DIMECC

FINAL REPORT 6/2017

S4Fleet – Service Solutions for Fleet Management

Service transformation

Digitalization

Global fleet of equipment and people

S4Fleet – Service Solutions for Fleet Management

CONTENTS

Toward Business for Business Relationships

Over several decades, manufacturing companies have provided services and solutions that supplement their traditional product offerings. That trend continues, as integrated product and service combinations deliver value to users. Digitalization, with smart and novel usage of data, provides new opportunities to manufacturers to take a broader view of their customers' needs. They do not only aim to decrease the overall costs in the value chain. Smart usage of data will transform business relationships between existing partners, and completely new competitors may also emerge with new service concepts and business models.

Thus, it is obvious that the themes of the DIMECC S4Fleet program have an important role to play in ensuring the competitiveness of Finnish manufacturing companies. The program has worked in three major areas: strategic intelligence in fleet management; changes needed in the operational management of companies during that transformation; and technology enablers for fleet-based industrial data symbiosis. In addition to looking at industry needs, these topics are extensively studied in the global research community.

The DIMECC S4Fleet team has achieved promising results in the program, and these are summarized in this final report. The quality of the work is demonstrated through numerous high-quality scientific publications. It is obvious that such a high impact research is to be done in close collaboration with companies, piloting with customers to achieve important business results. DIMECC S4Fleet industry partners have developed new business offerings and capabilities to develop new types of services in the future. Concrete examples of results achieved in the program are different categories of services ready for market entry, new business intelligence, and financial forecasting systems. Companies have built the confidence to continue to develop the services business area, which is visible through the larger strategic importance of services and a reported increase in employment.

I want to thank the whole team for good work in the program. In addition, a special acknowledgment is made of program manager Pekka Töytäri for facilitating the work. Furthermore, the program would not have been possible without partial funding by Tekes.

We at DIMECC are pleased that good progress has been achieved through our programs. While reading, you will also note that there is still a lot of R&D work needed in the future; the program's partners, together with DIMECC's strong ICT partner network, could comprehensively support those needs in digitalization.

Ülo Parts, EVP
DIMECC Oy

Value and Competitiveness through Digitally Enabled Industrial Services

The DIMECC S4Fleet program was implemented during a period of disruptive change in industrial operations, exchange, and technology. Digitalization of industrial operations enables completely new methods of value creation, but brings a need and an opportunity for closer cooperation between business ecosystem members; calls for internal changes in organizational structures, incentives, and management; and requires new business practices for gaining and leveraging customer understanding. Simultaneously with digitalization, industrial companies respond to competitive pressures and exploit new opportunities through service-led growth. Hence, the key goal of the S4Fleet program was to identify opportunities by combining three elements: the installed base of equipment and people, increasing availability of information from industrial (and other) processes, and the business transformation toward services.

A few remarks on the program implementation: reflecting the cross-industrial demand of capabilities required implementation of digital service solutions and software-based value creation. The 23 companies in the program consortium extended beyond industrial firms to include a broad range of ICT capabilities, featuring data management and advanced analytics. The six research institutes carried forward a major body of knowledge around the program's three key elements of strategy, operations, and technology. This setup provided for a problem-specific focus, as well as for a broader horizontal focus across the key cross-program themes. To support broader coalition-building and information exchange, the program arranged a number of special interest group programs open to all program participants: more than ten open seminars with a total of more than 300 visitors, doctoral seminars and development workshops, international researcher exchange, and conference participation. So far, more than 27 business results have been published, 163 articles and book chapters published, and three books released.

One perspective for understanding the results achieved and identifying future opportunities is to map the results against a framework of digital industrial services. One approach to classifying industrial services is to use the service goal as the criterion. The framework below suggests that industrial services can be analyzed as function preserving, availabil-

ity guaranteeing, performance improving, operational outsourcing, and fleet-level optimizing services. Generally, digitalization of function- and availability-related services presents rather low-hanging fruit for the consortium, while genuine fleet-level innovations remain less frequent. However, the program has identified and partially implemented services and concepts that build on fleet-specific topics, such as benchmarking specific equipment and processes against the entire fleet, to identify improvement opportunities, a fleet management platform concept, fleet data management standards, and similar results, helping to leverage fleet-specific opportunities. In a slightly narrowed scope, many of the digital innovations leverage production-generated data for control, prevention, and optimization of the process itself. The digital information also supports process development, task allocation, and near real-time evaluation of business performance. S4Fleet has also developed generic business value assessment practices to support performance-based agreements between business partners, evaluate the benefits of service outsourcing decisions, and communicate service value. These examples illustrate the spread of innovative services across the service categories.
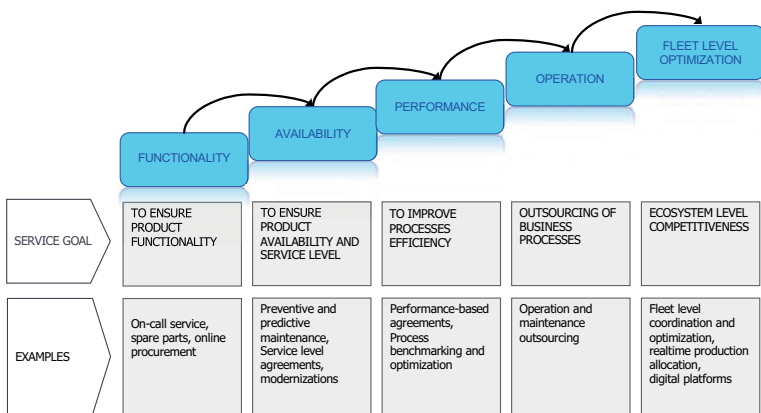
Figure 1. **A view of digitally enabled service categorization**

Cross-project results highlights

Six workshops explored the key cross-project themes: digital platforms enabling advanced services; digital service provider requirements; predictive maintenance service offering; value-based selling, pricing, and business models; fleet-enabled services; and service portfolio manage-

ment. These company-hosted workshops broadly explored the key topics shaping the service business. Digital platforms dynamically integrate resources and capabilities as meta-organizations, and enable very efficient resource utilization and value creation. Digital services impose requirements on organizational structures and management of business networks. Business exchange is transparently focused on value created for the involved parties, and requires managerial focus to shift from value capture to value creation.

Next steps

During the DIMECC S4Fleet program implementation, novel approaches to digital value creation, such as digital platforms and ecosystems around these platforms, gained attention and investment. Traditional industrial ecosystems grow rather slowly, but the digital platforms are likely to introduce a new level of dynamism in linking actors, capabilities, and resources as purpose-specific production, development, and learning entities. Digital platforms bring specific challenges around agreements, value creation, fair sharing of value created, and many topics. The results achieved in S4Fleet feed seamlessly into these new research initiatives, and they will be further implemented e.g. in DIMECC's Design for Value (D4V) program.

I would also like to take the opportunity to express my gratitude to my closest partners in running the program: Prof. Marko Kohtamäki, Prof. Miia Martinsuo, and Prof. Timo Kärri. I have also received much support from DIMECC program management, marketing, and finance, as well as from the program management committee.

Pekka Töytäri
DIMECC S4Fleet Program Manager
Efecto Oy

Toward Digital Management of Global Fleet

Building software and connectivity into industrial devices and systems to improve their performance has already been a development trend for decades. Recently, the level of digitalization of industrial operations has enabled increasingly new opportunities in the management of the installed base of equipment and systems for organizations active in industrial services. Increasing information intensity in sensing, analyzing, monitoring, and optimizing industrial operations imposes vast requirements for connectivity and integration. One aspect of the digitalization of industrial services is that the role of intelligent and efficient utilization of fleet-generated information is becoming increasingly important compared to traditional maintenance services.

The challenges and research and development needs arising from connecting sensor and other data sources, collecting information for systems, and analyzing and utilizing the collected information in a systematic, cost-efficient, and value-adding way are broad and demanding. As life-cycle data of long-lifetime equipment fleets are often fragmented and possessed by several players, like manufacturers, owners, operators, and service providers, the emerging issues must be resolved concurrently, to everybody's satisfaction. There are often technical issues, such as what information to collect from various sources and how; operative issues, such as how to make information collection, analysis, and utilization so efficient that the value exceeds the cost; and business model issues, including how the value is shared between different players involved in services around complex distributed fleets. For all the stakeholders, the expected benefits must exceed the effort, and attractive incentives for individuals and organizations must be in place to achieve sufficient levels of trust, networking, and cooperation for effective, digitized fleet management. These challenges require new types of competencies and capabilities in companies, in developing new tools, concepts, platforms, organizational structures, and business models.

The DIMECC S4Fleet program has provided a good collaborative platform for tackling these strategic, operational, and technological challenges. The role of S4Fleet has been valuable both in horizontal cooperation between companies from different industries and with different capabilities, and in vertical cooperation between research institutes and firms.

In addition to the scientific value of the program results, the joint research has provided good demonstrations and piloting platforms for companies' own R&D to test and further commercialize the results. In this way, the results of the S4Fleet program are directly contributing to the participating companies' future competitiveness in industrial services. As fleet management solutions and services often need seamless collaboration between several organizations, the continuum from S4Fleet on, the widest of these being DIMECC D4V program, is a valuable basis for future R&D collaboration and business. Future R&D around the key topics identified can take many forms, including both consortiums of companies and research institutes, and direct bilateral collaboration between companies. In addition, of course, companies should and will continue implementing and rolling out the results achieved in the DIMECC S4Fleet program in their business.

Kimmo Forsman, ABB Oy

Susanna Horn, Outotec Oy

Jyrki Keskinen, Wapice Oy

Building Foundation for Digitized Service Operations

The idea of focusing on the development of service operations and strategies from the fleet management perspective emerged within the DIMECC innovation ecosystem during the Future Industrial Services (FutIS) program. The Service Solutions for Fleet Management (S4Fleet) program was launched as companies and research institutes faced the reality that the industrial internet was becoming a relevant contextual factor influencing the development of data-enabled service business across technology industries. To grasp the opportunities that the development of the technology landscape provided, novel research was needed in themes that were not covered by other programs.

The previous research led by DIMECC and funded by Tekes (including DIMECC FutIS, Tekes' SERVE, and various smaller projects) provided a fruitful starting point on which to build new research in the competencies developed throughout Finnish research institutes and companies. The University of Vaasa (UVA), Tampere University of Technology (TUT), Lappeenranta University of Technology (LUT), Aalto University (Aalto), VTT, and the University of Eastern Finland (UEF) brought to S4Fleet their uniquely profiled teams, with complementary capabilities and interests. This national cooperation, which extends to various initiatives taken with international partners, has been an evident success for the research conducted in the DIMECC S4Fleet program.

Besides fostering national competencies in service solutions in Finland, the S4Fleet program has provided an important platform for the development of international collaboration. Together with international partners such as the University of Cambridge, Aston Business School, Luleå University of Technology, Delft University of Technology, Queensland University of Technology, the University of Sunderland, the University of Stavanger, and Linköping University, the researchers have produced impactful scientific publications, new conceptual and empirical models, and managerial impact for the industry. Researchers in the S4Fleet program have had important roles in conferences, leading program-related tracks and seminars, including EURAM (European Academy of Management), IMP (Industrial Marketing and Purchasing group), WCEAM (World Congress on Engineering Asset Management), MPMM

(Maintenance Performance Measurement and Management), and the Academy of Management. The program has enabled multiple research visits that have had a great positive impact on the capabilities and personal networks of the researchers and, consequently, the quality of their research.

Within the DIMECC S4Fleet program, the active collaboration among the universities and companies has created a community for joint learning on fleet-level service solutions. The program has provided multiple platforms for interaction between researchers, managers, and experts in new service solutions. The participants have held countless seminars and workshops on industrial service operations and technologies, customer relationships, business intelligence, and real-time strategic management. The program has organized special interest groups, monthly meetings, and webinars on the key areas of interest. The collaboration with the DIMECC S-Step program has revealed the tight connectedness between business and technology. In addition, and most importantly, the interaction between managers and researchers has greatly supported the education of the next generation of professionals in companies and through university education.

The collaboration among industrial and software firms has provided a very inspiring and fruitful basis for universities to develop teaching and student assignments. Not only has the program resulted in a continued flow of Master's theses and the generation of data for multiple doctoral theses, but the companies have also offered their service ideas and solution portfolios as targets of course assignments and case analyses. For example, many companies have been involved in the courses provided by Aalto, TUT, and UVA on the various aspects of industrial service business, enabling the students to convert research-based ideas into service concepts and, thereby, create new capabilities for new service development in practice. In addition, the collaboration in teaching has fostered the implementation of new solutions and skills for managing industrial service portfolios. The collaboration for joint learning has resulted in new insights into the opportunities that information-intensive services provide for industrial firms, thereby producing a variety of managerial implications.

The DIMECC S4Fleet program has been an ambitious pursuit for generating scientifically rigorous and practically relevant knowledge of the transition from the management of industrial services toward the mastery of digitized service operations. This transition has involved the development of competitive capabilities for the management of the dif-

ferent dimensions of the fleet of equipment and processes, the provision of service solutions through digitally enabled platforms of multiple actors, and an improved understanding of the factors that affect value creation and sharing in new service ecosystems. Through this program, the research teams in the participating universities have taken a strong foothold in the international research arena in shaping the discussion on digitalization-related industrial service transition.

One of the key milestones in the program has been the publication of the compiled book on the industrial internet renewing service business and maintenance, in collaboration with Promaint. With a highly topical theme, the book has become a path opener in activating maintenance and service professionals' competence and attitude changes, which are necessary to convert the industrial internet into a full business opportunity. It has also turned the "hype" of the industrial internet into a viable, practical phenomenon, through which firms can improve their capabilities for value creation. The book provides practical examples and topic-specific managerial guidelines for service operations and maintenance management. Further, the program has produced an international book on "Real-time strategy and business intelligence: Digitizing practices and systems," which focuses on the role of digitization, business intelligence, and the industrial internet in the solution providers' business. Moreover, the S4Fleet program is involved in creating an international book on "Facilitating servitization: Practices and tools for managing service transition." This book sheds light on the tools and practices needed for managing the servitization process, including contents related to the industrial internet and business intelligence in servitization.

The research conducted in the DIMECC S4Fleet program can be considered as a kickoff for the next generation of industrial service business research. S4Fleet will foster multiple streams of new national and international initiatives concerning fleet and maintenance management, the industrial internet, and industrial service development. The findings will provide a springboard for new collaborations, as well as new research and project initiatives that continue to contribute to the research and management of industrial service business far beyond the program.

The research field of industrial service business seems to be continuing its strong growth, with the industrial internet and digitization paving the way for new opportunities to automatize, digitize, and robotize product and service operations. Future research needs to tap into the service transition facilitated by virtual and mixed reality and artificial intelligence. Further research is needed in many areas, from company-

level managerial practices to service operations and service technologies. Large collaborative programs in the DIMECC innovation ecosystem, e.g. D4V, are needed to integrate knowledge among research institutes and companies in the industry, and to provide platforms for high-quality research and development. Bridging strategic intelligence and operational excellence in technology firms – as well as understanding the opportunities that new technologies provide to transform business ecosystems – continue to be among the essentials in developing international competitiveness in digitalization of the Finnish manufacturing industry.

Marko Kohtamäki, University of Vaasa

Miia Martinsuo, Tampere University of Technology

Timo Kärri, Lappeenranta University of Technology

Risto Rajala, Aalto University

Program Key Characteristics

Company partners (Pcs):

ABB, Analytics Cloud, Anvia, Etteplan, Fastems, Granlund, HUB Logistics, IBM, KONE, Leinolat Group, Metso Minerals, M-Files, Outotec, Prima Power, Ramentor, Raute, Solita, Sympa, Valmet, Wapice, Vindea, Wärtsilä Services, Puolustusvoimat.

Research institution partners (Pcs):

Aalto University, Lappeenranta University of Technology, Tampere University of Technology, University of Vaasa, VTT, (University of Eastern Finland).

Volumes:

Duration: .... 1.10.2014 – 31.12.2017
Budget: .... 18 924 606 €
Company budget: .... 11 996 463 €
Research institute budget: .... 6 928 143 €
People involved: .... 146 persons

Results:

Number of publications: 163
Number of doctoral theses: 3
Number of other theses: 7
Research exchange months: 23

Enabled business potential (estimate): .... 1 500 M€

STRATEGIC INTELLIGENCE FOR FLEET MANAGEMENT

1

Marko Kohtamäki/University of Vaasa
Taru Hakanen/VTT
Teemu Laine/Tampere University of Technology
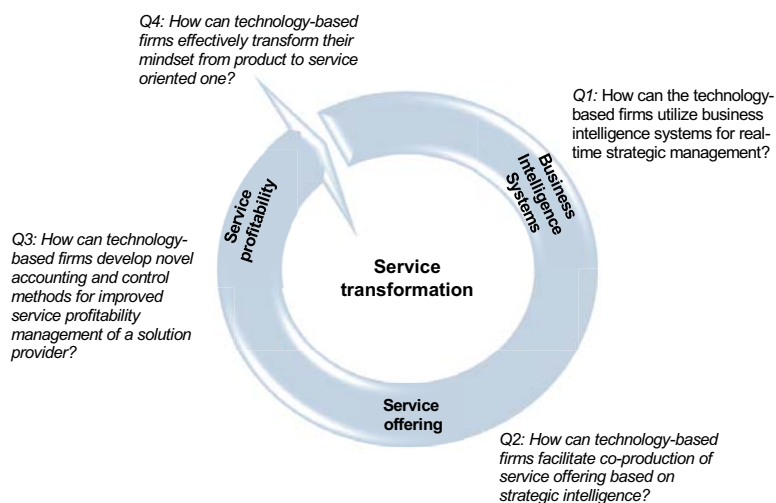**Risto Rajala/**Aalto University

Motivation and achievements

The increasing speed of innovation and technological change, competition, diminishing returns from product sales, and the industrial internet facilitate manufacturing firms' transition toward services and integrated solutions. This change has been named servitization, which is the concept used from service transition, in which a manufacturing company moves from a product-based business model toward a service-based business model (integrated solutions, including both products and advanced services). At a strategic level, industrial companies have been seeking an advantage from product-service solutions, servitization, and the internet of things, all combined under the discussions on servitization, product-service solutions, integrated solutions, and service science. For the task of developing leading-edge competitive product-service solutions, companies need capacity to absorb and implement knowledge, which we have named here business intelligence (BI), with new and innovative product-service offerings to fully cover the product life-cycle; effective, yet impactful product-service delivery processes; and capabilities to create value from product-service solutions. Companies need capabilities and practices for managing their fleet in real-time.

