thesis projects at Vanderlande Industries, Marel Stork Poultry Processing, and Ceva Logistics
Duration:	1 year
Deliverables/ Milestones:	• Completion of 60% of the BETA PhD program • Completion of 3 master thesis projects. The project at Ceva Logistics will provide input for a postdoctoral researcher, and the remaining two will provide ground basis for the Ph.D. project that continues in subsequent phases.
Phase 2	Activity 4: Finalize Ph.D. project problem definition and formulate model for optimal condition-based maintenance based on real-time remote monitoring data. Activity 5: Two master thesis projects at ASML and Vanderlande Industries. Activity 6: Start of one postdoctoral project on inventory management using advance demand information from remote monitoring. Activity 7: Write two journal articles in preparation for submission to ISI journals and present the preliminary findings at INFORMS and/or MSOM conference.
Duration:	1 year
Deliverables/ Milestones:	• Model formulation ready, along with test instances of it solved. • Completion of the PhD educational program within BETA research school • First drafts of 2 journal articles. • Completion of 2 master thesis projects.
Phase 3	Activity 8: Analytical results of the model on optimal condition-based maintenance based on real-time remote monitoring data. Activity 9: Two master thesis projects at ASML and one other company. Activity 10: Finalization of the papers in activity 7 and submission to the relevant journals. Activity 11: Write 2 journal articles (postdoctoral project) and 1 journal article (Ph.D. project).
Duration:	1 year
Deliverables/ Milestones:	• Structural results of the optimal policy for the model in Activity 8. • Two to three papers submitted and the draft of an additional paper finalized. • Two presentations at INFORMS and/or MSOM. • Completion of 2 master thesis projects. • Completion of 1 postdoctoral project.

Phase 4	Activity 12: Construction of a second model for the Ph.D. project on sensor-based spare parts inventory management, building on the outcomes of the postdoctoral project from the previous phase. Activity 13: 1 master thesis project. Activity 14: Writing 1 journal articles for submission in ISI journals. Activity 15: Writing and defense of PhD thesis.
Duration:	1 year
Deliverables/ Milestones:	• Finalized model, including structural results and model validation, for sensor-based inventory management. • One journal article submitted to top ISI journal. • PhD thesis. • Completion of 1 master thesis project.

Activity 1: Ph.D. educational program
Description: PhD educational program within the BETA research school. The PhD student has to complete an educational program at post-graduate level in the area of operations management. This educational program has a size of at least 960 hours and will be completed after two years
Planning: To be completed after two years.
Work distribution: • Constructing an educational plan: PhD in close cooperation with Elwany and Van Houtum. • Following courses and completion of educational program by PhD student
Expected results/deliverables/milestones: Completed BETA educational PhD program

Activity 2: Literature survey and preliminary problem definition for Ph.D. project
Description: The PhD student has to study the relevant scientific literature, explore the problem area from a practical perspective and to construct a detailed research plan for the four-year period. Writing this proposal is related to the BETA course “Research Perspectives on Operational Processes”, at the end of which the research plan should be completed and presented to BETA staff and fellow PhD’s.
Planning: To be completed in the first year.
Work distribution: PhD student under supervision of van Houtum and Elwany
Expected results/deliverables/milestones: Detailed research plan

Activity 3: 3 master thesis projects
Description: The master thesis project at Ceva Logistics will serve as input for a postdoctoral project to be started in the next phase. The other two projects will serve as input for the Ph.D. project.

Planning: Start as soon as possible after project start; completion within the first year
Work distribution: Master students, in cooperation with and under supervision of van Houtum, Elwany, and Tan.
Expected results/deliverables/milestones: Three master theses.

Activity 4: Final Ph.D. project definition and development of first model
Description: Model formulation using a relevant tool (e.g. Markov decision processes), and preliminary exploration of the properties of the model using small to medium test instances.
Planning: Second year
Work distribution: PhD student under supervision of van Houtum and Elwany
Expected results/deliverables/milestones: First model, together with insight with regards to its structural properties.

Activity 5: 2 master thesis projects
Description: One of the master thesis projects builds upon the previous master thesis project at Vanderlande. The other intends to explore the implementation of remote monitoring and condition-based maintenance at ASML given very large data streams.
Planning: Second year
Work distribution: Master thesis student, in cooperation with and under supervision of Elwany, van Houtum, and Ph.D. student.
Expected results/deliverables/milestones: 2 master theses.

Activity 6: Postdoctoral project
Description: The postdoctoral project will be in collaboration between Erasmus University and Eindhoven University of Technology. The project will build on the insight provided by the master thesis project completed at Ceva Logistics.
Planning: Second year
Work distribution: Postdoctoral researcher, in collaboration with Tan, van Houtum, Dekker, and Elwany.

Expected results/deliverables/milestones: Draft of journal article completed, and presented at INFORMS, MSOM, or ISIR.

Activity 7: Two journal articles
Description: Two journal articles to be written as part of both the postdoctoral and Ph.D. projects.
Planning: Second year
Work distribution: Postdoctoral researcher in collaboration with Tan, van Houtum, Dekker, and Elwany, and Ph.D. student under supervision of van Houtum and Elwany.
Expected results/deliverables/milestones: First drafts of the two papers ready and presented in international conferences.

Activity 8: Analytical results of condition-based maintenance model
Description: Analysis of the model on optimal condition-based maintenance under remote monitoring, and structural results of the optimal policy.
Planning: Third year
Work distribution: PhD student under supervision of van Houtum and Elwany.
Expected results/deliverables/milestones: First model completed and validated.

Activity 9: 2 master thesis projects
Description: Two master thesis projects. The first one builds on the previous project at ASML, and the second one is to explore research questions that arise throughout the Ph.D. project.
Planning: Third year
Work distribution: Master thesis students, in cooperation with and under supervision of Elwany, van Houtum, and Ph.D. student.
Expected results/deliverables/milestones: 2 master theses.

Activity 10 and 11: 5 journal articles
Description: Work on five journal articles in the pipeline.
Planning: Third year
Work distribution: Postdoctoral researcher and Ph.D. student with van Houtum, Elwany, Tan, and Dekker.
Expected results/deliverables/milestones: The five papers submitted to ISI journals, three of which at least fully accepted.

Activity 12: Development of a sensor-based spare parts inventory model
Description: Second model for Ph.D. student on sensor-based inventory management, building on the outcomes of the postdoctoral project.
Planning: Fourth year
Work distribution: PhD student under supervision of van Houtum and Elwany.
Expected results/deliverables/milestones: Second Ph.D. model finalized.

Activity 13: 1 master thesis project
Description: Start of 1 master thesis project.
Planning: Fourth year
Work distribution: Master thesis student, in cooperation with and under supervision of Elwany, van Houtum, and Ph.D. student.
Expected results/deliverables/milestones: 1 master thesis.

Activity 14: 1 journal article
Description: Focus on writing a journal article for submission at a top journal (e.g. Operations Research, Management Science).

Planning: Fourth year
Work distribution: PhD student under supervision of van Houtum and Elwany
Expected results/deliverables/milestones: One journal article submitted at top journal.

Activity 15: Ph.D. thesis and defense
Description: writing of PhD thesis and defense. Integration of all written papers so far in a coherent PhD thesis.
Planning: Fourth year
Work distribution: PhD student under supervision of van Houtum and Elwany
Expected results/deliverables/milestones: PhD thesis

Planning

This section describes planning of activities / work packages and the timing of deliverables. This can also be included in the previous section. A summary of the planning (schedule) must be part of the project plan.

The Work Packages I, II, and III, their activities, and timing of deliverables have described above. In addition we have a work package on valorisation. For this work package, we formulated a strategy; see “E. Valorization and implementation strategy”. Detailed planning of valorisation activities follows later.

Each of the Work Packages I, II, and III has been structured in phases with a length of 1 year. In parallel, we will have valorisation activities in each year. This leads to the following planning schedule (where each column represents a period of 1 year):

WP I-Phase 1	WP I-Phase 2	WP I-Phase 3	WP I-Phase 4
WP II-Phase 1	WP II-Phase 2	WP II-Phase 3	WP II-Phase 4
WP III-Phase 1	WP III-Phase 2	WP III-Phase 3	WP III-Phase 4
Valorisation	Valorisation	Valorisation	Valorisation

C. Consortium and Project organization

Research Team

This section describes the research team, each specific role and input in the project (if necessary per activity / work package) and their quality / specific expertise.

Short CV's (max ½ page A-4) of the scientific researchers should be included as Annex, along with a shortlist (titles and sources) of their 5 most relevant publications or relevant project experience.

Also describe the relevant past performance of the other consortium partners.