The literature on servitization, product-service systems, and integrated solutions highlights the need to understand how solution providers adapt toward solution provision, customized offerings, higher and thoroughly understood solution profitability, and new capabilities in value creation. However, the existing body of research fails to provide a perspective on how to effectively utilize IT systems to increase the speed and impact of service transition. In a similar vein, the strategic management literature has failed to engage in the opportunities provided by digitalization. As much of the existing literature on strategic management

(e.g. organizational economics, resource-based view, and strategy processes) is still utilizing theory developed before digitization, strategic management theory has become outdated to an extent. The existing literature fails to develop theory in real-time strategic intelligence in the context of the provision of integrated solutions. This project set out to fill the gaps, developing strategy theory and managerial practice for integrated solution provision and strategic fleet management.

Strategic intelligence for fleet management creates the knowledge of capabilities needed to facilitate new product-service offerings, to increase profitability throughout the product life-cycle. To fill the gap presented above, the strategic intelligence project set out to answer four main research questions. Q1: How can technology-based firms utilize business intelligence systems for real-time strategic management? Q2: How can technology-based firms facilitate co-production of the service offering based on strategic intelligence? Q3: How can technology-based firms develop novel accounting and control methods for improved service profitability management of a solution provider? Q4: How can technology-based firms effectively transform their mindset from product to service oriented? Our research, in this 'strategic intelligence for fleet management' project, set out to create concepts, models, and solutions to drive the industry toward a vision in which companies can dynamically adjust their product-service solutions in real-time to achieve a competitive advantage. To achieve this target, we decided on four sub-themes: 1) real-time decision-making, 2) new innovative service offerings, 3) management for service profitability, and 4) enablers of service transformation. These sub-themes present a critical success factor for future industrial companies, in which the need for more advanced customized solutions is becoming a necessity. We intended to develop models that enable real-time management of fleet and integrated solution providers. Thus, studying integrated solutions and fleet management from a strategic perspective, 'strategic intelligence for fleet management' contributes to the scientific and managerially relevant discussion about how to develop and manage profitable service business at the level of the fleet. Research conducted in strategic intelligence for fleet management has provided a tremendous platform to develop theory on servitization strategies under the influence of digitization. By conducting multiple theoretical reviews, more than 200 interviews in companies, more than 50 company workshops, and approximately 10 seminars on strategy, business intelligence, profitability management, and servitization, the project has produced a vast variety of knowledge and several frameworks that can be utilized in companies. Companies have progressed and piloted a variety of solutions, as presented by high-tech

results, monthly results, and the multiple workshops organized by this project. The following sections provide some highlights and insights for the achieved results, integrating both theoretical frames and company examples.

Figure 2. Strategic intelligence for fleet management

STRATEGIC INTELLIGENCE FOR FLEET MANAGEMENT

Marko Kohtamäki/University of Vaasa

Strategic service business intelligence (BI) and management systems

Strategic service business intelligence (BI) set out to develop theoretical frameworks and organizational capabilities for the real-time strategic management of solution providers by studying state-of-the-art practices from industrial solution providers, business intelligence software suppliers, and other industries. Integration between business intelligence, strategy, and servitization was studied by means of literature research, comparative case studies, and surveys. To investigate these issues, collaboration between ABB, Anvia, Leinolat, Metso, Prima Power, Ramentor, Sympa, Wapice, and the University of Vaasa was established.

Background and objective

When reviewing the literature on information systems, strategic practices, and servitization, we found integration missing between these streams of research. Moreover, when examining technology companies from manufacturing to software, we found a gap between the offerings provided by the software system providers, and the software systems utilized by large manufacturing companies. The project for strategic service business intelligence set out to study and fill this gap, to bridge information systems and strategy literature, software suppliers, and manufacturing companies, by jointly investigating the latest concepts around business intelligence, strategy, and servitization. Thus, by combining the literature on business intelligence, strategy, and servitization, and investigating manufacturing and software suppliers, we intended to provide answers for the research question: how can technology-based firms utilize business intelligence systems for real-time strategic management?

Results

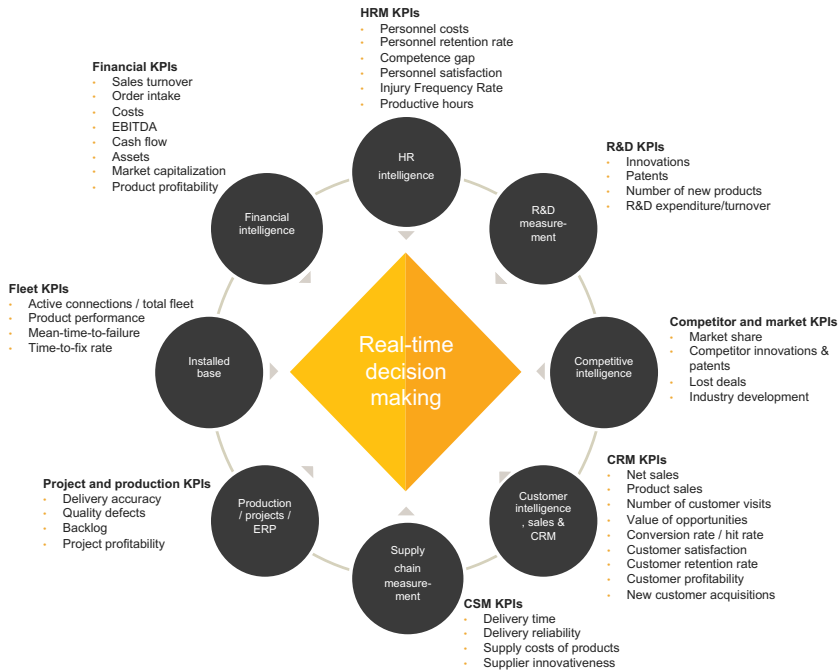To answer the research question, we reviewed previous literature on servitization, business intelligence, and strategic practices, to understand the interplay between these streams of research. To answer the research question, a variety of empirical data was collected using surveys, interviews, and case observations. Empirical data was utilized throughout the analysis to establish the overall concept, dimensions, and

measures. The lessons learned have since been utilized in multiple strategy processes and in-class teaching, to test and implement concepts (see the figure below). The figure defines our main concept, the dimensions of real-time decision making, and some of the measures based on the collected data. The developed framework takes a 360-degree perspective toward the manufacturing company, and intends to cover a variety of perspectives both internal and external to the company, and relevant for managerial practice. The framework illustrates multiple measures utilized by the studied companies, but also communicates the main idea underpinning the development of management systems in general: a company needs to decide some key measures to constantly follow up and manage the organization and its fleet effectively. Too many measures, or too complex a set of measures, will just sacrifice the intended behavioral effect the measurement is supposed to have; measures and follow-up practices should influence the strategic praxis. If implemented properly, the decided measures enable an improved management system, real-time management of a company, and strategic agility when needed. Thus, strategy is here defined through social and discursive practices that enable the achievement of the desired outcomes.

Hence, to have the intended effect on behavior, the measures should be such that: 1) the measures steer behaviors in the intended direction, 2) personnel truly understand the measures and their purpose, and 3) data can be collected effectively on a monthly or quarterly basis. To achieve the intended behavioral outcomes, an organization should set targets based on the measures, and most importantly, follow up the implementation and achievement of the targets on a monthly to quarterly basis. Surprisingly, despite the simplicity of these tasks, according to our findings, many organizations fail to decide on measures, set targets, and follow up achievements. Thus, quite typically, organizations seem to fail in management, which is likely to lead to failure in leadership. Centrally, the decision about measures is of importance when collecting any data. Without systematic strategy-led decisions, collected data is often wasted, causing noise instead of providing answers. For this purpose, our work suggests a strategy map as a methodology to understand a firm's strategic logic, and how to develop operations to meet the strategic targets (see the following chapter).

Impact It is obvious that measurement plays a central role in managing operations, if the follow-up based on measurement is implemented accordingly. Without understandable measures, target-setting, and effective follow-up practices, the organization will end up missing the impact. Figure 3 illustrates the business intelligence framework, reminding readers

of the importance of measurement selection, to enable effective management for strategic agility. As a single, particularly important strategic practice, management should be explicit regarding the selected measures.

HRM KPIs
- Personnel costs
- Personnel retention rate
- Competence gap
- Personnel satisfaction
- Injury Frequency Rate
- Productive hours

Financial KPIs
- Sales turnover
- Order intake
- Costs
- EBITDA
- Cash flow
- Assets
- Market capitalization
- Product profitability

R&D KPIs
- Innovations
- Patents
- Number of new products
- R&D expenditure/turnover

Fleet KPIs
- Active connections / total fleet
- Product performance
- Mean-time-to-failure
- Time-to-fix rate

Competitor and market KPIs
- Market share
- Competitor innovations & patents
- Lost deals
- Industry development

Project and production KPIs
- Delivery accuracy
- Quality defects
- Backlog
- Project profitability

CRM KPIs
- Net sales
- Product sales
- Number of customer visits
- Value of opportunities
- Conversion rate / hit rate
- Customer satisfaction
- Customer retention rate
- Customer profitability
- New customer acquisitions

CSM KPIs
- Delivery time
- Delivery reliability
- Supply costs of products
- Supplier innovativeness

Central: HR intelligence, R&D measurement, Competitive intelligence, Customer intelligence, sales & CRM, Supply chain measurement, Production / projects / ERP, Installed base, Financial intelligence — **Real-time decision making**

Figure 3. Business intelligence framework

Business intelligence and management systems as precursors of organizational agility

Yassine Talaoui, Rodrigo Rabetino / University of Vaasa

Companies strive to develop new ways to become agile, and swiftly respond to the changing expectations of their customers and the soaring pressure of market dynamics. For instance, Amazon deploys a code every 11.6 seconds, senses how it changes their customers' behavior, and immediately responds to any twist: optimizes if positive and amends if otherwise. Evidently, Amazon's Redshift in the data storage industry is not an outlier in today's business world, which continuously witnesses newcomers busting market leaders. Recall Nokia losing their market share, if not their entire business, to disruptive new tech-driven entrants; Tesla in the auto industry; and Salesforce.com in the software world, where analysts are predicting Cisco Systems will pull the rug out from IBM and Hewlett-Packard, once considered the industry's traditional players.

Background and objective

We looked at the issue of organizational agility and its enabling mechanisms with the help of multiple S4Fleet partners. For them, organizational agility seems to be the result of a well-integrated BI system that presumably empowers companies with real-time actionable intelligence. Notwithstanding a ubiquitous consensus regarding the salience of agility among our S4Fleet partners, the mechanism whereby agility seems to unfold appeared elusive at first. In response, we conducted a thorough review of extant literature on agility and BI, to decipher linkages and hypotheses that we could hence examine in collaboration with different S4Fleet partners. We found ample evidence indicating the role of business intelligence in enhancing organizational agility; but we found little about how such a linkage occurs. We therefore decided to explore such a conundrum by looking at the ways in which business intelligence influences tactical, operational, and strategic decision-making across various S4Fleet partners. We sat down with a cross-functional and diversified group of S4Fleet collaborators and examined their views on BI and agility through semi-structured interviews.

Results

The main result of our research is a framework of organizational agility that rests upon two engines: the BI system and the firm's business logic. Accordingly, we present organizational agility as the outcome of agile practices that are embedded in two types of related processes: data

transformation and knowledge infusion. Whereas the first represents the firm's capacity to scan the environment for intelligence and translates it into actionable knowledge that could be acted upon, the second refers to the organization's ability to swiftly input the new knowledge into the firm's business logic. Obviously, the infusion of business logic entails a recursive and iterative process that might seem lengthy for some and confusing for others. In response, we tap into information management and strategic management literature, and import the concepts of management systems and tools that can orchestrate knowledge translation into business logic. In this vein, we suggest that the new knowledge absorption could be captured through management systems and tools. By so doing, our model places organizational agility as an outcome to two precursors: new knowledge creation through BI systems, and new knowledge infusion through management systems.

Impact *Our model contributes to organizational agility by suggesting two new constituents:* new knowledge creation and infusion. The sum of these may enhance the organizational agility of S4Fleet participants in the following ways. First, it places BI as a sequential process that creates new knowledge for firms, which in turn enhances their agility practices through a high degree of sensitivity in detecting and predicting market fluctuations. Second, our framework indicates the need for firms to possess a strong BI system that delivers new knowledge to management systems in order to facilitate the implementation of actionable knowledge, and eases the pivoting of processes and resources, which in turn enhances the infusion of this knowledge into the business logic. Third, our model offers a strategy map as an example of a management system, and positions it as an igniter of agility through its capacity to visualize the new knowledge infused into the business logic of the firm.
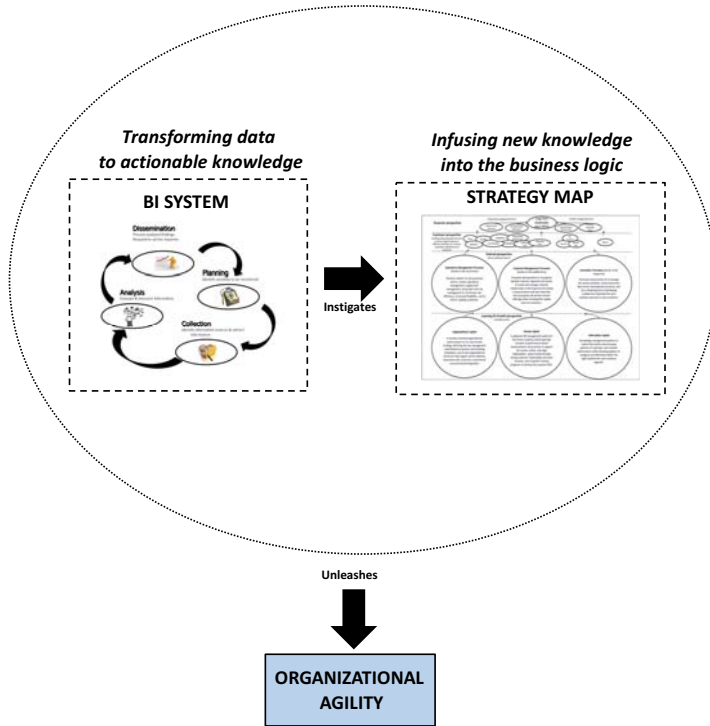
Figure 4. Organizational agility framework (developed based on Bernhardt (1994); Kaplan and Norton (2000))

Knowledge creation, utilization, and renewal by business intelligence

Jesse Heimonen, Tuomas Huikkola, Iivari Kunttu/University of Vaasa

Background and objective

Recently, Western manufacturers have increasingly transformed themselves into service companies that provide different knowledge-intensive business services to their clients. The importance of business intelligence (BI) tools to facilitate this strategic renewal from products to services has been stressed in the earlier work related to servitization. Therefore, the practices needed to acquire, assimilate, transform, and exploit business-critical customer and installed-base data in a way that facilitates strategic change have been seen as critical. Thus, the motivation behind this chapter is to identify the central practices required to efficiently utilize the data to support the change process through the utilization of BI.
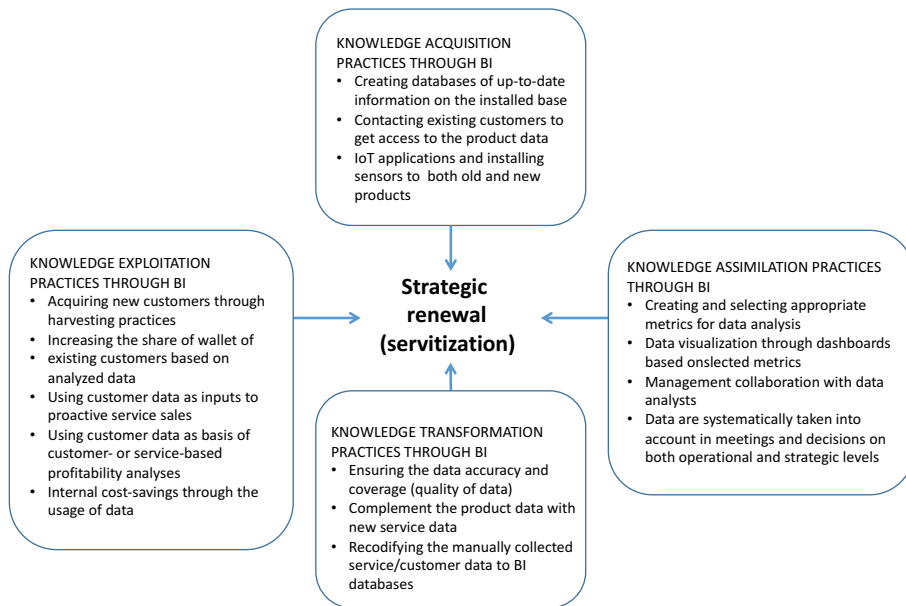
In the search for capabilities enabling a firm to adapt to the changing business environment and to renew its own operations, one established concept is absorptive capacity (ACAP), which originates from the earlier research on organizational learning. ACAP refers to the organizational practices, processes, and routines used to acquire, assimilate, transform, and exploit knowledge (Zahra & George, 2002). The first phase, knowledge acquisition, is defined as an organization-wide ability to identify and attain external knowledge that may provide value for the organization, whereas the second phase, *knowledge assimilation*, refers to the practices enabling the interpretation and internalization of acquired information in the organization. The third phase, *knowledge transformation*, occurs through practices and routines that enable an organization to create valuable insights from acquired and assimilated knowledge by combining existing internal and external knowledge bases and transforming them into new forms of knowledge. The fourth phase, *knowledge exploitation*, involves capturing the value of new information; it is thus an organization's ability to apply the transformed knowledge for commercial ends. BI tools can be utilized to support the servitization process and the strategic renewal of a firm by facilitating knowledge absorption. In the following, we will explain and discuss how knowledge absorption practices facilitated by BI are externalized in practice.

Results   Despite the fact that prior research mainly considers the four phases of ACAP to be sequential, in industrial reality the organizational knowledge absorption processes tend to occur simultaneously in a constant loop. To facilitate the strategic change from a product-based model to one highlighting the role of services, the manufacturing companies involved in the project acquired new knowledge by creating databases of up-to-date information on the installed base of products. The companies also contacted their existing customers to get access to the data on their installed base. In most cases, this access was established by utilizing sensors or IoT applications collecting data on the product usage or its operational measurements.

The companies assimilated new knowledge by creating, selecting, and developing appropriate metrics for data analysis. Furthermore, these metrics (such as total cost of ownership, mean time to failure) were visualized on dashboards. The metrics that were based on the collected data could then be utilized as key indicators when building incentives and guiding a firm's future direction. The interpretations made based on the metrics also enabled the personnel to make decisions, set priorities, and optimize their own processes. To assimilate the data and develop the metrics and decision tools, industrial managers actively collaborated with data analysis specialists. Establishing dedicated teams for data analytics targeted at utilizing and understanding the collected data may be a natural course of action for many technology companies.

Data transformation involved with the practices related to ensuring the accuracy, coverage, and quality of the data. Typically, the companies had to collect and transform their service reports into the databases manually. Finally, to utilize the data for new commercial ends, the companies used the collected data to acquire new customers or increase the share of spend from existing customers. In a similar vein, the companies utilized the customer data as input for proactive service sales (e.g., predictive maintenance) or to analyze individual customer or service product profitability. In particular, the collected customer data enabled the companies to achieve internal cost-savings in service contracts because of increased knowledge of maintenance intervals and cycles, as well as the estimation of customers' service potential.

Impact   In the S4Fleet program, one of the main goals of the ABB Medium Voltage Services local business unit was to develop a process and tools to support the utilization of installed base data in service development, pro-active service sales, and the strategic management of service business. The development work made in the company case followed roughly the phases of ACAP. The first phase, *knowledge acquisition*, started with the

KNOWLEDGE ACQUISITION PRACTICES THROUGH BI
- Creating databases of up-to-date information on the installed base
- Contacting existing customers to get access to the product data
- IoT applications and installing sensors to both old and new products

KNOWLEDGE EXPLOITATION PRACTICES THROUGH BI
- Acquiring new customers through harvesting practices
- Increasing the share of wallet of
- existing customers based on analyzed data
- Using customer data as inputs to proactive service sales
- Using customer data as basis of customer- or service-based profitability analyses
- Internal cost-savings through the usage of data

Strategic renewal (servitization)

KNOWLEDGE ASSIMILATION PRACTICES THROUGH BI
- Creating and selecting appropriate metrics for data analysis
- Data visualization through dashboards based onselected metrics
- Management collaboration with data analysts
- Data are systematically taken into account in meetings and decisions on both operational and strategic levels

KNOWLEDGE TRANSFORMATION PRACTICES THROUGH BI
- Ensuring the data accuracy and coverage (quality of data)
- Complement the product data with new service data
- Recodifying the manually collected service/customer data to BI databases

Figure 5. Data utilization practices for strategic renewal, presented in terms of the four phases of ACAP

creation of databases for the installed base information on the selected ABB devices sold for domestic customers during the last few decades. This data collection process involved the acquisition and merging of relevant installed base data from the company's own internal service and sales organizations, as well as customers' device lists and service reports. Special emphasis was given to ensuring the validity of the data. The next phase of the development work (*knowledge assimilation*) was to create an internal process, agree on the working procedures, and nominate appropriate managerial roles to steer, manage, and operate the analysis, and monitoring tasks related to these customer databases. This required close collaboration between service teams and sales organizations, as well as with key customers. In this phase, relevant metrics were selected and developed to be monitored during the process, and preliminary tools for the visualization of key metrics were selected. In the phase of *knowledge transformation*, the practices for updating and cleaning the database were created. These practices involve the sales persons in updating the database based on the information that they acquire during interaction with customers. For straightforward additions and updates in the database, a mobile application for service technicians operating on the field was developed. In the final phase, knowledge exploitation, tools for analyzing and utilizing the installed base data were developed.

In this case, the specific tools developed were related to: 1) recognition of customer-specific service potential, to be used as input for proactive service sales, 2) customer- or product-based profitability analyses, and 3) data analysis and visualization, to be used to manage the customer-specific service sales process.

Business intelligence in delivering projects

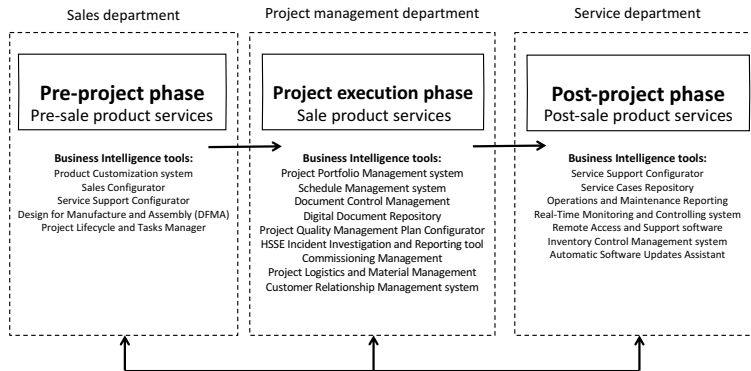**Valeriia Boldosova**/University of Vaasa

The delivery of life-cycle solutions as projects is not a new concept. However, there is a lack of understanding of how business intelligence (BI) can be used to facilitate the successful delivery of projects to customers. Building upon current research, empirical data was collected from technology companies, and utilized to develop a BI-driven project delivery life-cycle. Furthermore, close collaboration between Prima Power and the University of Vaasa resulted in the development of the Fleet Management BI tool.

Background and objective

Over the past decade, an increasing number of companies have been delivering solutions as projects, and integrating new emerging business intelligence tools into the project delivery process. Many of the research studies demonstrate the relevance of BI practices, but there is a lack of research contributions on the implications of BI tools in the project delivery life-cycle. Accordingly, the motivation and objective behind the project was to further understand the role and dynamics of BI in the delivery of projects, outline the step-by-step project delivery process, and identify the key BI tools used in technology companies to facilitate the delivery of a solution to the customer.

Results

To achieve the project goals, an extensive review of the literature was made and numerous interviews were conducted with the technology company representatives in the sales, project management, and service departments. As a result, it was identified that a traditional project delivery life-cycle comprises a pre-project phase, a project execution phase, and a post-project phase, responsibilities for which are divided between the sales, project, and service business units. Given the number and complexity of the project deliveries, companies use a variety of BI tools to facilitate the delivery of the project to the customer and to enhance internal communication and document management. Drawing on data collected during the project, and aiming to identify the key BI tools used throughout the project delivery life-cycle, the BI-driven framework was developed (Figure 6).

| Sales department	Project management department	Service department
Pre-project phase Pre-sale product services	**Project execution phase** Sale product services	**Post-project phase** Post-sale product services
Business Intelligence tools: Product Customization system Sales Configurator Service Support Configurator Design for Manufacture and Assembly (DFMA) Project Lifecycle and Tasks Manager	**Business Intelligence tools:** Project Portfolio Management system Schedule Management system Document Control Management Digital Document Repository Project Quality Management Plan Configurator HSSE Incident Investigation and Reporting tool Commissioning Management Project Logistics and Material Management Customer Relationship Management system	**Business Intelligence tools:** Service Support Configurator Service Cases Repository Operations and Maintenance Reporting Real-Time Monitoring and Controlling system Remote Access and Support software Inventory Control Management system Automatic Software Updates Assistant

Figure 6. BI tools in project delivery life-cycle

During the project, it was discovered that the following BI tools support and contribute to the successful project delivery process: a product customization system, a sales configurator, a service support configurator, a design for manufacture and assembly, a project life-cycle and tasks manager, a project portfolio management system, schedule management, document control management, a digital document repository, a project quality management plan configurator, a health, safety, security and the environment (HSSE) incident investigation and reporting tool, commissioning management, project logistics and material management, a customer relationship management (CRM) system, a service cases repository, O&M reporting, a real-time monitoring and controlling system, remote access and support software, an inventory control management system, and an automatic software updates assistant. The project demonstrated the various multiple benefits that each of the BI tools brings to companies. However, the process of integrating BI into the project life-cycle and using it on a daily basis is challenging and requires increased attention to such areas as: a user-friendly BI interface, data codification, inadequate IT, a lack of motivation to use BI, integration with other BI systems, time needed to learn to use BI, training, and quality of data in BI.

In addition to developing the BI framework for delivery of project solutions, the project contributed to the development of the Fleet Management BI tool in Prima Power, which is remote access and support software combining the functions of a service cases repository, O&M reporting tool, and real-time monitoring and controlling system. Fleet Management is a BI tool used primarily in the post-project phase by sales managers, project managers, and service managers, and it has built-in descriptive and predictive data-driven analytics, extracting valuable

insights from the equipment online, connected to the cloud (Figure 7). "Fleet Management helps Prima Power to analyze machine-generated data, speed up troubleshooting and minimize the need for on-site maintenance" (Esko Petäjä, R&D Manager, Prima Power). Fleet Management contains information on real-time and historical equipment condition and performance, service maintenance cases, field service logs, triggers, and alarms. It also provides an online overview of the product portfolio and supports service managers in improving machine availability and enhancing machine performance.
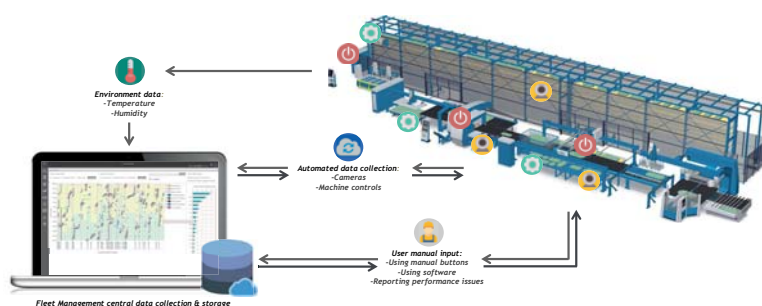
Figure 7. An overview of Prima Power Fleet Management

Impact   The results of the project shed light on how BI tools can be used for the successful delivery of project solutions to customers. The Fleet Management tool developed in Prima Power is one example of a BI application that is used during the post-project phase of the project delivery life-cycle, and it has further potential applications in other technology-driven industries.

Further information

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INDUSTRIES: Technology industry, software industry

STRATEGIC INTELLIGENCE FOR FLEET MANAGEMENT

Taru Hakanen / VTT

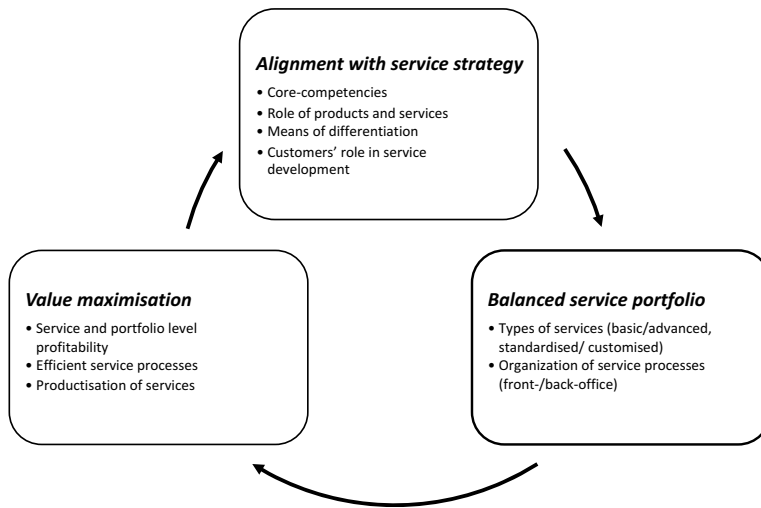# Customer-focused service offering development for fleets

Companies need a holistic, future-oriented, and strategy-driven approach to developing customer-focused service offerings for fleets. Companies need a systematic approach that increases strategical guidance in service-offering development and helps them in navigating the servitization process when the balance between products and services changes in the offering. Service portfolio management offers a means for developing the service offering in a strategy-driven way and for ensuring profitability in service business.

Background and objective ABB, Fastems, and Transval provide various industrial B2B services related to transformers (ABB), production automation (Fastems), and internal logistics development (Transval). The motivation for this sub-project was derived from the need to view and develop a company's product-service offering as a whole, and not to concentrate on developing single services.

Results This study developed an approach for **service portfolio management** for companies that provide and develop service offerings that include several B2B services. The approach utilizes the main elements of product portfolio management, which are alignment with strategy, a balanced portfolio, and maximizing value. While product portfolio management predominantly concern companies' internal resources and operations, the central characteristics of service business were included in the service portfolio management approach. Thus, the role of business customers and customer participation in service co-production and value co-creation is essential and needs to be taken into account in portfolio management.

Alignment with service strategy
- Core-competencies
- Role of products and services
- Means of differentiation
- Customers' role in service development

Value maximisation
- Service and portfolio level profitability
- Efficient service processes
- Productisation of services

Balanced service portfolio
- Types of services (basic/advanced, standardised/ customised)
- Organization of service processes (front-/back-office)

Figure 8. **Service portfolio management**

Service portfolio management can be used when evaluating, selecting, and prioritizing services in the service portfolio so that the total offering is developed according to a company's business strategy. While companies often include several different types of services in their offerings, an optimal balance between various services is achieved between different services. Then, not only service types are balanced, but balance is also achieved between the internal back-office and customer-facing front-office service operations. All in all, the economic aspect is also included in selecting services in the offering, so that the offering is profitable as an entity. Cost-efficiency can be sought through efficient service processes, productization of services, and an optimal balance between front-office and back-office operations. Typically, front-office operations and, for example, working on fleets around the world is costly. Then, for instance, remote services can be developed to ensure cost-efficiency.

The central elements of service portfolio management are interconnected. That is, the servitization strategy guides the selection and balance of the service portfolio, which in turn influences the way value co-creation takes place between the service provider and its business customer. When a company proceeds in servitization, changes in one element of service portfolio management result in changes in other elements, too.
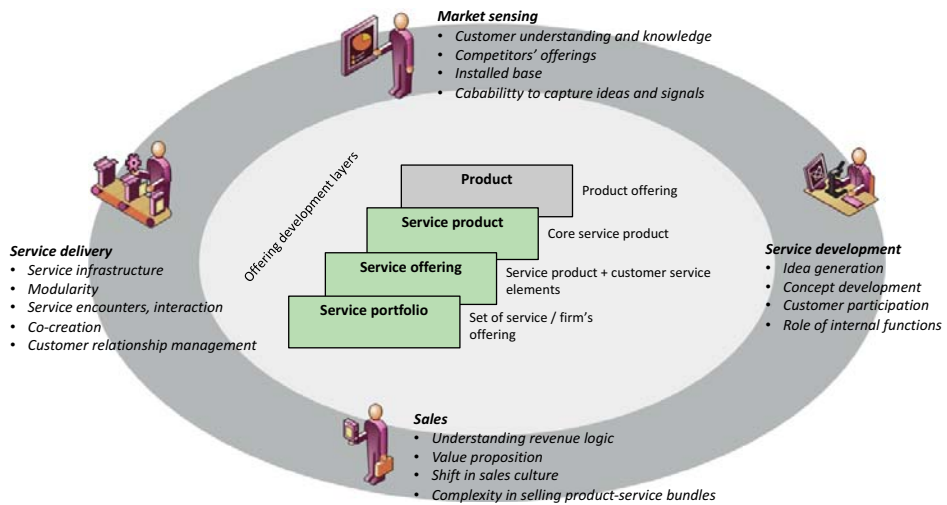
The development projects of ABB, Fastems, and Transval provided new insights into service portfolio management, as they develop their service offerings for fleets. ABB and Fastems have proceeded in servitization during the past decade, and have increased the role of services in

their offerings. On the other hand, Transval has always been a service company, and products (packages) play a minor role in their internal logistics service portfolio. Both ABB and Fastems base their offerings strongly on products that are augmented with O&M services. Service portfolio management differs in the different stages of servitization, depending on the service-intensity of the whole portfolio. Table 1 provides case examples of service portfolio management.