Name partner	Role and input	Specific competence
Eindhoven University of Technology	Project leader, leader of WP III	Project leading experience (IOP-IPCR project), knowledge on service logistics and in particular on proactive maintenance
Erasmus University	Leader of WP I, also involved in WP III	Knowledge on service logistics and in particular for capital goods
University of Twente	Leader of WP II, also involved in WP I	Knowledge on service logistics and in particular for capital goods
Service Logistics Forum	Platform for knowledge dissemination, provides chairman for steering committee	The platform for service logistics in The Netherlands
Gordian Logistic Experts B.V.	Work package leader for valorisation	Leading consultancy firm in the area of service logistics, experience with knowledge transfer between universities and the industry
ASML Netherlands B.V.	Leading company for WP III	Innovative spare parts planning concept developed in collaboration with Eindhoven University of Technology, applies already remote monitoring technology
Ceva Logistics Netherlands	Involved in WP III	Knowledge on 4PL function of logistics service providers
DAF Trucks N.V.	Involved in WP III	Applies already remote monitoring technology (used by their ITS system to help stranded trucks)
Fokker Services BV	Leading company for WP I	Innovative player in the area of total aircraft support
IBM Nederland B.V.	Leading company for WP II	Generally recognized for their innovations in the service supply chain in the past 20 years

Océ Technologies BV	Leading company for WP II	Strong focus on TCO for already 10 years, development of innovative planning concept for car stocks and quick response stocks
Marel Stork Poultry Processing B.V.	Involved in WP I and WP III	Innovation leader in the poultry processing industry
Thales Nederland B.V.	Leading company for WP I, also involved in WP III	Leading for performance-based logistics in the defense industry
Vanderlande Industries B.V.	Leading company for WP III, also involved in WP II	Leading in maintenance services for baggage handling systems and parcel sorting systems, applies already remote monitoring technology

Extensive descriptions of all partners, their roles and competences are given in Appendix II. As one can see there, all companies have clear roadmaps and the topics in this project proposal match with the roadmaps.

In Appendix I, CV's of all scientific researchers are given. Their interests match also with the topics of this project proposal.

Project organization

This section describes the project organization; roles, tasks and responsibilities are described, including diagram.

Prof. Van Houtum will serve as project leader for the proposed project. He will be supported by the workgroup and the steering committee.

Workgroup

The workgroup consists of the project leder and work package leaders:

1. Prof. Dekker: WP-leader for "WP I: Shared parts for performance-based contracts"
2. Dr. Van der Heijden: WP-leader for "WP II: Last buy and re-use of spare parts"
3. Dr. Elwany: WP-leader for "WP III: Proactive maintenance via remote monitoring" (together with prof. Van Houtum)
4. Dr. Rustenburg: WP-leader for the valorization activities
5. Prof. Van Houtum: Project leader

Van Houtum will be responsible to manage the project as a whole according to the agreed upon deliverables, schedule and budget. He will interface with the (service logistics) program manager of Dinalog. The WP-leaders will be responsible to manage their WP's according to the agreed upon deliverables, schedule and budget.

Steering Committee

In addition to the project organization there will be a steering committee, which will be chaired by Gräve (SLF), and which consists of senior representatives of all participating partners (one representative per partner). In order to assure maximum synergy between the project and Dinalog, both the scientific and the business director of Dinalog will be invited to be part of the steering committee. The members will be nominated/appointed during the first three months of the project.

D. Evaluation and monitoring

Evaluation

This section describes how the consortium will evaluate the project (in terms of innovation process, cooperation and results) during and after finishing the project. The results of this evaluation will be submitted to Dinalog.

Describe how often measurements have to be made to be able to make project adjustments in time. Describe how will be monitored, using which criteria and who will execute the evaluation.

The project will be evaluated and monitored by the workgroup and the steering committee.

Scorecard

For the projects as defined, the evaluation and monitoring process will concentrate on the following three main factors of innovation deliverables, all in terms of actual result versus planned result:

a. Innovation content: Per WP and WP phase, three main innovation aspects will be closely evaluated and monitored:
    i. Conditions for effective innovation: How to enable an effective innovation process; Innovation conditions are defined and will be evaluated.
    ii. The innovation deliverable: What are the new deliverables in terms of approach, procedures, processes, IT systems etc.; Innovation deliverables are defined and will be evaluated.
    iii. Effects of the innovation: The realization of the business case elements for the companies directly involved in the innovation project; Innovation effects are defined and will be evaluated.

b. Innovation schedule: Per WP and WP phase, milestones are defined and progress will be monitored accordingly.

c. Innovation budget: Per WP and WP phase the financial and/or resource budget has been established and monitoring will be performed accordingly.

Per WP, a scorecard will be established containing all above elements with qualitative and quantitative assessments with the green/amber/red indicators.

Management System

In order to achieve world-class service logistic innovations, the following management system will be applied:

- WP meetings:
    - Monthly the WP-leaders will meet with their key project members to review progress according to plan and to address (potential) issues for resolution.
    - Once a quarter the full project scorecard will be assessed for input to the overall WP meeting, including the three “innovation content” scorecard elements. This assessment/meeting will include the companies participating in the specific WP.
- Project meetings:
    - Quarterly the project leader will meet with the rest of the workgroup to review the WP scorecards and to address (potential) issues for resolution.
    - Special focus is required by the workgroup to assess the quality of the innovation content elements throughout the total project cycle. Cross WP reviews will be performed in order to assure the highest standards.
    - Every second quarter, the project leader consolidates the scorecard for input to the steering committee. This assessment/meeting will include the Dinalog (service logistics) program manager.

- Steering Committee meetings:
    - Every 6 months the steering committee meets to review with the project leader the project scorecard and to address (potential) issues for resolution.
    - Special focus is required by the full steering committee team to assess the quality of the innovation content elements throughout the project cycle. As required the steering committee can address external (national or international) project reviews in order to assure the highest standards.
- Progress reports:
    - The scorecards and minutes of meetings per WP and of the whole project will be published for all involved partners after validation in the appropriate meetings.
    - Publication will be included in the project website (hosted by the Service Logistics Forum) with access restricted to the involved partners.

E. Valorization and implementation strategy

Valorization and knowledge dissemination

This section describes the way the consortium plans to organize valorization and dissemination activities (what, who and when), plans to make project results and knowledge widely available and plans to implement the project results (leading to what results). How do these activities enable the transfer of (intermediate) project results, outcomes and possible tools in practice beyond the project to other companies, regions, sectors etcetera (potential up-scaling effects). For instance can a business start-up be realized? What do the outcomes and results mean for the social networks?

Implementation

This section describes the way the consortium plans to implement the results of the project (how, who and when), what (additional) budget is needed and to what results this will lead.

Introduction

With this R&D project on Service Logistics, we intend to contribute significantly to the financial objectives of Dinalog. In this section we present a valorization strategy to achieve those objectives. This strategy is among others based on discussions with several executives such as Prof. Henk Zijm (as former Rector Magnificus of the University of Twente), Wim Bens (Managing Director Dinalog), Ben Gräve (as former Director Global Service Logistics at IBM), Dirk ‘t Hoofd (President of Holland International Distribution Council), and Marc de Haas (Program Manager Logistics of the “Brabant Development enterprise”).

Strategy

As a strategy we combine direct and indirect business development activities. Direct activities are related to business generation, such as making startups happen. Indirect activities need to support this process such as implementations and dissemination.

We intend to create multiplier effects by an effective circulation process: an ongoing process of research => making adequate, accessible and tangible products => disseminating the products => creating value => finance new (valorization of) research.

Deliverables

Below you find a table of foreseen deliverables:

Value creation	Implementation	Dissemination
startups	Workbooks	Seminars (also outside the Netherlands)
Labor places	Demonstrations	Publications in non-scientific magazines, including blogs
Accepted business cases	Prototype tools/ decision support models	Courses/Education for various platforms (e.g. HBO, commercial courses)
Educated resources	Checklists/scans/assessments	Continuous exposure of products
Cost reductions	(Development of) course material	Produce “campaign” material
	Library of products	

As an overall objective, this project will deliver **25 million Euro extra GNP** after 4 years, on an annual basis. This annual amount contains all business developments that can reasonably be attributed to this R&D project.

Multi-channel approach
In order to produce all deliverables we intend to use a multi-channel approach.

For the *value creation*, we have the following channels:

Regional development enterprises	**Branch associations**	**Entrepreneurs**
BOM	EVO	Gordian
REWIN	NDL	To be determined
NV Oost	Scheepsbouw Nederland	
LIOF	BWMT	

For the *implementation*, we have the following channels:

Universities	**HBOs***	**Entrepreneurs**
Twente	To be determined	Gordian
Eindhoven		To be determined
Erasmus		

*We believe that HBO students can be very instrumental to creating workbooks from Ph.D. theses and other studies.

For the *dissemination*, we have the following channels:

Media	**Forums**	**Associations**
Reed Elsevier (among others logistiek.nl)	Service Logistics Forum	vLm
Supply Chain Media	World Class Maintenance	NVDO
Logistics Europe	International Service Logistics Association	NVSM
	Reverse Logistics Association	AFSMI

Please note we only mentioned the companies that have a direct relation to Gordian or the universities involved. However, also other parties are very welcome to join.

Factors determining the success

1. Make a head start
In order to start up the circulation process, we need to make a head start. This can be done quite easily because we developed a lot of sound material in earlier research projects (e.g. in the SLF-Research project or other current projects). Based on this material we can make a lot of implementation products (see the table above).

2. Make extensive use of master thesis students
A great advantage of master students is that they tackle often practical issues in a short period of time. Hence, “the time to market” is short. In addition we create great value by making them ready for the service logistics market.

3. Buy in Executives
The process of valorization will not be an easy one. Many obstacles will have to be overcome. Therefore we will introduce an Executive group to guarantee the required support and to advice the program management. The following executives have stated their positive intention to be part of this group:

- Henk Zijm, former Rector Magnificus University of Twente
- Dirk ‘t Hoofd, President Holland International Distribution Council
- Marc de Haas, Program Manager Logistics of the “Brabant Development Enterprise”
- Remco Overwater, Managing Director Vanderlande Industries
- Frank Rustige, Director at DAF Trucks)
- Ben Gräve, former Director Global Service Logistics at IBM)

The Managing Director of Dinalog will also be invited to join this group.