Table 1. **Service portfolio management in the case-companies**

Alignment with strategy	Case examples of alignment with strategy	Balanced portfolio	Case examples of balanced portfolio	Value maximization	Case examples of value maximization
Overall business strategy as a guideline	Prioritization of a high-end maintenance service based on solid expertise regarding their products (LICY)	Balance between advanced and basic services	Providing operative warehouse services vs. mapping and developing material processes (LOGI)	Balancing between value maximization of single services and the whole portfolio	Individual services may even be unprofitable if it serves profitability of the whole portfolio (LOGI)
Identified core competencies in a key role	Focusing on remote online service in service offering development (RESU)	Balance between standardized and customized services	Small standard maintenance operations vs. large customized projects that combine expertise from various branches of the group (LICY)	Individual services supporting the sales of products	Services are expected to increase sales of products (LICY and RESU)
Customer involvement in service development as a strategy	Service development as a joint effort between the service provider and customers (LOGI)	Balance between front- and back-office services	Close interaction and cooperation with customers in service process (LOGI) vs. remote helpdesk services (RESU)	Cost-efficient service processes and resource management	Optimal division of front- and back-office operations with remote online services (RESU)
	Customer's outsourcing strategy enables service offering extension (LOGI)			Productization of services	Productized repair and maintenance services (LICY)
				Value creation	Holistic internal logistics management benefits the customer and enhances the business of the service provider (LOGI)

Impact Transval Industrial Services enabled its customer to achieve significant logistics cost savings through their renewed internal logistics development services. As a result of the service offering development, Transval Industrial Services was able to utilize customer knowledge efficiently and to conceptualize their service offering for industrial customers. Their customer, Metso Flow Control, achieved 14% cost savings in internal logistics and packing operations. A holistic approach to service offering development was applied, including the phases from market sensing to service offering conceptualization and refinement of the sales and service provision approach (Figure 9).

Market sensing
• *Customer understanding and knowledge*
• *Competitors' offerings*
• *Installed base*
• *Cababilitty to capture ideas and signals*

Offering development layers

Product — Product offering

Service product — Core service product

Service offering — Service product + customer service elements

Service portfolio — Set of service / firm's offering

Service delivery
• *Service infrastructure*
• *Modularity*
• *Service encounters, interaction*
• *Co-creation*
• *Customer relationship management*

Service development
• *Idea generation*
• *Concept development*
• *Customer participation*
• *Role of internal functions*

Sales
• *Understanding revenue logic*
• *Value proposition*
• *Shift in sales culture*
• *Complexity in selling product-service bundles*

Figure 9. **Customer-focused service offering development**

Transval Industrial Services gathered customer knowledge as the basis for their offering development. Consequently, they gained thorough customer understanding in terms of business customers' outsourcing strategy, logistics, and purchasing processes, and value expectations were identified. The customer insight that was gathered facilitated the planning of sales and the refining of service concepts. Both inbound and outbound logistic services were re-conceptualized in terms of the value proposition, as well as task division and interfaces between the service provider and the manufacturer.

A significant logistics cost reduction was gained as a result of several development actions in-built into the new service concept. Reception and shelving times in inbound warehouse operations were shortened as a result of Transval's services and earlier investments (e.g. WMS,

mobile display terminals). Feeding times into production were shortened at the same time as the manufacturer developed its production process to be more efficient. Outbound logistics operations evolved as a result of building a new packaging line and applying lean principles to the packaging process. Thus, picking, packaging, and shipping were conducted in a more efficient way than before. As a result, lead-times were shortened in outbound operations. One success factor that resulted in the achieved aims was the holistic approach in logistics development that the customer enabled for Transval.

Service portfolio management helps companies to shift the focus from the operative level of service integration and provision to the strategic level of offering development with a more long-term focus. Service portfolio management helps companies in:

- Creating a long-term vision, strategy, and roadmap regarding the way the offering will be developed
- Aligning the portfolio with the servitization strategy
- Putting a servitization strategy into practice
- Selecting and prioritizing (or eliminating) services in the portfolio
- Balancing the portfolio in an optimal way in terms of different types of services and front-office and back-end service operations
- Adjusting the portfolio according to customer preferences in outsourced operations and the level of interaction
- Communicating with business customers regarding the fit of their needs with the offering
- Increasing customer focus in service offering development
- Ensuring profitability in service business.

STRATEGIC INTELLIGENCE FOR FLEET MANAGEMENT

Teemu Laine/Tampere University of Technology

Profitability-driven service business renewal

An enhanced profitability management practice enables fulfillment of the aims of servitization initiatives. This requires major developments in management accounting and control tools, techniques, and practices, which we outline in this report. These developments were examined by the Cost Management Center (TUT), CTF (KAU, Sweden), and actively advanced in interventionist research involving the researchers and practitioner participants of the program.

Background and objective

In addition to the effective development of the offering, to justify, define, and effectively enhance a solution provider's competitive advantage, firms need advanced service profitability management practices, including advanced accounting and control methods. Thus, the sub-project Profitability-Driven Service Business Renewal, led by the Cost Management Center (CMC) from TUT, responds to the lack of methodology for supporting service business renewal in manufacturing companies, which has hindered meeting the ambitious objectives of service business in many companies. Although service business has been considered as a strategic issue, service business renewal has not been supported with well-functioning profitability management practices. Some challenges can be considered to inhibit service business renewal in practice, by hampering the use of profitability information for decision-making and gaining an overview of the operational environment in companies.

Indeed, understanding the role of services in business impacts and profitability is at an inadequate level. The typical case is that 25-50% of revenues with a significant impact on the profitability come 'as a surprise' for the management. This occurs despite the fact that services play an increasingly important role for revenues, profitability, and even market value. More specifically, the design, adoption, and use of management accounting methodologies currently lag behind the requirements for service profitability management.

To answer this need, the project seeks to enhance the awareness of the long-term profitability of products and related services, and to enhance the profitability management practices in this context, by using the interventionist research approach (IVR). IVR supports both scientific and practical development by engaging academic researchers in tight and long-term co-development in companies, and thus it provides significant opportunities for creating societal impacts.

Research interventions in this sub-project include, for instance, conducting 10-year profitability analyses in selected product categories and related services in the case firms. This requires very close collaboration with company representatives to acquire a solid basis for the analyses made. Such research interventions will add critically important knowledge about the role of services in industrial firms' profitability. The project engaged with companies intending to identify, design, and utilize an advanced service profitability management practice for selecting and supporting the development of new services and service businesses. Indeed, the project seeks to answer the question of how technology-based firms can develop novel management accounting and control tools for improved service profitability management practices.

Firm profitability
Products
Services
Product-service systems
Life-cycles

Customer logic
Customer segments
Customers' profitability
Metrics for ensuring customer performance and benefits

Control package
Financial and non-financial performance measures
Incentives
Cultural controls
Ways to organize

Business renewal actions
Unveiling the ecosystem and fleet's architecture for service business renewal

Developing new tools to understand customers' profitability and decision-making

Selecting and steering service offering development projects

Selecting and steering business model renewal projects

Continuous refinement of the service profitability management practice

Results = Success stories
Enhanced understanding about long-term profitability of the firm and the customers

Competitive business models & new service offerings

Advanced service profitability management for service business renewal

Figure 10. **The concept of profitability-driven service business renewal (see Lindholm et al. 2017 for more details, and Lyly-Yrjänäinen et al. Forthcoming, for the interventionist research approach that was a focus in collaboration between CMC and companies)**

Results The concept of profitability-driven service business renewal (Figure 10) was designed, detailed, and validated during the project. During the interviews, analyses, and interventions, new knowledge was attained about the information sources and units of analysis regarding service

business (left side of the figure); the scope, content, and critical success factors of the actions to be taken during renewal (middle); and the actual and potential business impacts of renewal. Already during the project, the analyses identified, grasped, and enhanced processes and activities beyond the traditionally functional/regional organization structures.

Altogether, addressing profitability-driven service business renewal (using the concept outlined above) offers possibilities for significant advancements in profitability and innovation management at fleet level. PROS has investigated the business potential that industrial organizations have in their current and coming fleets, and has actively contributed to realizing such potential. Such research outcomes are based on extensive real-life data and in-depth IVR.

Impact The results will clearly benefit Finnish industry in rethinking and renewing their fleet-based service business. In this report, the following result descriptions focus on the cases of (1) profitability management and management control for designing and improving fleet-based services, and (2) customer profitability management, improved by fleet-based profitability considerations.

Further information

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AUTHORS: Teemu Laine, Petri Suomala, Tuomas Korhonen

KEYWORDS: Profitability management, management accounting, management control, customer relationship management, Internet-of-Things (IoT), interventionist research, servitization

INDUSTRIES: Technology industry, machinery manufacturing, software industry

Designing performance measures and management controls for service business development

Anni Lindholm, Teemu Laine /Tampere University of Technology

Servitization challenges the current reporting structures of global operations in technology industries. In particular, developing new service concepts and implementing advanced practices require detailed understanding about the potential business impacts and underlying dynamics. In the following case, such understanding was attained, paving the way for a profitable new service business.

Background and objective

The profitability-driven development of service businesses, despite its rationality, represents a challenge for the management control of globally operating manufacturing companies, since there is a need to understand profitability implications across different product lines and business units. Actually, limited empirical evidence exists on how manufacturing companies plan and control their service activities with the help of management accounting. Thus, there is a need for detailed examinations of approaches to steering the exploitation of service business potential in manufacturing companies.

Performance indicators are typically used to guide the decisions made in companies. In this vein, servitization initiatives require revision of the performance measurement systems in use. In other words, servitizing firms should explicitly acknowledge and monitor the interaction between product and service activities. Moreover, knowledge of the installed base could indeed advance, for example, spare-part sales and maintenance service management. In practice, creating supportive information for decision-makers may require the collection of financial and non-financial information that is scattered across different systems in different forms.

Results

The concept of profitability management for service business renewal, as developed in this project, clearly responds to this scientific and managerial challenge. In the project, it was found that service-business renewal actions may require a case-specific approach to profitability management, and a rethinking of the traditional views of business and existing management accounting and control devices. Analysis of the spare-part business potential used combined financial data and equipment fleet information from across product lines (machinery and service sales) and organizational units. Market area experts across global units

were interviewed in order to understand the characteristics of the business. To assess alternative service business concepts, a profitability scenario tool was created. In addition, new performance indicators related to the equipment fleet were developed, and examination of the RFM (recency, frequency, monetary value) customer segmentation method was applied to sort customers into meaningful segments.

Total profitability simulations and extensive market area analyses, together with actual numbers from global fleet operations, have worked as eye-openers regarding the elements of profitability in service business. The project highlights how management accounting could facilitate service business development through collecting and consolidating the scattered financial data. Actually, these aspects have not gained attention in the previous literature. The results suggest that the development of a global service business is necessary to build on market area characteristics. The project revealed that servitization initiatives highlight the need to develop new performance measurement practices. To assess and justify the profitability potential of new business activities, a company must intimately understand the costs behind its current processes. In order to channel the business actions in different market areas, there is a need for metrics that reflect the customer segmentation. Indeed, the results indicated that the RFM method that has been used in the consumer goods business is also applicable in manufacturing companies.

Impact One of the key impacts is that companies could assess the un-deployed service business potential by measuring their financial figures against equipment fleets. This responds to the lack of measures that reflect the market performance of companies providing products and services. In all, the analyses, new performance indicators, and profitability scenarios will clearly support managers in developing new service concepts (e.g. remote technologies), choosing the right spare-part approaches (e.g. online services), and enhancing service business profitability. The concept of profitability management for service business renewal, as developed in this project, encourages managers of global machinery manufacturing companies to take into account the overall profitability implications of development actions, rather than simply focusing on their own areas of responsibility.

Forecasting customer behavior and profitability based on extended fleet information

Kati Stormi, Teemu Laine/Tampere University of Technology

Machinery manufacturing companies possess a significant amount of information about their fleet in use on customer sites. Utilizing such information in planning and control has not yet been thoroughly understood. The case shows that advanced statistical models may greatly support planning and controlling of industrial service sales and customer relationship management practices.

Background and objective

Service business renewal also challenges the financial control of industrial organizations. Product profitability information needs to be supplemented with customer profitability analyses (CPA). Fleet profitability is yet another new unit of analysis. Fleet profitability analysis (FPA) requires a combination of multiple information sources and supports managerial work on capacity planning, customer relationship management, and new service development.

Promising results have been obtained: profitability analyses have shown the contribution of each customer to firm-level profitability. The analyses have been supplemented with additional customer fleet information.

Utilizing installed base information is a timely topic in business planning. One example of customer-level analysis is forecasting the service business potential (and the actual demand) based on fleet information. The fleet (installed base) lays the foundation for industrial services such as maintenance and spare-part supply. However, forecasting and stabilizing service demand is extremely difficult for OEMs. Hence, a key resource for designing and delivering successful manufacturing services is a field service organization, especially with the capability to manage it effectively and manage execution risk. Reliable demand forecasts will reduce the execution risk, since they enable efficient production of industrial services. In addition, the information included in the fleet also helps suppliers to identify potential customers for increased sales; that is, the customers who do not order as much as they could be expected to in light of the installed base they possess.

Results

In this project, a statistical model was built to forecast service demand. The model was based on actual orders and detailed information about the customers' installed bases (Figure 11). The model gave a list of cus-

tomers that would probably place an order during the following year, and an estimate of the volume of industrial services the active customers would order. In practice, utilizing the model requires companies systematically to collect, store, and maintain data about their installed base. Compared to typical demand forecasting models, the model can be used even if a customer's order history over a long period of time is unavailable.

	Active	Forecast	Potential	Gap
Customer 1	X	10 000	15 000	5 000
Customer 2			5 000	5 000
Customer 3	X	35 000	60 000	25 000
Customer 4	X	50 000	50 000	0
Customer 5	X	30 000	40 000	10 000
Customer 6			50 000	50 000
Customer 7			20 000	20 000
Customer 8	X	25 000	30 000	5 000
Customer 9			60 000	60 000
Customer 10	X	40 000	40 000	0
Customer 11			10 000	10 000
Total	6	190 000	380 000	190 000

Input — Order history / Fleet info → *Model* →

Figure 11. The model input and output (see Korhonen et al. 2016 for more details)

Impact The early moves in servitization have often centered on single services for a single item of equipment or a single customer, and the ramp-up of full volumes in service offering and service delivery have revealed new kinds of issues. Within the Finnish mechanical and engineering sector, an emerging concern deals with the highly distributed fleet that is being served for a diversity of customers, in distant locations, and in diverse ways. Companies need new enablers for a high-volume, dynamic, and global service business. The predictability of service demand plays an important role in enabling operational efficiency and dynamic service delivery, creating added business value, for both the supplier and its customers.

The predictability of service business has been clearly enhanced during the project, as the new model for forecasting was designed and piloted. In the designed model, the coefficient of determination was high. The model explained as much as 80% of a customer's yearly order volume. The key message of the study is clear. Companies should more actively sell their services or products to the potential customers that the model pinpoints. The model could also be advanced by including other factors affecting the demand for industrial services. For example, the age of the installed base affects the forecasting of industrial service demand to a crucial extent. The way the customers use the equipment also

influences service demand: some customers only use the equipment every now and then, whereas other customers basically use the equipment non-stop. The current model only acknowledges the size of a customer's installed base.

During the project, other analyses and models regarding customer profitability were also conducted. As a result, it was found that analyzing and realizing the service potential of customers, regarding their fleet, requires a proactive stance and the ability to find new ways to scrutinize and measure service business and its profitability (potential). Besides, more agile, iterative approaches are required on the journey toward better service business profitability.

Finding novel avenues for accounting and control for new service development within servitization

Tuomas Korhonen, Teemu Laine,
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Tampere University of Technology

The results of PROS have proven the great benefits from studies on outlining and realizing new service business potential. The concepts and approaches developed in the project help numerous companies in realizing their servitization objectives. At the same time, no shortcuts exist toward long-term service profitability.

Background and objective

The CMC research group at TUT aimed to design and pilot a concept for profitability-driven service business renewal. This concept was intended to clearly justify, define, and control service business renewal on a case-by-case basis. Some initial company motivations for NSD (new service development) were explicated during the project:

The project used IVR for designing and piloting an advanced profitability management approach for service business renewal in the case companies. This profitability management approach was expected to support selected business model innovation and product/service development projects from idea to market launch. Interventions focused on gaining familiarity with the R&D control within the company, identifying timely R&D project ideas and their characteristics, understanding spare-part business/customer behavior/service market area characteristics, and discussing projects, project ideas, and R&D control with the help of accounting prototypes. These prototypes were business impact analysis tools and analytical models under development.

> *'What we want from accounting in the near future is to provide customer profitability analysis and service contract profitability analysis...'*
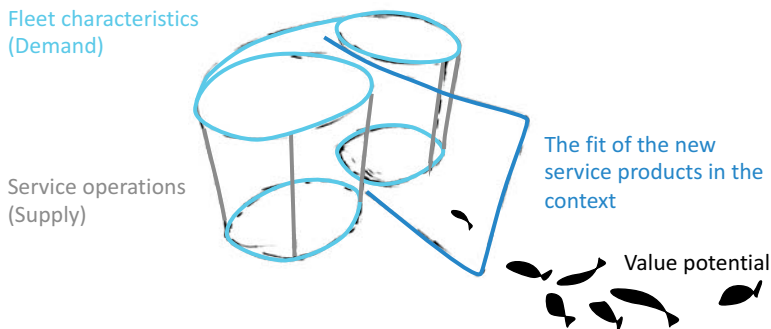> *(life-cycle service manager)*

> *"We just want to be in the ballpark."*
> *(service development manager)*

Results Altogether, in addition to discovering new ways to measure performance and control and use forecasting within servitization, CMC managed to open up a variety of novel avenues for accounting and control for NSD. More specifically, the sub-project focused on themes with clear implications for industrial practice:

- Facilitation of NSD: Yields investments in the development of radically new services, bearing in mind the dynamics of profitability and business impacts in a wide sense.

- Extensive analyses on the profitability of after-sales and service contracts: Investments in remote technology development and utilization for service transformation and the design of new (multi-level) service contracts.

- Analyses on profitability at customer, fleet, and product levels: Investments in effective resource planning and the design of intentionally profitable service concepts.

- Extensive analyses of spare-part business and different channels: Engaged in the investments in spare-part concepts and the wider evolution of IoT utilization.

As a result, our work yielded a conceptual fish-trap model (in Finnish: Katiska), which is presented in Figure 12.

Fleet characteristics (Demand)

Service operations (Supply)

The fit of the new service products in the context

Value potential

Figure 12. The model of NSD as an intersection of fleet characteristics, service operations, and the fit of the new service products in their context (presented in Laine et al. 2017 in Promaint)

The fish-trap model explains that, in order to provide meaningful support for NSD, managers in the field need to capture the characteristics of their fleet, which forms the bottom and the top of the fish trap. The service operations are the walls that give structure and also restrict the range of opportunities with regard to new services. Therefore, a manager needs

to be aware of the possibilities and limitations linked to service operations. Finally, the guiding fence will drive the value potential (i.e. the "fish") into the fish trap and therefore capture a part of this potential. A manager in the field needs to know how and how well this fence, representing the fit of the new service product in its context, works. In all these aspects, business numbers are central.

Impact
The reported actions in our work and the fish-trap model together confirm the need for tools and technologies to support servitization, define the scope and content of the profitability management practice in response to this need, and provide examples of the actual utilization and implications of the enactment of the profitability management practice. The key impact of our work paves the way for practitioners and academics alike toward more profitable service business renewal.

First, it is crucial to rethink the accounting objects and control devices for developing comprehensive and advanced service offerings; this work includes revealing new and innovative business models and respective business opportunities.

Second, the analytical potential of machinery fleet information is largely undiscovered. However, profitability-driven service business renewal was able to derive meaningful results from company invoicing data, which was relatively easily available. By using this data, it was possible to create an analytical model that forecasts customer demand in services. This forecasting holds enormous potential for companies to boost their service sales and focus sales activities on specific customers, such as those whose volume of service purchases is less than the model expects.

Third, profitability-driven service business renewal gives practical insight into how it is possible for machinery manufacturers to understand the factual possibilities of the machinery fleet service market. The sub-project particularly highlights the role of individual managerial actors in identifying and putting forward the possibilities (requiring new information sources and new forms of communication among different actors). Many accounting facts could be gathered or constructed after finding the proper form of collaboration and communication. These accounting facts depend on the case, but can include, for example, fleet sizes and types for selected regions, wear and spare-part consumption, machine usage, and customer service consumption behavior. In this case, the S4FLEET program was the avenue to support firms' otherwise limited resources with analytical skills offered by CMC's interventionist researchers.

Fourth, fleet characteristics should be considered when seeking avenues for service business development, and managers of global machinery manufacturing companies should take into account the overall profitability implications of development actions, rather than simply focusing on their own areas of responsibility. In practice, this means meaningfully combining equipment sales data and service sales data, and thereby laying an analytical basis for NSD.

> *"The Excel platform was surprisingly easy to use and the logic enabled the participation of those of us who are not used to working with financial numbers..."*
>
> *(NSD workshop participant)*

In all, profitability-driven service business renewal has shown how the utilization of the advanced profitability management practice is able to clearly support servitization, with remarkable scientific novelty and yet practical relevance, especially in selecting and steering the avenues of service business renewal with the most potential.

Further information

STRATEGIC INTELLIGENCE FOR
FLEET MANAGEMENT

Transformation of service operations toward the mastery of fleet-related services

Granlund, KONE, Valmet and Outotec are S4Fleet partner companies that participated actively in the research and development of competitive organizational capabilities related to service transformation. For these companies, the transition to service-centric value creation is a strategic response to the changes that are taking place in almost all technology industries.

Therefore, this research project studied the development and implementation of strategic initiatives in the Finnish technology industry – even beyond the participating companies – to create value through proactive fleet management. We studied how organizations pursuing such transformation can make advanced use of digital service platforms as the backbone for service operations, and in connecting components and processes to the platform. We learned that the transformation to value-based business strategies requires changes in the ways companies utilize technology for managing information in their inter-organizational processes, but also in the institutionalized processes, practices, and beliefs of conducting business. Moreover, the transformation was found to call for competitive organizational capabilities, leadership methods, and competencies and tools for assessing value. Although the pressures to emphasize value-based business strategies are acknowledged by the top management in many industrial firms, most of the firms still struggle with implementing a value-based approach to service operations management. In addition to the competencies required in mastering single instance-based services that support individual customers in their specific contexts, proactive fleet management requires technologies that enable the large-scale management of several context-specific processes.

The project asked the following research questions: How can industrial firms implement strategic change toward value-focusing business strategies, making advanced use of the industrial internet for fleet management? How can they shift from the level of instances of things or events to managing fleets? What obstructs such a transition?

In addressing these questions, we found that service transformation involves institutional complexity. This is largely because the mastery

of multi-actor service operations requires the organizations to develop new ways to perceive their surroundings and implement service strategies, while their existing competitive strategies are bound to their prevailing capabilities and industrial logics, based on possessing information and knowledge resources. The responses to create value in multi-actor settings include new types of information and knowledge processing based on classifications of instances as part of a fleet, codified in their information and communications systems. In order to respond to these challenges and opportunities, manufacturing organizations need to be able to flexibly manage the fleets of their assets, service processes, encounters within them, instances of equipment, and so on. There is an increasing need to classify and re-classify instances of things. Such activity is enabled by instance-based management of services, that is, activities that are focused on the capture, maintenance, use, and sharing of data on the level of instances of things or events. The key problems for industrial organizations in implementing this change include the shift to transforming the ways installed base-related information is managed from single-equipment based services to proactive fleet management services. In addition, decisions pertaining to making advanced use of industrial internet technologies are beyond the control of single firms. They call for multi-actor collaboration in industrial service systems.

The redesign and management of global presence and the efficiency of service business benefit from ecosystem thinking by enabling the transformation from single equipment-based services to fleet-based services. The renewal of service business models requires rethinking of the industry platform and its management. This project and task seek to provide knowledge about the overall transformation toward company-level service business management. However, the increasing information availability will have wider impacts, in addition to the offering and profitability. Increasing information intensity in the service-based economy urges organizations to rethink their service strategies.

Therefore, mastering multi-actor value creation can be considered a key capability for achieving high business performance and long-term survival and success in competitive industrial markets. The value-focused approach calls for effective use of the enabling technologies, as well as organizational capabilities, managerial practices, and methods that enable productive ways to leverage customer-perceived value throughout the life-cycle of the entire fleet of installed equipment and assets. By addressing the reasons why industrial firms struggle with implementing a value-based approach to service management, the project improves the capabilities of the participating organizations to master the desired transformation. Altogether, this project facilitates manufacturers' profitability-driven service business renewal by means of advanced service profitability management systems and practices.

Value proposition development framework for industrial service

Risto Rajala, Pekka Töytäri/Aalto University

Value proposition is a widely used but vaguely defined concept in everyday business language. Innovative service-driven industrial value creation requires compelling and measurable value propositions for efficient business opportunity identification, marketing, selling, pricing, and partnering.

Background and objective

Industrial value creation is increasingly based on innovative services and close cooperation, which leverages participating firms' unique strengths. The firms innovate new (digitally enabled) services that help to improve performance, reduce cost, and generate new revenue. Unfortunately, the business value of novel services is initially unknown, and difficult to estimate and communicate. The intangibility, future orientation, and innovativeness of industrial services demand quantifiable value propositions to communicate compelling evidence of value.

Results

The value proposition development model provides a customer-centric tool to systematically develop effective value propositions and support building interactive sales tools for adapting, quantifying, and communicating the value proposition in different customer situations. The development process selects a key customer segment as a starting point, and researches the customer situation and process to understand and map customer activities and business goals. The analysis phase identifies challenges ("pains") and improvement opportunities ("gains"). Those pains and gains that have the biggest impact on the customer's goal, and that leverage the supplier's key capabilities and services, are selected for value proposition development. The actual value proposition development implements the value proposition as reference stories, value calculators, and other tools, to support marketing and sales in value communication.

Impact

Value propositions that explicitly address customer challenges and business goals create interest, deepen relationships, quantify joint value creation opportunities, and help in differentiation from the competition. Without such tools, the adoption of new ways of working within business ecosystems is slow, costly, and even random.
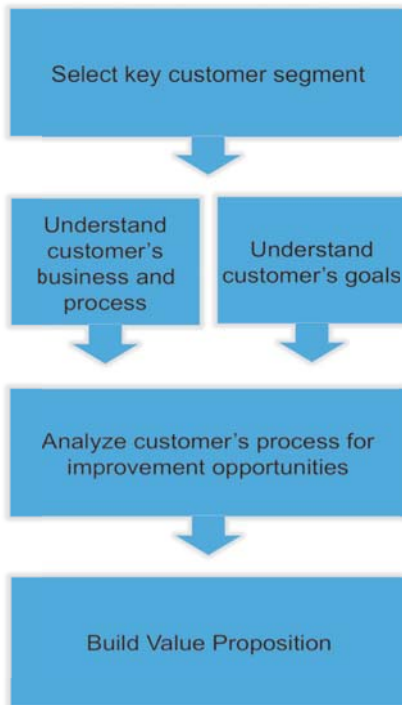
Figure 13. **Value proposition development framework**

Creating customer value through digitally enhanced industrial services

**Elli Taimela, Shan Gao, Juri Matinheikki,
Risto Rajala, Esko Hakanen, Pekka Töytäri**
/Aalto University

Performance-based revenue models are applications of service-based value creation that enable linking the price of a service to realized customer value. Researchers propose that such revenue models can be realized through digital services that make the imperatives of value creation more transparent between the service provider and the customer. To gain the benefits of performance-based service contracts, service providers need to identify, measure, and verify the realized customer value.

Background and objective

The digitalization of industrial services provides new means for industrial service providers and customers to utilize performance-based revenue models, as it enables the service provider and the customer to measure and verify the value created through a service. Realization of customer value in many industrial fields requires operational actions executed at the customer site. To ensure value creation for the customer, service providers should possess service capabilities that operate resources in the service process at the customer site, to identify, ensure, measure, and verify the customer value in collaboration with the customer.

Results

We identified two main options for business models associated with digitally enhanced industrial services. First, the service provider can support customer value creation through providing digitally enhanced services for the customers, to help customers in their decision-making concerning industrial processes. Alternatively, service providers can provide customer value by means of value co-creation, by which the service provider and the customer collaboratively seek to optimize the entire industrial process in which the customer is involved. Firms are increasingly interested in the latter option, since the exchange of value, instead of the exchange of physical goods and resources, enables the utilization of performance-based revenue models, which provide a wider variety of options for value capture.

Figure 14. Your customized performance-solution
Source: http://new.outotec.com/services/service/performance-solutions/

Impact Performance-based revenue models for industrial service call for applications of value-based pricing that enable linking the price of a service to realized customer value. Such revenue models enable industrial firms to build their value propositions on improved customer value. The utilization of value-based pricing in terms of performance-based revenue models requires a service-dominant mindset, not only in the service provider's organization, but in all parts of the collaboration with the customer. In addition, service providers are required to execute operative actions that ensure and verify the creation of customer-perceived value at the customer site. In doing so, the offerings of the service provider and the practices in its service delivery should support the service provider's role as a customer value co-creator.

Further information

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KEYWORDS: Value creation, value verification, value co-creation

INDUSTRIES: Mining industry, OEM

Leveraging the benefits of a circular economy through material intelligence

**Esko Hakanen, Ville Eloranta, Risto Rajala/**Aalto University

Material intelligence depicts shared, profound understanding of material properties and their history. It can improve product quality and material life-cycle management. With material intelligence, single pieces of material can carry messages in the supply chain and enable value creation through service. By knowing the history of the items, actors can configure their operations better. This idea underlines both the potential and the need for cross-organizational collaboration.

Background and objective

Raw materials, such as steel products, are challenging to differentiate. However, we see promise in developments on the internet of things front, to resolve these challenges. We analyzed the current business models and networks in the steel industry and tried to identify potential changes in the roles and responsibilities of actors in the end-to-end business ecosystems. Our results reveal considerable interest within the industry in solutions in which customers could receive detailed product properties, far beyond the accepted variation levels within the standards. This indicates that the level of detail for material properties could become a source of product differentiation in the future. In particular, our findings indicate how material intelligence enhances value creation from the primary processing of the material, products, and solutions to value-adding services.

Results

The proposed system for material intelligence is based on equipping each material instance with a unique identifier, which is coupled to a corresponding virtual reference. These enable the companies to share detailed information about the instances throughout their life-cycle. Our findings indicate that the exact properties from the material producer could prove to be much more valuable to the next actor in the ecosystem, because they are used to optimize the manufacturing process. For example, the elastic response that derives from the stiffness of each steel sheet is a crucial parameter in bending. Without the exact stiffness data, the next actor cannot optimize its bending process. In turn, when the manufacturer receives feedback on suitability and product performance, this surpasses the value of data obtained from the company's own tests or simulations. So, for both actors, the data from the other party can prove more valuable than their own.
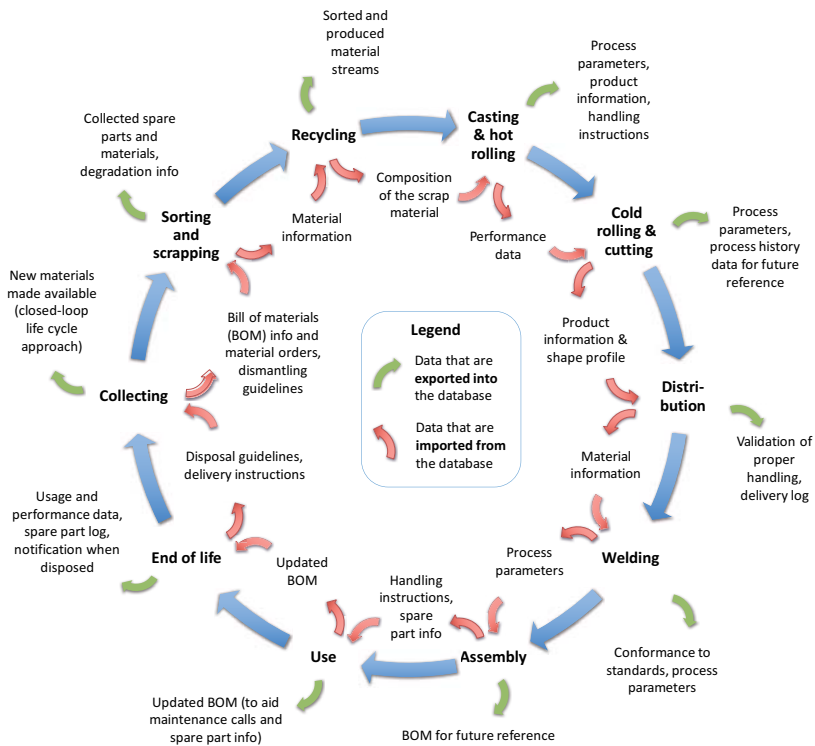
Figure 15. Material intelligence cycle

Impact　The ability to create value will gain more importance in the future. We see that industrial value creation can be enhanced with innovative services and close cooperation that leverage the unique strengths of each participating company. Cooperation helps to identify the need for innovations and to reveal participants whose data complements the other. In sum, when data are put to effective use across the industry ecosystem, the result can be something of significant value; it becomes material intelligence.

Further information

Harnessing emerging technologies for field service

Henri Jarrett, Jan Holmström, Pekka Töytäri/Aalto University

Emerging technologies, such as augmented reality, virtual reality, artificial intelligence, drones, and additive manufacturing, have great potential to improve field service processes. We studied how the new technologies improve the elevator installation process.

Background and objective

Emerging technologies have great potential to automate, scale, and improve industrial processes by integrating digital, physical, and human resources and capabilities. The technologies will likely disrupt the existing processes, power positions, value creation, and value sharing.

Figure 16. Illustration of the use of augmented reality

Results

Our research provides a starting point for evaluation, piloting, and stagewise implementation of different emerging technologies, to improve the efficiency, quality, and safety of an elevator installation process. The study performs an extensive literature review of augmented reality, virtual reality, artificial intelligence, drones, additive manufacturing, intelligent

sensors, radio-frequency identification, smart/intelligent tools, robots, holography, 3D scanning, and building information modelling (BIM). The review is combined with an in-depth analysis of an elevator installation process from different stakeholder perspectives, resulting in three use cases for leveraging emerging technologies in the elevator installation process. The three use cases are: 1) a combination of 3D scanning and BIM, 2) augmented reality, and 3) RFID. The study finds that the applicability of the technologies is dependent on their maturity, the cost, and the degree of undesirable effects on the installation process.

Impact The results achieved support immediate piloting and further evaluation of the use cases, and changes in the current practices wherever the cost of implementation, the maturity of the technology, and the value created are favorable. The new practices likely incur fundamental changes in the way human resources in the installation processes work and benefit from the technology.

Further information

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KEYWORDS: Augmented reality, virtual reality, artificial intelligence, additive manufacturing

INDUSTRIES: Construction industry, logistics

Service transformation as a firm boundary decision

Esko Hakanen, Mikael Öhman, Pekka Töytäri, Risto Rajala/Aalto University

Much of service transformation is about reorganizing operational activities between firms. The economies of scale and scope have been used to explain the potential benefits of service transformation decisions. We feel that this approach has limited the explanatory power, and argue that service transformation should be examined and explained as a firm boundary decision.
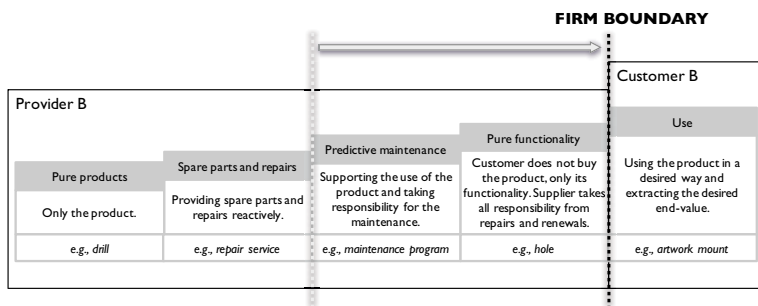
Background and objective

In essence, service transformation depicts a phenomenon in which the responsibility for performing a specified task is changed from one party to another. In other words, this decision entails a redefinition of the organizational boundary between the supplier and the customer. Therefore, the theoretical lens of organizational boundaries is particularly well-suited for analyzing the decisions that the companies make related to service transformation and the potential outcomes of these decisions. However, this view has not been sufficiently utilized in the existing research.