4. Set up of a revenue model
The initial final support must be sufficient to make a head start. However it will certainly not be sufficient to carry out all activities to meet the financial goals. Therefore we need to set up a revenue model with which we can generate alternative revenue streams. This is also part of the circulation process.

This specific topic will be discussed with the Innovation Lab of the University of Eindhoven.

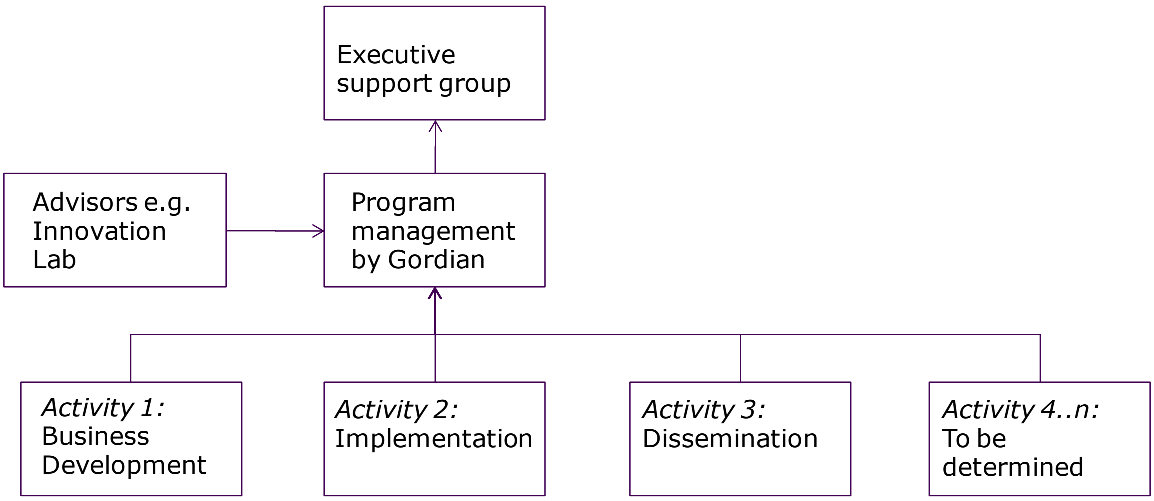
5. Business attitude required
Valorization is all about generating business. For that reason a real business attitude is required. Also to create a revenue model such an attitude is required.

For this reason entrepreneurs need to be involved, and this is also the reason why Gordian is in the “driving seat” of valorization.

Needless to say, we need to manage the combination of scientific and business attitude effectively.

6. Create synergy within Dinalog
We expect the other R&D projects to have similar challenges. Therefore Dinalog is expected to fulfill a coordinating, facilitating and inspiring role to create synergy.

Foreseen organization
The foreseen organization for the valorization activities is as follows:



The time horizon for the activities within this budget is 12 months. Hence, during this period we need to have a new revenue model in place.

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Appendix I: Short CV’s of Scientific Researchers

In this appendix, we give short CV’s of scientific researchers involved in this project:

- Geert-Jan van Houtum (Eindhoven University of Technology)
- Alaa Elwany (Eindhoven University of Technology)
- Tarkan Tan (Eindhoven University of Technology)
- Rommert Dekker (Erasmus University)
- Adriana Gabor (Erasmus University)
- Matthieu van der Heijden (University of Twente)
- Henk Zijm (University of Twente)

Geert-Jan van Houtum

Geert-Jan van Houtum is Professor of Maintenance, Reliability, and Quality at Eindhoven University of Technology since 2008. Prior to that he filled positions as assistant/associate professor at the University of Twente (1994-1998) and Eindhoven University of Technology (1999-2007) and as visiting professor at Carnegie Mellon University (2001). He obtained his M.Sc. and Ph.D. degree in Applied Mathematics from Eindhoven University of Technology in 1990 and 1995, respectively. He does research on the maintenance and reliability of capital goods, and in particular on: (i) Design and control of service supply chains; (ii) Maintenance concepts; (iii) Design for availability. He publishes in journals such as Operations Research, Manufacturing and Service Operations Management, IIE Transactions, European Journal of Operational Research, OR Spectrum, and International Journal of Production Economics. He is associate editor of OR Spectrum, the Flexible Services and Manufacturing Journal, and Mathematical Methods of Operational Research.

Much of Prof. Van Houtum's research is in cooperation with industry. He works with companies such as ASML, DAF, Gordian, IBM, Nedtrain, Océ, Philips Healthcare, Stork, and Vanderlande Industries. He is scientific director of the Beta Research School for Operations Management and Logistics, and he is a board member of the Service Logistics Forum and the European Supply Chain Forum. He is project leader of the IOP-IPCR project on “Life cycle oriented design of capital goods”, a consortium project with the University of Twente and 15 companies; this project started in 2005 and will be completed in September 2010.

Five Key Publications

- Rustenburg, W. D., Van Houtum, G. J., and Zijm, W. H. M., "Spare parts management for technical systems: Resupply of spare parts under limited budgets", *IIE Transactions 32*, 1013-1026, 2000.
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Alaa Elwany

Alaa Elwany is an Assistant Professor of Maintenance, Reliability, and Quality at Eindhoven University of Technology. He received his Ph.D. in Industrial Engineering and Systems Engineering in 2009 from H. Milton Stewart School of Industrial and Systems Engineering at the Georgia Institute of Technology, Atlanta, GA, USA. He holds a B.Sc. in Production Engineering and an M.Sc. in Industrial Engineering from Alexandria University, Egypt in 2002 and 2004, respectively.

His major research interests are in the areas of sensor-based prognostics, degradation modeling, reliability engineering, manufacturing systems, maintenance management, service logistics, and replacement and spare parts inventory models.

Dr. Elwany's research on sensor-driven maintenance operations and service logistics has been recognized in the "Industrial Engineering" magazine as well as Ivanhoe Broadcast News and the American Institute of Physics. He has served as "General Motors Manufacturing Scholar" in 2008-2009 after receiving a scholarship from GM in Atlanta, GA, USA.

Five Key Publications

- Elwany, A., Gebraeel, N.Z., and Maillart, L., "Structured Replacement Policies for Components with Complex Degradation Processes and Dedicated Sensors", *Operations Research*, 2010. To appear.
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- Elwany, A., Kaiser, K., and Gebraeel, N., "Sensor-Based Models for Maintenance Management Decisions," QSR Best Student Paper Competition at the INFORMS Annual Meeting, Seattle, WA, USA, Nov 2007.

Tarkan Tan

Tarkan Tan is an Assistant Professor in the School of Industrial Engineering at Eindhoven University of Technology, The Netherlands, currently spending an academic term at the University of California, Los Angeles, as a visiting scholar. Dr. Tan received his Ph.D in Industrial Engineering from the Middle East Technical University, Ankara, Turkey, in 2002. He pursued one year of his studies towards his Ph.D. degree at Columbia University, Graduate School of Business, Management Science/Operations Research division, New York, as a Fulbright scholar. In 2003, he started as assistant professor at Eindhoven University of Technology. Dr. Tan has been involved in the supervision of six Ph.D. students and numerous M.Sc. students. He also serves on the executive board of the European Supply Chain Forum.

Dr. Tan's current research is focused on service logistics, inventory systems with advance demand information and green supply chains. Within service logistics, he concentrates on spare parts management of capital goods in multi-echelon networks.

Five Key Publications

- Tan, T., Güllü, A. R., and Erkip, N., “Modelling Imperfect Advance Demand Information and Analysis of Optimal Inventory Policies”, *European Journal of Operational Research 177*, 897-923, 2007.
- Alp, O. and Tan, T., “Tactical Capacity Management under Capacity Flexibility”, *IIE Transactions 40*, 221-237, 2008.
- Mincsovics G., Tan T., and Alp, O., “Integrated Capacity and Inventory Management with Capacity Acquisition Lead Times”, *European Journal of Operational Research 196*, 949-958, 2009.
- Tan, T., Güllü, A. R., and Erkip, N., “Employing Imperfect Advance Demand Information in Ordering and Inventory Rationing Decisions”, *International Journal of Production Economics 121*, 665-677, 2009.
- Van Kooten, J. P. J. and Tan, T., “The Final Order Problem for Repairable Spare Parts under Condemnation”, *Journal of the Operational Research Society 60*, 1449-1461, 2009.

Rommert Dekker

Rommert Dekker (1957) is a full professor in Quantitative Logistics and Operations Research at the Erasmus School of Economics, Erasmus University Rotterdam. He holds Masters degrees in Mathematics (1980) from the University of Leiden, in Industrial Engineering (1990) from the University of Twente and a PhD degree in Operations Research (1985) from the University of Leiden. After his PhD he worked as research mathematician at the Shell Research Lab Amsterdam (1985-1990) and as refinery information analyst at Shell International The Hague (1990-1991), before taking up a professorate at the Erasmus University in 1992.

His research interests include spare part inventory management, maintenance optimization, reverse logistics, port and container logistics and transportation management. He has published about 85 papers in international refereed scientific journals in these areas. He has supervised over 90 master thesis projects in the area of logistics, most of them in industry, and over 20 PhD theses. He has been awarded with the UK's OR Society's Goodeeve medal for the best applied paper and with the Erasmus ERIM Research School impact award for the Revlog project. He has figured several times in the top 40 of most publishing persons in economics faculties in the Netherlands and obtained an 11th place in the latest rating within economic faculties based on the *h*-factor (his *h*-factor is 19).