Results

In its most simplified terms, a boundary decision can be defined as a selection between "Which business activities should be brought within the boundaries of the firm?" and "Which business activities should be outsourced?" From this activity-based perspective, service transformation is portrayed as a straightforward decision to realign the boundary between two (or more) firms. Here, it may well be that the method of producing the outcome, or the end-value, may remain entirely the same, while only the party performing these actions changes.

The firm boundary appears both in business-to-business (B2B) and business-to-consumer (B2C) contexts. As an illustrative example, consider if you want to hang artwork in your living room. To hang the painting, you need to drill a hole, for which you need to have a functioning power-drill. You can either purchase the drill or hire a constructor to drill the hole on your behalf, or something between these extremes. All the scenarios lead to the same end-result, where you use the hole to mount the art piece on your wall. Typically, if you purchase the drill, you are responsible for maintaining it. The provider, which is the company that manufactures the drill, usually offers spare parts and repair services for the machine, but it remains the customer's responsibility to look after the tool and to decide if repairs are needed. The same principles apply to industrial machinery in the B2B context.

FIRM BOUNDARY

Provider B				Customer B
			Pure functionality	**Use**
		Predictive maintenance	Customer does not buy the product, only its functionality. Supplier takes all responsibility from repairs and renewals.	Using the product in a desired way and extracting the desired end-value.
Pure products	Spare parts and repairs	Supporting the use of the product and taking responsibility for the maintenance.		
Only the product.	Providing spare parts and repairs reactively.			
e.g., drill	*e.g., repair service*	*e.g., maintenance program*	*e.g., hole*	*e.g., artwork mount*

Figure 17. Firm boundary

Impact Our findings propose a more holistic perspective on service transformation-related firm boundary decisions. The setting of the firm boundaries is an important and extensively studied aspect in management, yet this view has not been fully utilized in the existing research on service transformation. Even though service transformation has been considered almost unanimously to be a wise strategic move for manufacturing companies, practice has shown that not all attempts lead to positive outcomes. This so-called service paradox may be explained through existing theories on competitive advantage, simply by analyzing the effects on the resources, capabilities, and transaction costs that service transformation induces. Therefore, boundary decisions are crucial to service transformation.

Further information

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KEYWORDS: Servitization, network position, value network, outsourcing

INDUSTRIES: Manufacturing industry, steel industry, construction industry, software industry

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PREDICTIVE SERVICE OPERATIONS FOR A DYNAMIC FLEET

2

Miia Martinsuo/Tampere University of Technology

Motivation for studying predictive service operations for a dynamic fleet

Manufacturing companies in the mechanical and engineering industry have included services in their offering and, consequently, have modified their organizational designs to feature service delivery. Companies have developed service processes and structures, infrastructures, IT systems, and competence profiles that have enabled repetitive service delivery. Companies have also invested in new sales and customer interface processes, to get closer to the customers' processes and to enhance the service experience. In line with previous research, however, the early moves in servitization have often centered on single services for a single piece of equipment, or single customers, and the ramp-up of full volumes in the service offering and service delivery have revealed new kinds of issues.

Within the Finnish mechanical and engineering sector, a concern at the beginning of the DIMECC S4Fleet program dealt with the highly distributed, even fragmented fleet that is being served for a diversity of customers, in distant locations, and in diverse ways. Companies needed new enablers for a high-volume, dynamic, and global service business. Companies also expected to understand their customers and customer processes better, to be able to predict the service potential of the future. Various automated (remote) options for collecting and using customer data were beginning to be available, but were not necessarily in active use. Therefore, the project on predictive service operations for a dynamic FLEET focused on the operational efficiency and dynamic service delivery systems intended to serve the distributed fleet. The central question for predictive service operations for a dynamic fleet was:

> *How can manufacturing companies optimize their service delivery system, to make it efficient and responsive to customer-specific needs at the same time?*

Even if single customers or single pieces of equipment needed certain unique services, from the perspective of the entire fleet, some degree of standardization, routines, and service solution integration is needed, to make the entire service delivery system efficient and to optimize costly customization. At the same time, however, suppliers need to identify instances in which they need to be dynamic and responsive, to the situation-specific needs in the fleet. The need to balance flexibility and efficiency was at the heart of the S4Fleet predictive service operations for a dynamic fleet. At the same time, there was a need to optimize the customers' service experiences and the manufacturing firm's service performance. Therefore, the project explored service operations from two perspectives: from the supplier's perspective on the level of the entire service delivery system (as a "system of systems"), and from the customers' perspective on the level of the customers' service experience as achieved through the delivered services. Figure 18 illustrates the thematic entity of S4Fleet Project 2 on predictive service operations for a dynamic fleet.
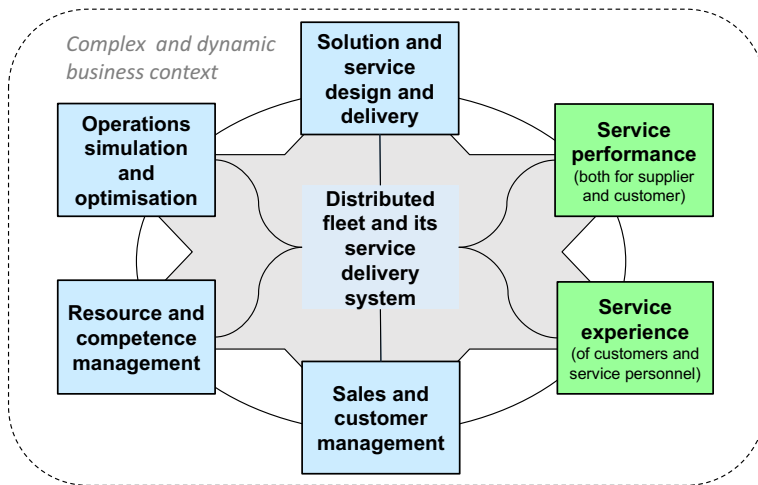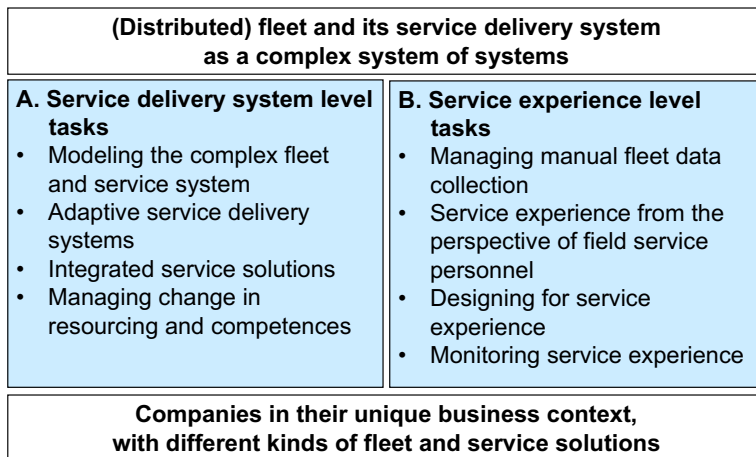

Figure 18. **Summary of the key themes covered in DIMECC S4Fleet Project 2 on predictive service operations for a dynamic fleet**

Demand and expectations in studying predictive service operations

Service delivery systems mean organizational design choices, for example in the structures and planning underlying service delivery, the infrastructures supporting it, and integration at the level of the organization, supply chains, technologies, and learning systems. Today's information

architectures, however, create completely new opportunities for companies in managing their fleets, as well as related services. Because plenty of remote or manually collected data is available concerning the fleet, companies need to use such information to optimize the service delivery system for different contexts, create customer-specific dynamics for system deployment, and involve their network partners in novel service delivery. In addition, forecasting future service opportunities may become possible, based on the intelligent use of fleet and customer information.

The research objective in predictive service operations for a dynamic fleet was new knowledge, understanding, and models for: a) managing a distributed fleet proactively, predictably, and efficiently, and b) operational excellence through enhanced system-level service experiences. Companies defined managerial objectives for achieving measurable change and cross-company benchmarks in fleet-related service system a) predictability and productivity and b) superior service experience for the company and its (selected) customer base, through a high-volume, fleet-level service offering and intelligent optimization of the fleet. With these objectives, the intent was to optimize the supplier's business value and customer value in the design of service delivery systems at the level of the fleet. The project was divided into two sub-projects, in line with Figure 19.

(Distributed) fleet and its service delivery system as a complex system of systems	
A. Service delivery system level tasks • Modeling the complex fleet and service system • Adaptive service delivery systems • Integrated service solutions • Managing change in resourcing and competences	**B. Service experience level tasks** • Managing manual fleet data collection • Service experience from the perspective of field service personnel • Designing for service experience • Monitoring service experience
Companies in their unique business context, with different kinds of fleet and service solutions	

Figure 19. **Implementation of predictive service operations for a dynamic fleet in two sub-projects**

Key achievements of the dynamic fleet and its service operations

In this project, we explored the dynamic fleet and its service operations at the interface of manufacturing firms and their customers, with manufacturing firms potentially involving their software and service providers as part of the service design and delivery. The research settings are illustrated in Figure 20. The starting point has been the core system or solution offerings of the manufacturing firms, and how service orientation has been "built into" the solution offerings, either by the prospect of additional services, or the use of remote monitoring systems, or even very advanced data-based services.
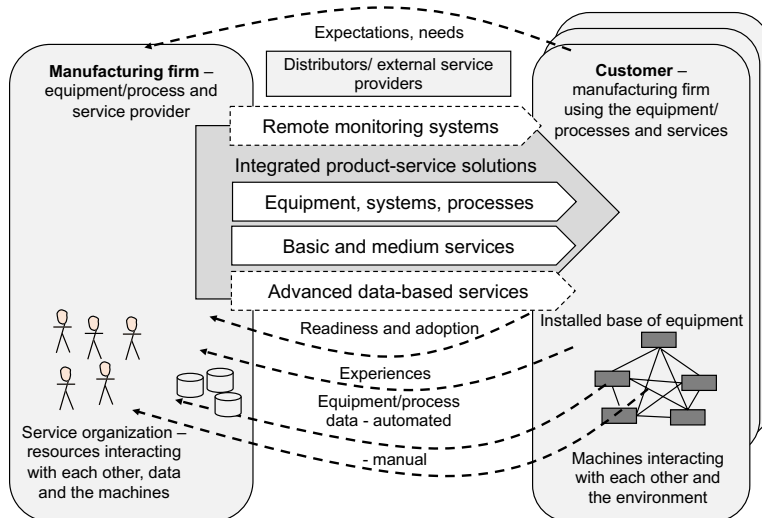
Figure 20. **Summary of the issues investigated concerning service delivery for the complex fleet**

The key achievements of the project deal with four major issues:

1. The **complex fleet** needs to be treated as a system of systems on multiple levels, each of which needs to be considered, modeled, analyzed, and developed for efficient service delivery: 1) the system of equipment and processes required for service delivery; 2) the system of multiple organizations in contractual and non-contractual relationships with each other; and 3) the system of people and machines interacting with each other and the environment.

2. Manufacturing firms' **service delivery** requires clear and flexible resource arrangements, not just inside the manufacturing firm, but also in customer firms and so-called third parties (software providers, external service providers, distributors and agents, etc.). The reconfiguration of resources for all actors needs to be balanced so that resource efficiency takes into account the multiple perspectives. Efficiency in service delivery may require renewal and even standardization of processes, as well as redefining the earning logics.

3. Customer firms' **service experiences** should be considered as an important key measure and service design driver when developing and delivering the manufacturing firm's service offerings. Different types of customers may have quite different expectations that may affect how service experiences take shape. The success of services can depend quite significantly on how customers and retailers accept services and experience their benefits in terms of business performance and supplier quality.

4. Fleet-level service efficiency requires **good systems for data availability**, collection, analysis, quality, and use for business-oriented decision making. It is crucial that business-relevant equipment and fleet-level data are readily available, valid, and usable, whether automatically or manually collected. Besides the technical parameters of the data, the relational and organizational conditions for data access and use must also be in place. This highlights the crucial interfaces from predictive service operations to other research streams within S4Fleet.

The research activities have shown that "prediction" is a long-term goal in fleet-level service delivery. Prediction implies anticipating the future and its events, to be able to manage the processes in a more efficient way, and detecting risks and dangers so that they can be avoided or mitigated anticipatorily. Data and efficient systems and infrastructures for data-enabled service delivery are prerequisites for prediction, and they are now being developed in and across companies. In this project, companies see prediction much more broadly than "predictive maintenance." It deals with predicting customer needs, market behaviors, and technological developments, and being ready to renew operations for any types of solution offerings.

Prediction, in turn, is a necessary precondition for optimizing the entire system for the different stakeholders involved in service delivery systems. This project paves the way to initiating new research on optimizing the service delivery system for multiple stakeholders' interests, including but not limited to the following questions:

- How can companies overcome the barriers (social, business-related, and technical/data-related) to predictive service operations, and speed up the development process in their service delivery systems?

- What are the requirements for optimizing the service delivery system from the viewpoints of different actors?

- What kinds of prioritization issues do companies face when optimizing their service delivery system?

- How can companies negotiate and balance the conflicting demands in the service delivery systems?

- How can companies develop the performance of their service delivery system over time in a dynamic, evolving business environment?

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PREDICTIVE SERVICE OPERATIONS FOR A DYNAMIC FLEET

Requirements for data-enabled fleet-level service systems

The "requirements for data-enabled fleet-level service systems" theme focuses on the requirements for data-enabled fleet-level service systems. It reports that the lifecycle orientation of equipment and processes is designed and planned already during solution design and delivery, which is long before companies engage in any service relationships. It identifies the basic requirements for data-enabled services not just in technology, but in the organization and its relationships. The key processes requiring modifications in service operations are identified, primarily from the manufacturing firm's viewpoint, but also reaching toward the customers' side. The results also cover the centrality of data access both automatically and manually, to design and deliver relevant data-based services, and highlight how relevant it is to model the fleet system and its status well, to identify the best possible service prospects.

Delivering the fleet machinery: Controlling the delivery of complex lifecycle-oriented solutions

Lauri Vuorinen/Tampere University of Technology

Background and objectives

The distributed fleet of an equipment manufacturing company consists of a set of solutions, such as machines, related information systems, and service functions, designed by the manufacturing company and delivered to customers, possibly across the globe. The distributed fleet does not exist or appear automatically. Instead, there is a need for solution deliveries that often include both tangible goods and intangible service elements. Solution deliveries are typically managed as delivery projects, and these projects have a central role throughout the solution lifecycle. In addition to delivering the distributed fleet case by case, projects build up the readiness for managing the fleet, maintaining it, or enabling its modernization later in its lifecycle. Management attention should not be limited to the efficient management of the project delivery, but a lifecycle-oriented approach should be followed, from solution design to solution disposal. The objective was to understand the different lifecycle-oriented strategies throughout the different phases of delivering customer-specific solutions.

The figure below summarizes lifecycle-oriented strategies in the different phases of a solution delivery.

Pre-delivery

- Project delivery as an integrated solution
- A modular project design guiding the inclusion of lifecycle-oriented elements

Delivery

- Management and control of the project delivery
- Different requirements of different projects
- Different changes taking place throughout a solution's lifecycle

Post-delivery

- The project deliverable becomes a target for future projects (e.g. modernization and service projects)

Figure 21. **Taking the solution lifecycle into account in the different phases of solution delivery**

Results

Starting from the early phases of the project, meaning the "front end" of solution delivery, companies can consider designing integrated solutions that consist of a combination of tangible goods and intangible service elements. This requires good intra-organizational collaboration, because different organizational units are often responsible for the capital delivery project and the service elements. In addition, a good relation-

ship is required between the manufacturer and the customer, both at the organizational and at the personal levels, to identify needs for the solution throughout the lifecycle.

Linked to the typical separation of the delivery project and the service business, another option is a modular project design. A modular project design can promote lifecycle-oriented integrated solutions by supporting project sales and by making the integration of tangible capital deliveries and intangible service elements easier. In addition, for instance related to data-enabled advanced services, a modular project design can assist by guiding the project team with the different requirements the service elements might set for the capital delivery.

When the project reaches the solution implementation phase, attention turns to ensuring the smooth progress of the project. Here, a crucial aspect is the management of different projects in the implementation phase. In particular, a manufacturing company often has a model for managing its project. This can be either an official and formal project management model or the more informally defined typical method of a project manager. However, this model might not be suitable for all types of projects. In particular, projects with different levels of complexity have to be managed differently. The management of less complex projects can follow the steps of an official project management model, while more complex projects require a lot more specific attention from the project manager and the project team. Thus, it is necessary for a manufacturing company to identify the factors differentiating its projects and the requirements these factors set for managing the different projects.

Despite the project management model, different types of changes occur in the solution implementation phase. Some changes may deal with the solution, some may affect the project itself, and some may focus on the ways of managing the project. The origin of the changes can be either internal (e.g. the project organization itself) or external (e.g. the customer or some other stakeholder) to the project. Companies have to take into account all the different types of changes and plan their actions accordingly.

After the solution has been delivered, it becomes part of the company's installed base, in the distributed fleet. The solution still has a role in the manufacturing company's project business, because fleet machinery is a target for service projects. These service projects often share similarities and thereby have a relatively repetitive nature, which may differ significantly from the unique, customer-specific solution deliveries. The manufacturing company should develop a management framework that enables the efficient and effective management of these repetitive service projects.

Impact   The results highlight the importance of project business throughout a customer-specific solution lifecycle. Companies should not treat capital project business and service business as separate, but should instead design and deliver integrated solutions that also enable efficient service delivery. A modular solution design is one potential approach for assisting the design and delivery of integrated solutions. In the solution delivery phase, companies should take into account the differences between projects and the potential changes that will likely take place despite good planning, and should build adaptable project management models accordingly. The repetitive nature of service business after solution delivery challenges the companies to consider how service delivery systems are integrated seamlessly with the delivery of unique customer-specific solutions on a global scale.

Company impact   "We have seen huge growth in all areas and a lot of development work being done. At the beginning of this project, we did not have any remote monitoring, and capital sales and services were separated. Today, remote monitoring (Metso Metrics) is included in all track-mounted mobile equipment and it is boosted by service programs to create a natural transition from capital equipment sales and delivery to after-market support and maintenance. Customers are also asking more and more for lifecycle contracts (maintenance contracts related to time or production tons). Without the digital systems developed recently and during this project, we could not offer such services on a large scale."

Julius Mäkelä, product manager, Portable solutions, Metso

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PROJECT PARTNERS: Metso, Raute, Valmet, Tampere University of Technology

AUTHOR: Lauri Vuorinen, Tampere University of Technology

Requirements for data-enabled services

Lauri Vuorinen/Tampere University of Technology

Background and objectives

The industrial internet and the more widespread utilization of data offer huge opportunities for both manufacturing companies and software companies. However, it is not sufficient to "just install sensors in products" and then start obtaining the benefits. There are many kinds of challenges and requirements that companies must take into account when starting the transformation toward the industrial internet. A number of manufacturing and software companies participated in research collaboration focusing on the benefits and requirements of the industrial internet and data-enabled business. The objective was to identify the requirements of the industrial internet and data-enabled service business. The initial viewpoint was that of a manufacturing company, but understanding the requirements is also relevant for software companies.

Results

Regarding the benefits of the industrial internet and data, the variety is large. Utilization of the industrial internet will enable companies to develop novel solutions, build intelligence into their tangible products, and offer sophisticated data-enabled services. In addition to new products, services, and solutions, the industrial internet can enable companies to adopt new types of business models. In particular, the industrial internet is a key enabler in the movement from transactional relationships toward value-based business models.

Despite the clear benefits of the industrial internet, there are several requirements that a company has to fulfill, to capitalize on its benefits. Three types of requirements were identified (Figure 22): technical, relational, and organizational requirements.
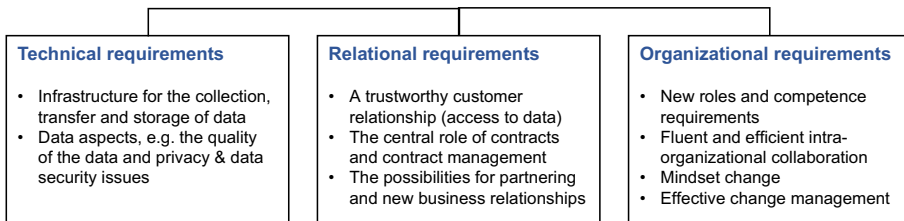
Technical requirements	**Relational requirements**	**Organizational requirements**
• Infrastructure for the collection, transfer and storage of data • Data aspects, e.g. the quality of the data and privacy & data security issues	• A trustworthy customer relationship (access to data) • The central role of contracts and contract management • The possibilities for partnering and new business relationships	• New roles and competence requirements • Fluent and efficient intra-organizational collaboration • Mindset change • Effective change management

Figure 22. **Summary of requirements for using the industrial internet for data-enabled services**

The first set of requirements refers to the technical aspects of the industrial internet. In particular, the industrial internet requires a comprehensive infrastructure for the collection, transfer, and storage of data. A good practical example is the sensors built into different machine solutions, enabling the collection of data. In addition to the infrastructure, the industrial internet also sets requirements for the data itself. In particular, companies have to ensure the quality and the comprehensiveness of the collected, transferred, and stored data. A typical challenge relates to the heterogeneity of the distributed fleet; companies have to put effort into enabling the utilization of data collected from a variety of different machinery. In addition, privacy, security, and data ownership have to be considered when the utilization of data increases.

The second set of requirements refers to the manufacturing company's external relationships. The industrial internet sets new requirements for the relationship between the manufacturing company and its customers. The utilization of potentially confidential data requires a high level of trust between the manufacturing company and its customers. The manufacturing company must put effort into building this trust, for instance by demonstrating the credibility and usefulness of the new solutions by means of reference cases and freemium deals, or by using only less-confidential data at the beginning. In addition, the importance of contracts will increase, and issues such as data ownership and data security and privacy will have to be considered from this viewpoint, as well. New types of external relationships might be required. In particular, engineering companies should consider the benefits of partnering in terms of data storage or data analysis. From the perspective of software companies, this can become an important new area of business opportunities.

The third set of requirements refers to the manufacturing company's internal and organizational issues. The industrial internet will set new requirements for the competencies and roles of the company. For instance, when the amount of remotely managed fleet machinery increases, respective actions must be taken in recruiting and staffing. In addition, the utilization of data and the industrial internet will require efficient intra-organizational collaboration. In particular, smooth collaboration is required between sales, technology and R&D, capital and project deliveries, and service business to develop, sell, and manage new types of data-enabled solutions. The move towards the industrial internet requires a mindset change throughout the organization. For instance, value-based business models require a more customer-centric approach throughout the organization than transactional business models. Furthermore, the whole transformation towards the industrial internet is a

major change for a manufacturing company. Thus, all aspects of change management become crucial, but in particular, top management support is emphasized.

Impact It is clear that the industrial internet and data-enabled business offer significant benefits for both engineering companies and software companies. However, there are several barriers and requirements that companies have to solve to convert data-enabled services into business benefits. In particular, it is not sufficient to focus only on data-related aspects, but relational and organizational requirements should also be taken into account.

Company impact

"Sometimes manufacturing firms do not yet know what they want from equipment data. That is partially because they do not know what it is even possible to do and, on the other hand, the changes it may generate. Open dialogue is required from all parties: there is much more to gain than to lose! So far, it has been possible to optimize data quantity, but soon we can focus on data quality and collecting the right data for the right purposes. There is plenty of basic work that has to happen, such as with operative IT systems and roles and responsibilities in organizations, to reach the business benefits from data-enabled industrial services."

Timo Lehtinen, CEO, Ramentor

"It is good to remember the twofold nature of digitalization: although it is a disruptive change driver, in the end it is only a tool for value creation. In order to enable value creation, the requirements of this tool must be understood."

Harri Nieminen, Head of Innovation Development & Research, Fastems Oy Ab

"One big challenge that all data-enabled service providers will face, is that you are not able to provide the real value of that service right from the start. It will take a lot of time to collect/record data, analyze it, and most importantly to learn from it, before you can really prove the potential value of the service."

Markus Halmetoja, Raute

"The industrial internet and data-enabled business are hot but not easy topics. It is obvious that change in the company culture is needed on many levels, collaboration between different organizations inside the company is essential, and value-based business ideas have to be convincing for different customer segments. Workshops organized by the Tampere University of Technology helped us to clarify these complex topics in a structured way. Internal interviews gave insight on the company's current status and ideas considering industrial internet utilization in our business. The results will be utilized in focusing our next steps in data-enabled business development."

Jari Kääriäinen, technology manager, Valmet

Further information

Processes for efficient service delivery for a distributed fleet

Miia Martinsuo/Tampere University of Technology; **Katrine Mahlamäki/**Aalto University; **Khadijeh Momeni, Henri Vainio, Lauri Vuorinen**/Tampere University of Technology

Background and objectives

Over the past decade, industrial firms' service business development has been dominated by a focus on the supplier's and customer's relationship at the level of certain single pieces of equipment and service products. When the focus moves to the level of the fleet of equipment, processes for service delivery need to be optimized not just for a single service, but for multiple different services and repetitive operations globally. This means that similar equipment at different customer sites must be covered, different service channels must be understood, and different kinds of equipment at a certain customer site need to be taken into account. The objective of this integrative part of S4Fleet Project 2 has been to identify core processes affected by fleet-level operations, and to summarize how companies have approached their process development while considering fleet-level service operations.

Results

The results show that establishing an efficient service system at the level of the fleet requires modifications to most or even all of the core processes of technology-supplying firms, as well as the processes of their customers, as summarized in Figure 23. Companies have needed to re-organize their sales and delivery units and educate their service personnel, to increase service-oriented sales and introduce new kinds of customer management practices that are sensitive to the customers' service needs. The potential for servicing competitors' equipment requires new technical skills and the capacity to respond to each customer's unique situations. Changes in sales and delivery processes have also included capability development for distributors and sales agents, as not all sales of complex solutions take place within the firm. In addition, resource allocation routines in development and delivery processes have been reconsidered, as job descriptions of individuals may change through fleet-level services, or completely new competencies may be required. Service business needs to be taken into account already in equipment design and delivery processes, as the possibility for services is created quite early in the design work.

Processes from supplier's perspective	Processes from customer's perspective
• Sales (including contract management) and customer relationship management • Resource management (HRM, resource allocation) • Equipment / solution development • Supply chain management • Equipment delivery • Delivery chain management • New service development • Monitoring of equipment use and fleet status • Service delivery, including maintenance, upgrade, modernizations… • Management and support processes	• Procurement • Early supplier involvement • Supply chain management • Manufacturing • Maintenance • Delivery • Sales and customer relationship management • Management and support processes

Expectations, needs

Solutions

Data, information

Services, performance…

Figure 23. **Processes that need to be taken into account when developing a service delivery system at fleet level**

Companies have made changes in their service offerings and delivery processes because the new data from equipment enables new service development process modifications. For example, various modular service solutions have been developed, and new kinds of service sales configurators have been considered in firms. This may have also caused the removal of unsuccessful services, and the improvement of old service concepts so that they can be repeated across different customer segments. In particular, analytics-related services have required new competence development for service delivery, including new routines and practices for remote analytics and related services. Standardization of service processes has been a natural consequence of repeating services on a larger scale globally.

Despite the dominant focus on supplier firms, it is an apparent finding that customer firms' processes are also affected by the new modes of service delivery. It is not only the maintenance and manufacturing processes that require development, but the entire value chain, starting from how customers procure and require new services for many kinds of support processes. If customers decide to outsource significant parts of their own work and operations, even their strategies and strategic positioning may change. Customer firms' experiences offer important feedback for suppliers regarding the ways in which services and solutions must be developed in the future. When customers become more mature in service procurement, they are also able to demand more sophisticated offerings from suppliers. Finally, customers' customers can also benefit from the fleet-level approach, potentially through better quality and more reliable offerings.

Impact The plurality of services, customers and customer needs, and service delivery channels, and the need to service not just the supplier's equipment but also that of competitors, challenges the efficiency of fleet-level service delivery systems. Global markets challenge the resources and presence of the supplier. In addition, the co-creation taking place in the core processes, jointly between the supplier's representatives and the customers' representatives, implies that efficiency is not controlled or developed by the supplier's actions alone. This study has drawn attention both to more radical business process re-engineering needs and to incremental, continuous process improvement needs in the technology supplier's and its customers' businesses. It is evident that not all firms yet have such data and capabilities to enable consistent process efficiency improvement or optimization at the level of the fleet. The findings, so far, suggest that the optimization of processes, as well as service timing, will require further development in many areas and at all levels of the firm in its customer cooperation.

Company impact

"One of the initiatives that was undertaken at ABB to enhance the efficiency of service delivery is called the "Drive Exchange service". This service offers fully functioning workshop-refurbished drives that can be stored on a customer's sites and that save the customer time and costs when replacing units or carrying out preventive maintenance. This service does not only affect service delivery from the supplier's perspective, but it also affects the customer's processes, such as procurement, supply chain management, and maintenance."

Timo Jatila, ABB

"To be able to serve our customers better and more efficiently, Raute has built a customer portal, where all of our fleet-based digital services will be centralized. It will be the main channel between us and customers, no matter what services they are using or what kind of service agreement we have with them."

Markus Halmetoja, Raute

Manually collected fleet data: balancing the possibilities, expectations, and resources

Katrine Mahlamäki/Aalto University

Background and objectives

Intelligent devices equipped with sensors provide large amounts of data. However, this data alone is not sufficient for providing services, nor for data-centric decision-making. The results of advanced data analytics rely on the quality of the data that is analyzed. If manually collected data is missing, it will affect the results. For example, sensors can usually give the exact downtime of a piece of equipment, but not the reason behind the downtime: redundancy, maintenance, waiting for spare parts, and so on. Manual data collection is error prone, however, and in order to motivate data collectors, the amount of manually collected data should be kept to a minimum. Therefore, end-user requirements for data are extremely important.

The objective was to find ways to motivate data collectors to provide good quality data. To achieve this, we started by studying the business needs that data users have for manually collected fleet data, supplementing sensor data. This was followed by an inquiry into the data collectors' point of view, with the intent to identify the factors affecting manual data collection and to develop a survey to measure them in industrial contexts.

Results

Table 2 shows that data users have several business needs for manually collected asset data in various functions within an industrial organization.

In order to guarantee good-quality data for the above business purposes, we identified the technological, organizational, and people factors that affect manual data acquisition. Figure 24 shows the links to data acquisition from business needs for technology, organization, and people, in the context of asset data quality. These factors are partly given, as, for example, the education level and native language are not something that management can change. However, several factors can be affected by management through training, organization of work, and development of data collection tools.

Table 2. **Business needs for manually collected asset data**

BUSINESS NEED	Description	Manually collected data
Business leads	Every maintenance technician is a company representative: talking to customers and working on their equipment reveals business needs. This is valuable information for sales.	Observations of equipment status, customer needs.
Maintenance services	Planning and operations require knowledge of equipment location. – Enterprise systems have a shipping address to OEM, but end-customers might be anywhere in the world. – GPS can give location information, but using GPS is not always possible. – Location information can be used to obtain details about the usage environment, such as weather conditions. – For large customers, maintenance services require detailed location information: in which part of the factory is the equipment located.	Equipment location (physical & functional).
Product and service development	Analysis of maintenance history is used in – developing the service offering – product development.	Field service information (spare parts, possible origin of damage).
Failure analysis	Failure analysis requires knowledge of the equipment's use context. – Functional location (what part of the customer's process does the equipment handle). – Technicians may also provide a possible origin of damage. – Environmental conditions can have an effect on equipment durability.	Functional location, possible origin of damage, environmental conditions (dust, dirt).
Advanced data analytics	Advanced data analytics require sensor and log data. Currently, transferring such data requires someone to download the data from the equipment and transfer it to a database. Only part of the installed base is accessible through remote control.	Log and parameter data.
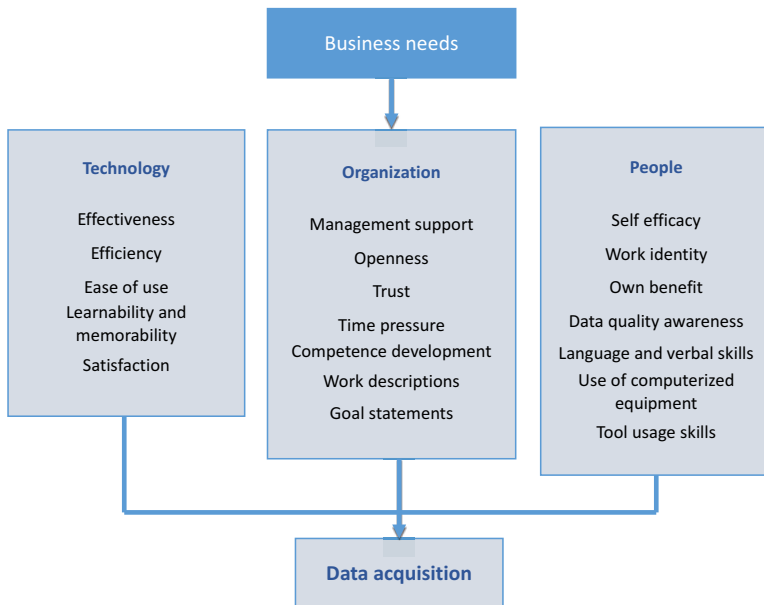
Figure 24. Linking technology, organization, and people to business-relevant data

Impact These results show the importance of manually collected data in several business cases. Furthermore, the results emphasize the need for manually collected fleet data to supplement automatically collected data. Our categorization of technological, organizational, and people factors affecting data acquisition helps managers to identify development needs and possibilities to improve the quality of manually collected fleet data. Having good-quality data available in decision-making can have a major impact both as an enabler of new services and in current service operations.

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System of systems modeling in an industrial process

Henri Vainio, Jussi Aaltonen, Kari Koskinen/Tampere University of Technology

Background and objectives

An industrial process, such as a production line or a quarry operation, can be seen as a heterogeneous fleet of machines. This domain also includes the supporting processes. Gathering data from a system of systems like this opens up possibilities to analyze and visualize process-level phenomena, as well as to gain information on how these phenomena affect individual machines. This research was done to discover and test methods of combining, analyzing, and visualizing such data.

Results

An industrial manufacturing process centered on the Fastems Flexible Manufacturing System was chosen as the target of this research. The scope of the modeling included the machines and the parts being manufactured, which were represented as work orders. Data from all of these was gathered using the internal sensors of the machines, as well as radio tags, which measure location and various physical phenomena and send data to a cloud server.