He was the coordinating scientist of a successful EU network on Reverse Logistics, Revlog. He was involved in several research projects in close cooperation with industry, such as a the E-SPIR spare parts advisory system for Shell and the Transumo Pilot program on prognostic logistics. Moreover, he is chairman of the daily board of the Service Logistics Forum Research project (since 2005).

Five Key publications

- Van der Laan, E. Salomon, M., Dekker, R. and Van Wassenhove, L.N., "Production planning and inventory control for remanufacturable durable products", *Management Science 45*, 733-747, 1999.
- Dekker, R., Hill, R.M., Kleijn, M.J. and Teunter, R., "On the (S-1,S) lost sales inventory model with priority demand classes", *Naval Research Logistics 49*, 593-610, 2002.
- Aronis, K.P., Magou, I., Dekker, R., and Tagaras, G.A., "Inventory control of spare parts using a Bayesian approach: A case study", *European Journal of Operational Research 154*, 730-739, 2004.
- Porras, E., and Dekker, R., “An inventory control system for spare parts at a refinery: An empirical comparison of different re-order point methods”, *European Journal of Operational Research 184*, 101- 132, 2008.
- Kroon, L.G., Maroti, G., Retel Helmrich, M., Vromans, M.C.J.M. and Dekker, R., “Stochastic Improvement of Cyclic Railway Timetables”, *Transportation Research Part B 42*, 553-570, 2008.

Adriana Gabor

Adriana Gabor (1974) is an assistant professor in Operations Research at the Erasmus School of Economics, Erasmus University Rotterdam. She has a Master degree (1997) from the Babes-Bolyai University in Cluj Napoca, Romania and a PhD (2002) from the University of Twente. After her PhD she was a postdoctoral fellow in Twente (2002-2005) and assistant professor at Eindhoven University of Technology (2005-2008). In 2008, she started at Erasmus University.

Her research focused on applications of OR in telecommunications and logistics, combinatorial optimization and stochastic optimization. She participated in two projects, one on stochastic network analysis for the design of self optimizing cellular mobile communications systems, funded by STW, and one on resource allocation in UMTS networks, as a part of a project between Vodafone and Eurandom. At Erasmus University, she became involved in the Service Logistics Research project.

Five key publications (also under the name A.F. Bumb)

- Gabor, A.F., and Van Ommeren, J.C.W., "Approximation algorithms for facility location problems with subadditive cost functions", *Theoretical Computer Science 363*, 289-300, 2006.
- Van Ommeren, J.C.W., Bumb, A.F., and Sleptchenko, A., "Location of repair shops in a stochastic environment", *Computers and Operations Research 33*, 1575-1594, 2006.
- Gabor, A.F., and Van Ommeren, J.C.W., "An approximation algorithm for a facility location problem with inventories and stochastic demands", *Operations Research Letters 34*, 257-263, 2006.
- Gabor, A.F., Tan, H.P., Nunez-Queja, R., and Boxma, O.J., "Admission Control for Differentiated Services in Future Generation CDMA Networks", *Performance Evaluation 66*, 488-504, 2009.
- Gabor, A.F., and Van Ommeren, J.C.W., "A new approximation algorithm for multilevel facility location problems", *Discrete Applied Mathematics 158*, 453-460, 2010.

Matthieu van der Heijden

Matthieu van der Heijden (1962) is currently associate professor in Supply Chain Management and Service Logistics at the University of Twente. He holds a Masters degree in econometrics (1986) and a PhD in Economics (1993) from the Free University in Amsterdam. Before, he has been working as consultant in operations research and statistics at Philips Electronics / CQM from 1986 to 1994, as an assistant professor at the University of Twente from 1994 to 1999 and as consultant in logistics at TNO in from 1999 to 2000.

His research interests include spare part inventory management, maintenance optimization, inventory management in supply chains and transportation management. He has published about 35 papers in international refereed scientific journals in these areas. He has supervised dozens of graduation projects in the area of operations management. He has participated in several research projects in close cooperation with industry, such as simulation, dimensioning and logistics control of an (underground) logistic system around Amsterdam Airport Schiphol (1997-2001), several projects within the TRANSUMO program on sustainable mobility (2005-2009), Service Logistics Forum Research (2005-...) and the IOP-IPCR project “Life cycle oriented design of capital goods” (2005-2010). He has reviewed dozens of papers for journals like Operations Research, European Journal of operational Research, International Journal of Production Economics, IIE Transactions and many others).

Five key publications

- Van der Heijden, M.C., Diks, E.B., and De Kok, A.G., “Stock allocation in general multi-echelon distribution systems with (R, S) order-up-to policies”, *International Journal of Production Economics 49*, 157-174, 1997.
- Van der Heijden, M.C., Van Harten, A., Ebben, M.J.R., Saanen, Y.S., Valentin, E., and Verbraeck, A., “Using simulation to design an automated underground system for transporting freight around Schiphol Airport”, *Interfaces* 32, 1-19, 2002.
- Ebben, M.J.R., Van der Zee, D.J., and Van der Heijden, M.C., “Dynamic access control for two-direction shared traffic lanes”, *Transportation Research Part B 38*, 441-458, 2004.
- Sleptchenko, A., Van der Heijden, M.C., and Van Harten, A., “Using repair priorities to reduce stock investment in spare part networks”, *European Journal of Operational Research 163*, 733-750, 2005.
- Basten,R., Schutten, J.M.J., and Van der Heijden, M.C., “An efficient model formulation for Level of Repair Analysis”, *Annals of Operations Research 172*, 119-142, 2009.

Henk Zijm

Henk Zijm is currently full professor in Production and Operations Management and head of the Dept. of Operational Methods for Production and Logistics in the Faculty of Management and Governance of the University of Twente. He worked for 8 years with Philips Electronics in various positions in manufacturing and supply chain management and in addition became full professor at Eindhoven University of Technology in 1987. In 1990 he joined the University of Twente as a full professor in Production Engineering and Management. His research interests include production and supply chain management, warehousing, maintenance planning and control, service logistics and process planning. He has been a consultant to a large number of companies both in the Netherlands and abroad. He has published more than 100 articles in international refereed scientific journals and is the (co-)author of two books. He supervised more than 150 master and more than 20 PhD students and serves as associate editor of two journals in his field. In addition, he held several administrative positions, including positions as Scientific Director of the Center for Telematics and Information Technology, and Dean of the Faculty of Electrical Engineering, Mathematics and Computer Science. In 2004, he was selected to become the Rector Magnificus of the University of Twente, a position he fulfilled until January 2009. Besides holding the chair in Production and Operations Management, he still serves as the Vice-Rector of Internationalization of the University of Twente (on request of the current Executive Board) and fulfils a number of external positions, among which Chairman of the Board of ASTRON (the NWO institute for Radio Astronomy) and Vice Chairman of the Council of Commissioners of the Development Agency East Netherlands (OOST NV). Also, he is currently President of the International Society for Inventory Research (ISIR), Budapest.

Five key publications

- Van Houtum, G.J., Inderfurth, I., and Zijm, W.H.M., “Materials coordination in stochastic multi-echelon systems”, *European Journal of Operational Research 95*, pp. 1-23, 1996.
- Zijm, W.H.M., “Towards Intelligent Manufacturing Planning and Control”, *OR Spectrum 22*, pp. 313-345, 2000.
- Rustenburg, W.D., Van Houtum, G.J., and Zijm, W.H.M., “Spare part management for technical systems: resupply of spare parts under limited budgets”, *IIE Transactions 32*, pp. 1013-1026, 2000.
- Shanthikumar, J.G., Yao, D.D., and Zijm, W.H.M. (eds.), *Stochastic Modeling and Optimization of Manufacturing Systems and Supply Chains*, Kluwer Academic Publishers, Boston, 2003.
- Timmer, J.B., and Zijm, W.H.M., “Coordination mechanisms for inventory control in three-echelon serial and distribution systems”*, Annals of Operations Research 158*, pp. 161-182, 2008.

Appendix II: Key Information of Consortium Partners

In this appendix, we give key information of all partners involved in this project:

1. Eindhoven University of Technology
2. Erasmus University
3. University of Twente
4. Service Logistics Forum
5. Gordian Logistic Experts B.V.
6. ASML Netherlands B.V.
7. Ceva Logistics Netherlands
8. DAF Trucks N.V.
9. Fokker Services BV
10. IBM Nederland B.V.
11. Océ Technologies BV
12. Marel Stork Poultry Processing B.V.
13. Thales Nederland B.V.
14. Vanderlande Industries B.V.

1. Eindhoven University of Technology

At the Department Industrial Engineering and Innovation Sciences of Eindhoven University of Technology, maintenance management has a long and strong tradition that dates back to the early 1970-s, when Prof. Geraerds started as Professor of Maintenance. Since then many scientific papers, Ph.D. theses, and master theses have been written. The research in this area has always been executed in close collaboration with the industry.

In the past 10 years, the following PhD theses were completed:

- J.M. Keizers, “Subcontracting as a capacity management tool in multi-project repair shops”, 2000, Supervisors: J.W.M. Bertrand and J. Wessels, in collaboration with the Royal Netherlands Navy.
- W.D. Rustenburg, "A System Approach to Budget-Constrained Spare Parts Management", 2000, Supervisors: G.J. van Houtum, W.H.M. Zijm, and A.G. de Kok, in collaboration with the Royal Netherlands Navy.
- A.A. Kranenburg, "Spare Parts Inventory Control under System Availability Constraints", 2006, Supervisors: G.J. van Houtum and A.G. de Kok, in collaboration with ASML.
- I.M.H. Vliegen, "Integrated Planning for Service Tools and Spare Parts for Capital Goods", 2009, Supervisors: G.J. van Houtum and A.G. de Kok, in collaboration with ASML.

The research of Kranenburg has lead to the implementation of a tactical planning algorithm for the spare parts in all local warehouse of ASML. After the implementation in 2005, this has resulted in both a drastic reduction in both downtimes and spare parts stock investment. This work had also a high scientific value. Kranenburg received the EURO Doctoral Dissertation Award 2007 for the best European PhD thesis within Operations Research. In the PhD project of Vliegen, the planning of service tools has been studied. The results of that project are currently being developed in further detail and this is planned to lead to the implementation of an integrated planning method for parts and tools.

The planning algorithm that we developed for ASML has lead to a lot of follow-up research. In one of the master thesis projects, P. Rijk developed a modified version for the planning of car stocks and quick response stocks at Océ Technologies and identified a large improvement in effectiveness and efficiency. After a successful pilot in France, this algorithm is currently being implemented in all service areas in Europe.

Currently, the following PhD projects are ongoing:

- K.B. Öner, "The Effect of Design Decisions on Service Costs of Capital Goods", Planned graduation date: August 30, 2010, part of the IOP-IPCR project on “Life cycle oriented design of capital goods”.
- I.C. Reijnen, "Planning and Design of Spare Parts Networks", Planned graduation date: 2011, Supervisors: T. Tan and G.J. van Houtum, part of the SLF Research project.
- A.C.C. van Wijk, "Pooling in Inventory and Queueing Systems", Planned graduation date: 2011, Supervisors: I.J.B.F. Adan and G.J. van Houtum.
- F.J.P. Karsten, "Competition and Cooperation in Service Supply Chains", Planned graduation date: 2013, Supervisors: M. Slikker and G.J. van Houtum.
- J.J. Arts, "Inventory and Capacity Management for Repairables", Planned graduation date: 2013, Supervisors: A. Elwany and G.J. van Houtum, in collaboration with Nedtrain.
- M. Driessen, "Planning of Spare Parts within MRO organizations", Planned graduation date: 2014, Supervisors: W.D. Rustenburg and G.J. van Houtum, in collaboration with Gordian and 5 other companies.

Many of these PhD projects are supplemented by master thesis studies (around 10 master thesis studies per year).

2. Erasmus University

The Erasmus University Rotterdam (EUR) has a long track record in the field of quantitative methods for logistics. Numerous projects have been completed in the past decades, many of them in close cooperation with industry and asset managers, like Fokker Services, Shell Pernis Refinery, Shell Services International, Europe Combined Container Terminals, ATT Telecom, Dutch State Water Authorities, ProRail, RGD and others. In the specific area of maintenance and service logistics, research dates back to the early 90's. Scientific projects that are particularly relevant for this research field and carried out within the Erasmus School of Economics include:

- Spare parts inventory advice at Shell Pernis refinery (Dekker, de Rooij, Rijneveld)
- Spare parts inventory control in case of priority demand classes (Kleijn, Teunter, Dekker)
- Development of an advisory rule for spare parts stocking to be incorporated in the E-SPIR program by Shell Services International (Dekker, Olthof, Sinnema, Buys, Teunter)
- Integrating Shell's E-SPIR advice with RCM projects (van Jaarsveld, Dekker)
- Spare parts inventory advice to Fokker Services (van Jaarsveld, Stassen, Dekker)
- Advice on Final Buys at Philips Consumer Electronics (Sigar, Pourakbar, Dekker)
- Install base forecasting and dynamic spare parts inventory control (Pince, Dekker)
- Maintenance optimization for buildings (vanWinden, Dekker)
- Road maintenance planning optimization (Plasmeijer, Dekker)
- Railway track maintenance optimization (Budai, Huisman, Dekker)

Next to that the Rotterdam School of Management (also part of EUR) has done several projects on maintenance and spare parts management, especially with IBM Global Parts Services.

Currently, the EUR participates in the Service Logistics Forum Research in collaboration with the universities in Eindhoven and Twente, Gordian Logistics Experts and 13 major companies in the Netherlands (IBM, Philips Healthcare, NedTrain, voestalpine RailPro, Marel Stork Poultry Processing, Vanderlande Industries, Océ, IHC, Thales Netherlands, Fokker Services, DAF, CEVA Logistics, ASML). Altogether, the research projects mentioned above have resulted in dozens of publications in the area of maintenance and service logistics in international scientific journals. Moreover, EUR algorithms are in use with Fokker Services and Shell's E-SPIR program.

3. University of Twente

The University of Twente (UT) has a long track record in the field of quantitative methods for operation management. Numerous projects have been completed in the past decades, many of them in close cooperation with Industry like Urenco, DAF Trucks, Scania, Stork Plastics Machinery, Grolsch, the Royal Netherlands Navy, Thales, Vanderlande Industries, and others. In the specific area of maintenance and service logistics, research dates back to the early 90's. Scientific projects that are particularly relevant for this research field include:

- road maintenance planning (Worm, van Harten)
- relation between maintenance planning and production (van Dijkhuizen, van Harten)
- budget constrained spare part management (Rustenburg, Zijm)
- re-engineering maintenance organizations (de Waard, Zijm)
- integration of spare part inventory management and prioritizing repair jobs (Sleptchenko, van der Heijden, van Harten)
- integration of maintenance planning and spare part optimization (de Smidt-Destombes, van der Heijden and van Harten)
- integration of repair decisions and spare part inventory optimization (Basten, van der Heijden, Schutten, Zijm)
- customer differentiation in service logistics (Alvarez, van der Heijden, Zijm).

Under supervision of Zijm, a long-term research programme has been carried out in the organization, planning and control of the logistics processes at the Netherlands Navy, involving organizational structures, process planning, project management of large overhaul projects and spare parts management. Currently, the UT participates in the Service Logistics Forum Research in collaboration with the universities in Eindhoven and Rotterdam, Gordian Logistics Experts and 13 major companies in the Netherlands (IBM, Philips Healthcare, NedTrain, voestalpine RailPro, Stork PMT, Vanderlande Industries, Océ, IHC, Thales Netherlands, Fokker Services, DAF, CEVA Logistics, ASML). Also, the UT participates in the IOP-IPCR project "Life Cycle Oriented Design of Capital Goods" in cooperation with Eindhoven University of Technology and several industrial partners (Thales Netherlands, Philips Healthcare, PANalytical and Vanderlande Industries. Altogether, the research projects mentioned above have resulted in dozens of publications in the area of maintenance and service logistics in international scientific journals.

4. Service Logistics Forum

Involved persons

- G.F.X.M. Gommers, Chairman
- B. A. Gräve, Secretary
- G. Wolf, Manager

Short description of the company

The Service Logistics Forum, SLF, an initiative of Districon Management Consultants, has developed itself since more than 15 years as the Knowledge Platform in The Netherlands where leading companies (approximately 50) and universities (Eindhoven, Rotterdam and Twente) are meeting for service logistics matters. The main activities are:

- Dedicated workshops (4 per year and for members only):
  Purpose of the sessions is to share know-how of service logistics matters in the widest sense.
- One open congress per year:
  European Keynote speakers share their knowledge and experiences and in addition dedicated workshops are organized zooming in on specific service logistic issues. This open congress attracts yearly about 180 visitors from many different industries and universities.
- SLF-Research:
  Over the last 5 years, SLF initiated and hosted a number of research projects which are executed by the universities of Eindhoven, Rotterdam and Twente together with 13 major companies,
- Forum website:
  A dedicated website (www.servicelogisticsforum.nl) for members and non-members to share information. See also this website for more detailed information about SLF and its members.

Roadmap and ambition

We distinguish the following parts:

- Service logistics competence: Service logistics is the core competence of SLF.
- Ambition: The ambition is to remain the Service Logistics Knowledge Platform in The Netherlands and to reach out to even more companies and knowledge institutes.
- Roadmap: Continue to organize the main activities of dedicated workshops, yearly congress, research and website. In addition, SLF will line-up with Dinalog (and other top institutes as required) to ensure maximum synergy for service logistic matters.

Role and input in the ProSeLo-project

We distinguish the following roles:

- Network / knowledge: The value that SLF will bring is the service logistics network of companies and institutes, and the related knowledge.
- Valorization: SLF can play an important role in the valorization of the research project by addressing results in their workshops, congresses and website. SLF will also facilitate and/or manage activities like dedicated learning, research, demonstration or implementation events for the project related valorization activities.
  The required input, role and responsibilities of the SLF valorization activities will be determined as part of the future detailed project description of the ProSeLo work packages.

5. Gordian Logistic Experts B.V.

Involved persons

- Jan Willem Rustenburg
- Jürgen Donders

Short description of the company

Gordian is a logistics management consultancy and deployment agency, specialized in service logistics and supply chain management.

With 15 professionals on board, Gordian built up a comprehensive track record of service logistics projects at a variety of customers. The projects generally aim at reducing costs, improving service levels and uptime, and improving the service profitability.

Gordian is a result driven company. Successes are measure along real metrics such as inventory reductions or service level increases. Generally Gordian takes a significant stake in the implementation, and hence in achieving the project objectives.

The customers generally use and/or maintain advanced capital goods. Examples include Nedtrain, Alstom, The Dutch Defense Materiel Organization, Varian and Eneco.

In order to maintain a leading position in Service Logistics, Gordian heavily invests in innovation. Examples include:

- Jan Willem Rustenburg fulfils the role matchmaker between science and practice in the SLF-Research project;
- Jürgen Donders is the chairman of the steering committee of the IOP-IPCR project on “Life cycle oriented design of capital goods”;
- Gordian hosted multiple master thesis projects in the past few years.

Given her profile and ambitions, Gordian is highly committed to creating a win-win between the Dinalog interests and her own interests.

For further information, please go to www.gordian.nl.

6. ASML Netherlands B.V.

Involved employees

- Harrie de Haas, Sr. Director Global Logistics Services
- Rene Botter, Sr. Manager Customer Logistics
- Lex Keij, Sr. Manager Customer Support Operational Services

Short description of the company

ASML is the world's leading provider of lithography systems for the semiconductor industry, manufacturing complex machines that are critical to the production of integrated circuits or chips. Headquartered in Veldhoven, the Netherlands, ASML is traded on Euronext Amsterdam and NASDAQ under the symbol ASML. ASML has more than 6,500 employees (expressed in full time equivalents), serving chip manufacturers in more than 60 locations in 15 countries.

Competences in service logistics

ASML's commitment to outstanding customer support is second to none. It's a well-established network of highly knowledgeable professionals committed to provide high quality support customized to the specific requirement of our customers. This support includes service engineers - armed with the most up-to-date technical information - to ensure the highest levels of machine performance, as well as applications specialists who support optimal (system) processing and new product implementation. Combine this with comprehensive training programs plus a logistics protocol that satisfies more than 99% of all parts requests within the first 24 hours and you have a professional support organization that is clearly focused on putting the "Customer First".

In order to reach these demanding service levels ASML has invested in development and implementation of advanced planning methodologies, which have been developed together with Eindhoven University of Technology. Both the research work performed and implementation have been awarded, with several prizes in the academic world (among which the EURO Doctoral Dissertation Award 2007 for the best PhD thesis in Operations Research, written by Bram Kranenburg) and from our key customers (best supplier prizes from e.g. Intel and VLSI Research).

Roadmap and ambition

Next step for ASML to optimize the relation between service level and investment in working capital, is to leverage actual parameter data from the individual machine and develop methodology and tools to improve the accuracy of forecasting of potential failures on machines. This is aimed to lead to improved uptimes for our customers against lower investments, by turning unplanned downtimes (corrective maintenance) into planned downtimes (preventive maintenance).

Role and input in the ProSeLo-project

ASML will be involved in WP III: Proactive maintenance via remote monitoring. ASML has highly complex machines that are capable of generating a lot of information which must be the basis for turning this into predictable service actions. The value ASML will bring to the project is the capability to validate business cases and solution directions in an extremely complex environment combined with an already existing advanced planning methodology.

7. Ceva Logistics Netherlands

Involved employees

- Ron Roest, Sector Manager Industrial, France, Benelux, Nordics
- Martin Gouda, Business Development Director, France, Benelux, Nordics

Short description of the company

CEVA is one of the world's leading integrated supply chain logistics providers, offering market-leading contract logistics and freight forwarding expertise and capabilities. We design, implement, and operate complex, end-to-end contract logistics and freight forwarding solutions for large and medium-sized national and multinational companies.
Our integrated service offering spans the entire supply chain:

- contract logistics services including inbound logistics, manufacturing support, outbound and distribution logistics, and aftermarket logistics;
- freight forwarding services including air, ocean, and ground-based transportation, and other freight transportation-related services such as customs brokerage, local pick-up and delivery service, materials management, and trade facilitation.

Our "asset-light" operating model uses third parties to provide the majority of the physical transportation and warehousing assets that benefit our customers. CEVA has a worldwide revenue of 5.5 billion Euro's, employs more than 46,000 people and our global network comprises more than 1,200 locations, with 10 million square meters in over 170 countries.

Competences in service logistics

The delivery of spare parts is an increasingly important element of the supply chain for many of our customers. Service expectations by end-users in industries such as electronics and automotive are increasing and spare parts delivery allows manufacturers to differentiate themselves from competitors. For CEVA, aftermarket logistics is a core activity. We provide these solutions around the world for customers in different industries. Services that we can offer in the area of aftermarket logistics are:

- Warehousing
- Managing network of forward stock locations
- Transportation management
- Returns logistics
- Repairs
- Reverse logistics
- Call centres

In the Benelux CEVA operates spare parts networks for customers like Sandvik Mining, Grundfos, Terex Aerial Works Platforms, Wartsila, Huawei, and Getronics. Next to this there are many more references in after market services in other countries, such as Airbus, Rolls Royce Aerospace, Jungheinrich, FIAT, and Volkswagen.

Roadmap and ambition

In relation to services in the after market CEVA has the following roadmap and ambitions:

- CEVA wants to become the industry leader in the after market logistics for companies in automotive, technology and industrial sectors.
- CEVA is developing a service offering called SMART SPARES that includes a standard solution set that can be implemented anywhere in the world based on the best practices that we have developed.
- The SMART spares solution sets include standard operating procedures, KPI's, IT solutions including specifications of the main value added services.

- The SMART solutions will be tailored for automotive, technology and industrial to include the main characteristics and specifics.

Role and input in the ProSeLo-project

CEVA sees a role in the ProSeLo project in supporting the development of supply chain structures for specific business cases. Remote monitoring will result in increasing preventive maintenance and this can result in optimized supply chain structures to support this. CEVA can provide its experience in designing and calculating various supply chain scenarios in terms of warehousing and transport networks to support the changing after market requirements.

8. DAF Trucks N.V.

Involved employees

- Johan Drenth, Director After Sales
- Kristof Smets, Manager Diagnostics
- Ton Noyons, Reliability Engineer
- Frank Rustige, Manager Projects & Support Paccar Parts
- Alex Huttinga, Project manager Paccar Parts

Short description of the company

PACCAR is a global technology leader in the design, manufacture and customer support of premium light-, medium- and heavy-duty trucks under the Kenworth, Peterbilt and DAF nameplates.

In 2009 DAF Trucks produced 16,460 CF and XF vehicles. Together with more than 5,300 Leyland-produced LF series, a total of 21,828 DAF trucks was manufactured. In a market of about 168,000 registrations in the over 15 ton segment, DAF achieved a market share in the European Union (including Norway and Switzerland) of 14.8%. In the 6 to 15 ton segment DAF's EU market share was 9.3% in a market of almost 50,000 truck registrations.

DAF's headquarters, engine factory, component plant, press shop and final assembly line for CF and XF models are located in Eindhoven, the Netherlands. Axles and cabins are produced in Westerlo, Belgium. Leyland Trucks (PACCAR company) in the UK produces the company's LF series of light and medium duty trucks, as well as CF and XF105 vehicles.

The company also provides customized financial services, information technology and truck parts related to its principal business.

Competences in service logistics

The profitability of a truck depends on its usability. The availability of parts for maintenance and repair plays an essential role in this. Parts distribution is one of PACCAR's key competencies.

In the early 70s, DAF was the first truck manufacturer to introduce an international assistance service (ITS) that stranded drivers could call on for help. DAF ITS is still a pioneering force in the commercial vehicles industry and is one of the most valued and professional service organizations.

PACCAR Parts has a total of 13 parts distribution centers at strategic locations around the world for the daily supply of parts to a growing number of PACCAR dealers and customers. PACCAR Parts has more than tripled its turnover since 1996 and realized a turnover of $2.3 billion in 2007.

Roadmap and ambition

DAF fully focuses on the Truck's uptime. In this focus, there are two important elements:

- In case a Truck has a breakdown, the Service Organization reacts adequately, coordinated by the ITS call center
- In case parts are required, there is sufficient stock available at the dealers, facilitated by the MDI (Managed Dealer Inventory) system. As the Parts Business is characterized by many slow movers, having the correct parts in stock is not obvious.

Until now, the focus has been limited to these two elements.

Remote Diagnostics should facilitate a more proactive approach in increasing the Truck's uptime:

- In providing information based upon which the Truck's uptime can be increased by preventative maintenance
- In providing information based upon which the Parts stock can be managed more accurately

This will be an attractive point at selling the Truck and Services: The DAF Service Organization manages the Repair and Maintenance during the Truck's lifecycle from delivery to the customer till the end of its lifetime.

Role and input in the ProSeLo-project

Specifically in the ProSeLo-project we try to increase the Quality of information on the riding Truck and/or its components and the Quality on interpretation of this information. This should facilitate a more proactive approach on the objective to increase the Truck's uptime by the DAF organization. The value DAF can bring is to provide practical real business scenario data and (development) expertise in this field as a basis for further research and optimization.

9. Fokker Services BV

Involved employees

- Cors van der Laan, Manager Supply Chain
- Erik Geertsema, Vice President Component & Material Services

Short description of the company

Fokker Services is an independent Aerospace services provider, combining OEM (design) knowledge and independent after-sales MRO support to performance based aircraft MRO services. Being Type Certificate holder of all 700 Fokker aircrafts operated today, Fokker Services has all the skills, facilities, equipment and systems in place to deliver Total Support Solutions to aircraft operators and owners in the continued competitive operation of their fleet.

Today, Fokker Services has earned its position as unique and valuable partner for the global aerospace industry, supporting a large fleet of various aircraft types. Capabilities include Component Availability Programs, Flighthour based Component Repairs, Engineering and Documentation Support and Airframe Maintenance, Conversion and Completion capabilities.

Competences in service logistics

Fokker Services is a front-runner in innovative aftermarket support solutions. Our supply chain solutions include:

- <u>Supply Chain Management</u>
  Guaranteed Performance commitments, tailored to customer's demands
- <u>Spare Parts Supply</u>
  Parts Obsolescence Management & Demand Forecasting Techniques
  Parts redesign (including PMA) engineering and supply
- <u>Component MRO Services</u>
  Extensive in-house capabilities in Europe and the USA
  Cost savings via Cost Driver Analysis, Reliability Improvement & Redesign (including use of PMA and DER repairs)
- <u>Component Availability Services</u>
  Lease & Exchange Pool with Availability Guarantees for Spare Parts
  "Power by the Hour" based Component MRO Agreements

Roadmap and ambition

Fokker Services' value proposition as service provider will develop to partnerships based on total aircraft support and fleet management solutions. Fokker Services will be recognized as an Out of Production Aircraft Specialist by OEM's, which partners with world class after sales services for outsourcing their aftermarket product support. Total care programs provide both aircraft owners, operators and manufacturers partnership models for financial and operational risk sharing.

In this respect Fokker Services is also stepping in, or growing in, supporting other than Fokker aircrafts, starting on a transactional / service-provider level. Fokker Services is looking for possibilities to maximize availability against reasonable cost whereby ideas like 4C and shared parts are beneficial.

Role and input in the ProSeLo-project

Fokker Services has expertise of the market needs and has business models in place which ensure long term availability and Fokker Services is willing to support the development of a global control of the supply chain of spare parts.

10. IBM Nederland B.V. (as part of International Business Machines Corp.)

Involved employees

- Michiel Kuipers, WW Business Transformation and IT leader for IBM Global Logistics (GL) and Service Parts Operation (SPO)
- Jaap Bolijn, GL / SPO Parts Cost, Quality & Reutilization Manager
- Joost Smit, GL / SPO Europe Business Transformation and IT manager
- Karin Sauren-Bakkers, SPO special projects manager

Short description of the company

IBM is a company of ± 400,000 individuals who do, in new ways, what IBM-ers have done for nearly a century: invent technology and apply it to business and society on a global scale to make the world work better. Today, we create and integrate hardware, software and services to enable enterprises, institutions and forward-thinkers around the world to succeed.

IBM operates in more than 170 countries and enjoys an increasingly broad-based distribution of revenue, grouping markets by common growth characteristics, not location.

Within IBM there are 5 major operations to be distinguished:

1) <u>Global Technology Services:</u> Primarily provides outsourced IT infrastructure and business process services
2) <u>Global Business Services:</u> Primarily provides professional services and application outsourcing services
3) <u>Systems and Technology:</u> Provides clients with Solutions that require advanced computing power and storage capabilities, as well as leading semiconductor technology and products
4) <u>Software:</u> Consists primarily of middleware that enables clients to integrate systems, processes and applications, and operating systems software that runs computers.
5) <u>Other:</u> Our Sales organization and our R&D and IP organization also deliver value to clients

Competencies in service logistics

IBM has located their European headquarter for SPO (Service Parts Operation) in the Netherlands back in the early 90's. Since that time major innovations and transformations took place relative to IBM's SPO, which has resulted in major improvement in terms of reduction of spare parts inventory, improvement of service levels and reduction of logistics costs.

In the early 90`s, IBM parts operations in Europe was organized at a country level, with country specific processes and inventory ownership at country level. This mode of operation was changed during the last decade of the 20th century into an operation managed centrally out of the Netherland for the whole of Europe. This was done by introducing a run-once do once single instance IT system called CPPS. This system enabled single ownership of inventory on a European level rather than on a country level and installed common processes across all European countries.

Since the beginning of 21st century we have been on a path of Globalization of the key process and the related organizational setup. For the key process in IBM's service parts operations this has been implemented.

Besides the introduction of WW common processes and the associated simplification, IBM has spent a lot of investment in improving and enhancing the planning of the spare parts in all of its life cycle. Key achievements here are the introduction of the Neighborhood planning system combined with an enhanced spare parts allocation algorithm that supported the concept of High Availability Time based services. Obviously here a strict link with the clients installed base and service contracts exists (i.e., service levels the client is entitled to get.)

Significant investment has been put in the optimization in other processes as well, like asset recovery, reutilization etc. In 2003 IBM has been awarded the annual prize from the VLM (the Dutch association for supply chain management) for IBM's advanced way of dealing with reuse of parts and reverse logistics capabilities in Europe.

Latest significant development related to the service parts operations is IBM's divestiture of the total physical parts delivery activities & supporting team to the Geodis company.

Roadmap and ambition

IBM's ambition with the service parts operation is to create a highly reliable and flexible service parts management service that delivers the requested level of service under optimized inventory and cost levels.

Specific challenges are

1. to support a wide range of service offerings and the ability to execute against the requested SLA for the agreed upon cost. This against a backdrop of a highly outsourced delivery infrastructure which should be flexible to quickly adapt to new SLA's and be 100% variable in cost (100% transaction based).
2. to support both IBM branded products as well as non-IBM (MVS) at the same level of efficiencies
3. to be best in class in planning service parts inventories in order to achieve the requested SLA's with lowest possible levels of inventory and cost during the complete lifecycle of the parts.
4. to achieve the optimal mix of new vs. used class/repaired parts with the aim of the lowest parts cost and environmental burden.
5. to put in place a WW service parts management control tower which enables IBM to manage and control the service parts business while the execution is done by third parties.

Role and input in the ProSeLo-project

Specifically in the ProSeLo-project we try to get more understanding of the combination of challenges 3&4 as mentioned above. The value IBM can bring is to provide practical real business scenario data and (development) expertise in this field as a basis for further research and optimization.

11. Océ Technologies BV (as part of Océ NV)

Involved employees

- Michiel Levels, Manager service parts planning
- Nynke van Balen, Manager Global Planning and Inventory control service parts and expendables
- Paul Rijk, Logistics Engineer Global Planning and Inventory control service parts and expendables
- Niels Beerens, Manager Unit M&L Machines
- Wil Heijmans, Manager Asset Recovery Logistics

Short description of the company

Océ develops and supplies digital printing systems, software and services for the production, reproduction, distribution and management of documents, in color and black & white, in small format and in wide format, for professional users in offices, educational institutions, industry, construction, architectural firms, advertising and the graphic arts market.

The broad and very complete product portfolio consists of products developed by the company itself for wide format and for the (very) high volume segments of small format, supplemented by selected machines from other Original Equipment Manufacturers.

Océ supplies its equipment as part of total solutions, ranging from the provision of initial advice through to the maintenance of the systems.

Competences in service logistics

Océ is commercially active in approximately 100 countries; in more than 30 of these it has its own sales and service organization. In Europe, the United States, Canada and Singapore, Océ has research and manufacturing facilities.

Océ's reputation is founded on productivity and reliability, ease of use and a favorable 'total cost of ownership'. The costs of service logistics have a considerable contribution to these costs of ownership.

To reduce the costs of ownership, Océ has been focusing on reducing these costs the last 10 years whilst providing the same high service level for its customers. The main focus was on centralizing the management of logistics processes and responsibilities. Regional warehouses were closed where not needed and replaced by smaller local Quick Response stocks. Recently the visibility and control of spares inventories has been globally centralized. This has lead to a significant reduction in costs and inventories.

Roadmap and ambition

In 2010, Océ was taken over by Canon. Following the completion of the merger, Océ will remain a separate legal entity and will become a division within Canon with headquarters in Venlo, the Netherlands. Océ will be responsible worldwide for wide format, commercial printing and business services.

For the inbound processes, Océ participates in the ProSeLo-project; see the next section for more information. For the outbound processes, the ambition is to harmonize processes and optimize service levels, costs and inventories via implementing best practices on a global scale. The focus will be on optimizing the inventory in the Operating Companies. This is a two-step approach;

1. A model is currently being implemented that will optimize the inventory levels of the technicians, and the Quick Response stocks (QRS's); this model is based on the

master thesis work of Paul Rijk (Eindhoven University of Technology, 2008), who was employed at Océ after the completion of his master thesis and who then worked on the further development of his model. Worldwide, Océ employs around 2500 technicians, each carrying their own car stock. Furthermore, each operating company uses several smaller QRS's, which support the technicians with additional inventory. The so-called fieldstock model optimizes both the car stocks and the QRS's, with regard to a target service level. The model will result in lower inventory levels and/or higher service levels, depending on the operating company.

2. When the model is implemented, the number, and location of quick response stocks will be optimized. Currently, there are significant differences between the operating companies regarding the quick response stocks, and it is expected that the total costs and/or service levels can be improved.

Role and input in the ProSeLo-project
With regard to the ProSeLo-project, Océ wants to focus on the inbound side. There are three sourcing channels for the service parts of Océ;

1. Failed parts that are returned from the field, and that are technically and economically repairable.
2. Complete systems that are returned from the field, and that cannot be sold or leased anymore to a new customer. These systems can be used as a source for service parts.
3. New parts which are manufactured by the own production department or external suppliers.

There are several uncertainties with regard to this process. The return of failed parts and returned machines is highly uncertain, the returned parts and returned parts have different quality levels, and the demand for service parts is, as always, uncertain. Given these risks, and the fact that the costs of a stock-out are high, this results in high inventory levels, and large costs for scrapping parts.

Therefore, Océ wants to get more understanding in these uncertainties, and achieve a better balance between system uptime and costs of servicing systems by more re-use of parts.

12. Marel Stork Poultry Processing B.V.

Involved employees

- G den Bok, Director of Service
- J Melssen, Senior Business Consultant

Short description of the company

Marel is an international supplier of high-end systems for the food-processing industry. Some of our internationally renowned brands are Stork Poultry Processing, Townsend Further Processing and Marel. We are constantly looking for opportunities to increase the productivity of our customers, within the limits of quality and innovation.

Worldwide more than 3700 people are employed for our four industry centers: Poultry, Further Processing, Meat, Fish, and for our regional sales and service units.

Marel Stork Poultry Processing LTD.

The working society Marel Stork Poultry Processing LTD. focuses on the design, manufacture and installation of machinery for the poultry processing industry.
Here we are world leader. In addition to the locations in Boxmeer, Dongen (Netherlands) and Gainesville, Georgia (USA), we have regional offices in a large number of countries.

Competences in service logistics

The poultry industry is becoming more professional and is getting more and more the nature of the process industry, with the result that, during the time that the machines are operational at the customer's facility, demands on our machines increase with respect to availability, reliability, and maintenance costs. If there is a good service provided it can directly be translated into a better result of the corporate contribution, to both the customer aand Stork Poultry Processing.

Stork Service department provides several services to them. Our services include e.g.

- Available Specialists around the world can be deployed
- Advise on areas such as preventive maintenance
- Modify and upgrade machines to the latest developments
- Technical and technological training for the customer
- Service visits of the Service Area Managers (SAM)
- Delivery of the appropriate components
- Service contracts
- Inform Customers through service letters about improvements

Roadmap and ambition

The company's view of the long term prospects of the market remains unchanged. Proteins play an increasingly large role in the global diet and the protein segment of the industry, in which Marel operates. This segment has been growing in an average of 5-6% for the past 15 years. There is strong underlying growth in the industry and market activity is expected to continue to improve in throughout 2010 and the next few years.

Role and input in the ProSeLo-project

The role of Stork Poultry Processing consists of hosting master thesis projects; define master thesis projects in consultation with the universities and internal monitoring and guiding of these master students. In addition to this direct task, it is also important for Stork to be a sounding board for both the PhD and master thesis projects.

13. Thales Nederland B.V.

Involved employees

- Peter Stoffer, Director Quality
- Koen ter Hofstede, Manager Logistic Engineering
- ir. Ivo Schukkink, Logistic Engineer
- ir. Rindert Ypma, Logistic Engineer

Short description of the company

Thales Nederland, a member of the Thales group, was founded in 1922 as a production plant for mechanical naval gunfire control systems. The company's research led to the development of advanced radar systems, electro-optical equipment, underwater detection systems, computers, software programs, displays and communication equipment, in short everything needed for the sensor, weapon control and command systems, and integration, of a naval vessel.

At present, Thales Nederland employs some 2000 people and its main products and services include surveillance equipment, combat management systems, weapon control equipment, programme management and combat system integration, training and Integrated Logistic Support. Over the years, the company has gained extensive expertise in implementing procurement programmes together with local industries in customer countries and to cater for comprehensive Transfer of Technology programmes.

Thales Nederland specializes in designing and producing integrated naval command and control, sensor, and communications systems, as well as ground-based air defense systems and telecommunication equipment.

Competences in service logistics

With current patterns of defense spending, naval planners must do more with less. Fleet and crew sizes are shrinking, and in many cases the service life of key naval assets is being extended. As a result, naval forces are more reliant than ever before on the contractor community for delivering specialized services and efficient support solutions so they can focus fully on their core missions. They need partners with a real understanding of the operational environment, proven expertise in complex naval systems, and the project management skills to fit all the pieces together. With more than 50 navies supported, with half a century of operational experience, Thales is that partner.

Thales is in a position to deliver a specified level of performance and system capability. Turnkey contracts, including performance based agreements or Contractor Logistic Support, optimizes resources, reduces risks and save both time and money.

With a full range of specialized services to support naval equipment and systems all over the world at all levels of maintenance, Thales experts are available to carry out any type of corrective or preventive maintenance task on site or using remote maintenance solutions. Thales believes in maximizing system availability on an ongoing basis. Thales systematically analyzes customers feedback and builds on lessons learned to deliver better, faster and more cost-effective services.

Roadmap and ambition

Thales Naval Service’s ambition is to develop into a reliable, responsive and flexible Performance Based Logistic service provider that delivers the contracted performance at market competitive prices.

In order to achieve the above ambition the following issues need to be addressed;

1. To be able to estimate accurately the expected cost to execute a Performance Based Logistic contract.
2. To perform remote maintenance efficiently, in order to reduce system down times and maintenance cost.
3. To identify the most effective actions, with respect to cost and availability, to improve the value of the Key Performance Indicator while executing a Performance Based Logistic contract.
4. To find an optimal mix in spares owned by the end-user and spares owned and managed by Thales to effectively and efficiently manage Performance Based Logistic contracts.
5. To be able to define the most effective Key Performance Indicators based on the end-users needs and costs.

Role and input in the ProSeLo-project

In the ProSeLo-project Thales will develop understanding and skills for the issues 2, 3 and 4 as mentioned above. Thales will contribute by providing realistic cases, implementing some results in real business cases and providing feedback to form a basis for further research.

14.Vanderlande Industries B.V.

Involved employees

- Erlend Hessel, Sr. Service Development Engineer
- Katja Kleinveld, Supply Chain Manager Services

Short description of the company

Vanderlande Industries provides automated material handling systems and accompanying services. It focuses on improving its customers' business processes and strengthening their competitive position.

The company is active in the markets for Baggage handling at airports, Distribution Centres and Parcel and Postal sortation facilities.

The company implements material handling systems of all sizes, ranging from many local sorting depots, airports and distribution centres to the world's largest facilities. Vanderlande Industries ranks among the top 5 worldwide in its field, and in baggage handling even as one of the leading suppliers

In every case the emphasis is on close partnership with the customer, extending from initial analysis of the underlying business processes through to total life-cycle support.

To achieve this, Vanderlande Industries possesses core competences in all the relevant disciplines, ranging from system design and engineering, through supply chain management and manufacturing, to information and communication technology, system integration, project management and customer services. The company employs 1,943 people of whom more than 50% has a B.Sc. or M.Sc. degree.

Vanderlande Industries is a global player with a presence in all key regions of the world. The company has subsidiaries in the Netherlands, Belgium, Germany, France, Great Britain, Spain, Canada, PR China, South Africa and the USA. These Customer Centres handle all key business functions and maintain direct contacts with customers.

Competences in service logistics

Within Vanderlande Services is a growing business. This is the reason why over the past few years lots of improvement projects have been realized. In 2006 a dedicated Supply Chain Management Service department was founded. This department is responsible for the world wide delivery of spare parts. In order to serve the customers better, the stock for projects and services was separated and the Service Central Warehouse of Vanderlande was founded in 2007. In this warehouse spare parts are stored.

During the past years the spare parts portfolio has been broadened. Instead of offering initial spare parts packages to the customers, consignment stock is offered as an extra service to the customers. Vanderlande owns this stock until the customer uses the stock. Consignment stock can be located on site at the customer or off site in a warehouse close to the customer.

Last year Vanderlande has started purchasing for services. Instead of buying through our purchasing department for projects, Vanderlande now has dedicated persons who are responsible for purchasing spare parts. This has led to a significant reduction in lead times, and better service to the customers of VI.

Currently Vanderlande is implementing a new ERP system which is better suited for the service needs.

Roadmap and ambition
Vanderlande's ambition for the next years is to grow in service and to double the service sales in 2015. This will be done by offering a wide portfolio of services.

One of the focus areas within Vanderlande services is the further development of condition based maintenance. By remote system monitoring the exact status and performance of the system, maintenance can be carried out just before a possible failure. This leads to significant efficiency improvements and thus cost reduction in the maintenance execution.

Within the service logistics the aim is to further improve the service to the customers. In order to achieve this, it will be necessary to improve internal processes (e.g., warranty & inventory control).

Vanderlande is also working on an internet portal which will help the customers to order their spares online, but also to assist in specific information of their system. In the future it might be possible to integrate this with condition based maintenance.

When the spare parts business is further growing, it might be necessary to set up extra spare parts warehouses in for example America and Asia.

Role and input in the ProSeLo-project
Vanderlande will be a leading company in the project 'Proactive maintenance via remote monitoring'. This fits perfectly in the project of condition based maintenance (see above) which has started a couple of years ago.

Furthermore, Vanderlande is involved in the project 'last buy and re-use of spare parts'. In the light of inventory control this is a very actual topic for Vanderlande. Currently a student of Eindhoven University of Technology executes her master thesis research at Vanderlande on the topic 'last buy'. For the ProSeLo project we can use our practical experiences in this topic.