An agent-based model called a multi-agent system was chosen as the basic structure of this work. Multi-agent systems are a well-researched method of modeling and simulating system of systems-level phenomena. The manufacturing process was modeled by creating agents to represent each machine in the process, while the work orders were modeled as a different type of agent.

The data from the radio tags, as well as the machine status data from cloud servers, was accessed and combined in real time in the model. The agents then became aware of the current, historical, and planned statuses of their respective physical world counterparts. This enabled process-level key performance indicator calculations in real time, as well as the representation of individual agent statuses. Methods of using machine learning algorithms to analyze accumulated history data were also prepared as a future addition to the model.

A web-based, interactive, 3D visualization of the case factory was built to visualize the model. Real-time 3D graphics were implemented as a method of sharing intuitively understandable situational information and analytics results with any number of users. The data pipeline is shown in Figure 25.
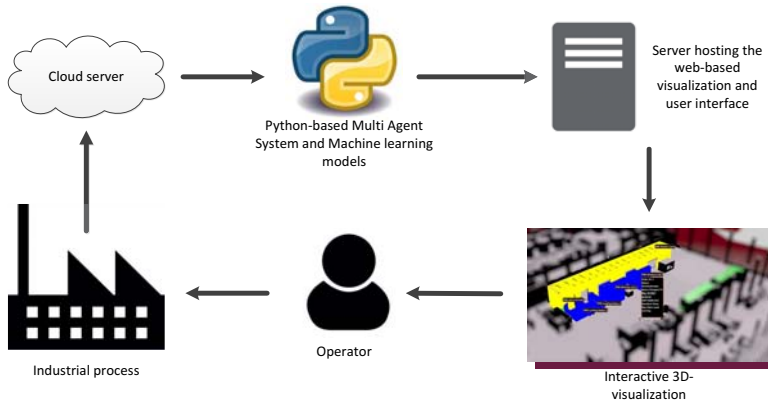
Figure 25. **The data-processing pipeline for the system of systems model and its visualization**

The use of radio tags enables the addition of industrial internet capabilities to all the required parts of the process, including legacy machines that do not have sensors or data-transfer capacity of their own. One-way data transfer also increases the safety of the system, as cyber-attacks, even if successful, are not able to access the control systems of the machines.

Impact Using modeling methodologies like multi-agent systems enables better understanding of an industrial process from historical, current, and future perspectives. Accumulating historical data on the level of a heterogeneous fleet enables process-level analytics that take into account the situation of the individual machines, the entire process, and the environment. Interactive 3D visualizations are an intuitive way of interpreting the situation, and the web-based approach makes it possible to share information with all the relevant parties, both within the company and outside it. The agent-based modeling, in combination with machine-learning algorithms, enables simulations of future events and the creation of suggestions and optimization plans for the process.

"The elements created in this research activity are not just interesting, they are also important. They enable true customer value and open totally new business possibilities."

Harri Nieminen, Head of Innovation Development & Research, Fastems Oy Ab

PREDICTIVE SERVICE OPERATIONS FOR A DYNAMIC FLEET

Customer orientation in fleet-level service delivery

The "customer orientation in fleet-level service delivery" theme covers the key processes and customer interplay in fleet-level service delivery. A central starting point is the identification of customer value and the creation of a mix of service offerings to match customers' needs. The results show that manufacturing firms need to be sensitive to the customer firms' readiness for services, in order to develop and deliver the right services for the right needs. They also need to prepare their resources and processes appropriately, to allocate the right people to the right service tasks, to be able to align real service needs with available resources at the level of the fleet. To accomplish positive performance effects from developing fleet-level service delivery, this chapter also covers the standardization of service processes and the possibilities to learn from customers' service experiences, to point out improvement possibilities on a global scale.

Value creation and steering the service mix in industrial service business

Jukka Simonen, Harri Nieminen/Fastems Group

Background and objectives Globalization and digitalization have caused intensifying competition and have forced industry companies to consider new solutions to generate revenue and cash flow. Several industrial companies have added services to their offerings, and servitization has blurred the boundaries between goods and industrial services. This transition has created a demand to understand customer value in industrial services, and to develop tools and principles to steer the service strategy and service mix. Manufacturers' transition toward being service providers should be implemented step by step, utilizing technology and knowledge acquired from existing service offerings. This research investigates sources of customer value in industrial service business. In addition, it provides industrial companies with advice on developing value propositions and methods of steering the service mix. This study produced knowledge about customer value in industrial services, and provides tools to shape and design value propositions. Steering the service strategy and service mix requires market intelligence and the exploitation of internal company capabilities to serve customers in the best way.

Results A manufacturing firm's transition to being a service provider requires understanding of the value components in industrial services. This study reveals that industrial companies emphasize service experience in evaluating service value, whereas economic benefits receive less attention. Five value components were identified in this study in industrial services. These components are: competence of service staff, personal contacts, responsiveness, transparent pricing and billing, and cultural factors (Figure 26).

There are value-creating and value-destroying elements inside these components. Companies should identify these to develop their current and emerging service concepts. This study reveals, for instance, that ambiguous billing and pricing confuses customers, obscures the value of services, and is therefore a value-destroying element. The most important value-creating elements in industrial services are the service company's high responsiveness and the competence of service personnel. The study emphasizes industrial companies' ability to respond to a customer's specific situation and solve problems quickly. The "chem-

istry," meaning the cognitive and behavioral alignment between service personnel and the customer's representative, can be either a value-creating or a value-destroying element, and it has a major role in the customer's perceived value of industrial services. In their value propositions, companies should emphasize responsiveness and communicate the benefits of services as clearly as possible.

Figure 26. Customer value components in industrial services

Impact This study provides tools for industrial companies to design the service concepts and steer development projects and the service mix. There were only minor differences in how customer value in industrial services is evaluated between companies from Finland and Central Europe. Constructing value propositions for industrial services requires communicating the monetary benefits of services to customers. One option could be to calculate the average monetary benefit achieved from industrial services, and to communicate this and implement it with customers.

Further information

Industrial customers' readiness to adopt new services

Eija Vaittinen, Miia Martinsuo/Tampere University of Technology

Background and objectives

Many manufacturing companies are complementing their goods-centric offering with services, to respond to increasing competitive pressures. Some companies are also adding advanced, value-adding services to their service mix, beside basic services. However, many of the new service introductions fail, and one of the most commonly mentioned reasons for this relates to the customers and changing customer relationships. Not all the new services get the necessary customer acceptance, even if the manufacturing firm is certain about the value of the services for the customer. The key questions in our study are: how do customers perceive a manufacturing firm's new services, and what is the level of customers' readiness to adopt new services.

Results

To promote the success of new services, companies need to consider the customer's point of view and how they will adopt the new services. Only when customers adopt the services are they willing to purchase them and create demand for the service. The customer's adoption of services in an industrial context can be complex, because different individuals as service buyers, decision-makers, and users may have different service expectations, and because of cultural features in the customer organization. When developing and launching new services, it is important to pay attention to the customer's readiness for services and to address the revealed customer concerns.

The results reveal that the customer's readiness to adopt new services is enhanced by their optimism toward the new services, their innovativeness, and their willingness to be part of developing something new. On the other hand, discomfort, a feeling of not being in control, and insecurity and skepticism about the ability of the new service to provide the promised benefits may hinder the customer's readiness to adopt services. In the industrial context, it is not enough to consider these individual characteristics, as organizational aspects also need to be taken into account. The customer company's habits may favor doing tasks themselves, and they may have a highly goods-centric organizational culture, which may complicate their adoption of services. Manufacturing firms need to consider how they can overcome these challenges when seeking to broaden their goods-based offering with new and more advanced services.
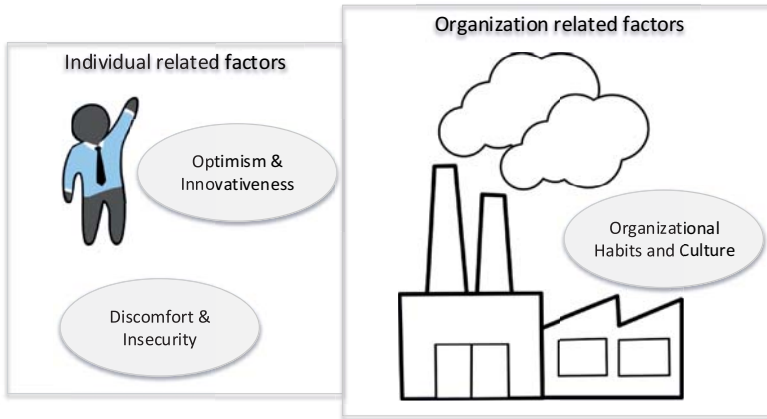
Figure 27. **Factors affecting an industrial customer's readiness to adopt new services**

Impact This study has charted customer perceptions about new services, identified challenges in service introduction, and proposed ways to deal with the challenges from the customer's point of view. Our findings offer new evidence of customers' service adoption, particularly in an industrial business-to-business context, as a contrast to the previous consumer-centric research. This kind of information offers manufacturing firms new means to understand customer needs and, additionally, their attitudes and uncertainties. Through this information, manufacturing firms can enhance their service development and consider in advance how they could promote the adoption of their future services.

Company impact

"A fact is that customers are mainly looking to find added value solutions that will improve their profitability rather than "nice-to-know data, but no added value." Larger companies usually have developed some solution of their own, whereas smaller and lower-scale technology companies today do not seem to yet understand added value, as this is still not so common in all industries. As much as cloud-based services in many industries are potentially growing, this is still seen as a challenge, for example, in the ply-wood industry. Companies might also have their own data security policies, and internal principles on how much they want to be dependent on equipment manufacturers, and on how much they want to share data. It is also easy to see a large variation in customer behavior if you look at this issue from a global perspective, as we do."

Markus Halmetoja, Raute

Managing resourcing in dynamic service delivery systems

Khadijeh Momeni, Miia Martinsuo/Tampere University of Technology

Background and objectives The dynamic contexts of service organizations create uncertain conditions and can influence various processes such as resource allocation. Resource allocation becomes more challenging in organizations that face rapid changes in their environment, activities, and priorities. In a service organization context, using the same resource pool to carry out different activities, such as repair and maintenance, proactive maintenance, service projects, and start-up and commissioning, creates challenges for resource allocation. The uncertainty in the service environment is high and service people need to react to changes fast. An organization in this type of environment needs to improve flexibility to react to changes by choosing between alternative actions. The key questions are, how do service staff experience uncertainty in the allocation of human resources, and how does a service unit manage resource allocation to overcome uncertainty.
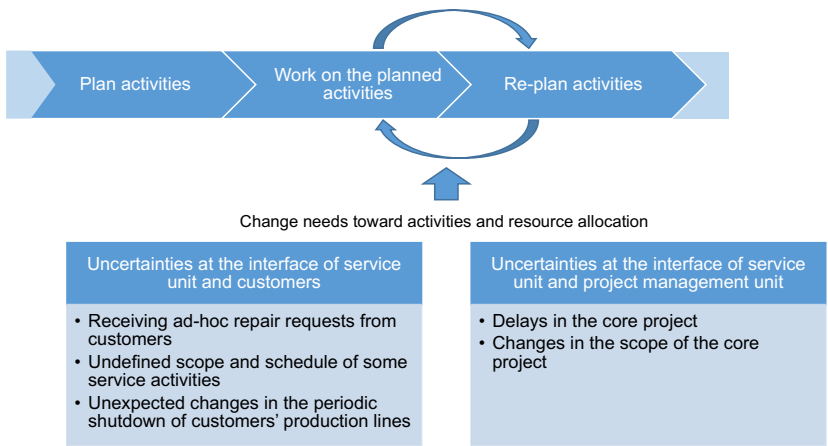
Figure 28. Issues faced by service units in resource allocation

Results Our findings direct attention to the challenges in delivering continuous and ad-hoc services beside planned and scheduled activities in service units. Besides resource availability, service staff face two main issues in the allocation of human resources: continuous prioritization of activities, and adapting to changes and delays in other organizational units' activ-

ities. These issues mainly result from uncertainties at the customer interface and at the interface with the firm's project management unit, as shown in Figure 28.

Balancing trust and control is an important dilemma in an uncertain environment. Our study emphasizes the role of individuals' experiences in coping with unexpected events. However, the study shows that, based on the level of uncertainty in the environment, service units might use different practices to allocate resources, as shown in Table 3.

Table 3. **Different types of resource allocation processes, with different types of practices**

	Hybrid resource allocation process	**Bottom-up resource allocation process**
Goal	Organized resource utilization; setting higher level priorities	Responding to the changes quickly and efficiently
Resource allocation process	Using resource planner as the intermediary role between service managers and service staff; negotiating with the managers and service staff to plan the workload and to solve issues.	Empowering the service staff to manage their activities in a customer-oriented and autonomous way; supporting by the managers in critical situations.
Authority to prioritise activities	The planner sets the priorities in cooperation with the service manager.	The service staff set the priorities of their own tasks. The service managers support them in critical situations.

The result of the study shows the importance of managing cross-functional links and discusses the effects on resource allocation of the information flow between different units. First, the results highlight how managing the interfaces and information flow with the project management team helps firms to manage uncertainties that result from organizational complexity (matrix structure) and project changes and deviation. Second, close cooperation with the sales unit is another important aspect to enhance resource allocation decisions. Receiving information about sales activities concerning both completed and ongoing deals can help service units to estimate their resource needs more precisely.

Impact The study focused on resource allocation issues in an uncertain environment. The challenge of resource allocation becomes more critical in service units with high uncertainty and dynamism. The service unit environment is highly dependent on resources, and resource allocation is a critical process to organize and manage the organization. Managing this environment requires a specific approach to respond quickly to changes and to share information to facilitate decision-making. Our findings show that the dynamics in customers' service needs may require continuous

re-prioritization in resource allocation between different activities, and adaptation to changes and delays, which in turn calls for cross-functional negotiation on the priorities. The result of the study shows that service units can improve their resource allocation by managing the continuous changes in the resource requirements of different activities. Moreover, exchanging information with other organizational units that affect or can be affected by the resourcing decisions of the service unit can improve the interaction between services and other organizational units, such as the sales unit and the project management unit.

Company impact

"Each company works in a specific environment, and different parameters, such as size of market, locations of customers, and types of customers, affect the choice of a suitable resource allocation approach. This means that a company cannot copy-paste a resource allocation model from other companies, but it needs to tailor it based on the company's situation and requirements. However, the use of information systems to share critical information that enhances decision-making is very important. ABB currently has some specific systems that help service staff to plan their activities, but we need to invest more in this area and provide the right information and suitable tools for our field service staff."

Timo Jatila, ABB

"We are delivering products all over the globe from different factories. Customers expect accurate and fast answers, but it is not realistic to assume that we have product specialists available 24/7 for each customer. The key to success is to have enough information available for field service/first point of contact in a usable format. Digitalization and product lifecycle data management have big role in this."

Julius Mäkelä, product manager, Portable solutions, Metso

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Standardization for fleet-level service delivery

Miia Martinsuo, Elina Poikonen/Tampere University of Technology

Background and objectives

Manufacturing firms need to develop efficient service deliveries that can be used for multiple customers with different equipment. Different service concepts and markets require different management and service design approaches. However, the efficiency of a service delivery system requires the system to be standardized at some level. The objective of this study was to increase understanding of features and requirements for standardization in the service delivery system, and to identify means for efficient service delivery. With S4Fleet companies, the settings of manufacturing firms were particularly interesting and complex: each piece of equipment is unique, the customers are multi-equipment and multi-service users, and various third parties may be involved, including dealers, external service providers, and software firms.

Results

Manufacturing firms that deliver industrial services to their installed base very typically use Enterprise Resource Planning systems to standardize and guide their service delivery processes. Their services can be divided into reactive (services that take place as a response to explicit customer needs) and proactive (services that the supplier can promote, by knowing customers' processes well and using, e.g., remote monitoring systems). The study revealed that these two types of services have quite different challenges (as shown in Table 4), and that standardization can be used differently for each of them. With reactive services, standardization of services and their processes is possible, but very often requires improved information flows from and to the customers. With proactive services, the companies already had very good experiences with standardization, but situation-specific uncertainties can create unique and unexpected challenges that need to be resolved case by case. In both cases, customer participation, even in standardized service processes, was highlighted.

Both core equipment technologies and remote technologies to monitor them are relevant in service delivery, and the development of technology-related services is currently ongoing in many S4Fleet companies. The different technologies embedded in the equipment create requirements for the service deliveries, in terms of allocating the right resources with the right competencies for maintenance tasks, and in terms of managing the service tasks for different generations of equipment with tech-

nologies that have evolved over time. Although remote monitoring and use data from the equipment may be helpful in providing information about the status of the equipment, the different information systems across different customers may also challenge the usefulness of the data.

Table 4. Challenges requiring standardization by manufacturing firms in different types of service deliveries

Challenges in reactive services	Challenges in proactive services
• Service delivery system variation case by case • Resource management • Increase in costs (often due to a lack of or deficient information) • Increase in delivery times (often due to a lack of or deficient information) • Defining the problem and its cause • Unexpected changes in service specifications	• Unique challenges, depending on the service, customer, context, and other factors • Customer participation in information collection • Unexpected changes in the customer's premises or the environment where the delivery takes place • Spare parts are not at the customer's premises at the right time, even if ordered on time

Figure 29 summarizes the framework developed for the factors to be considered in the service delivery system, when companies pursue increased efficiency in industrial service delivery.

Impact The study has mapped the parameters that companies need to consider when implementing a fleet-level service delivery system. Besides structural, infrastructural, and integration design choices, which have been pointed out already in earlier research, the findings draw attention to the service execution system and how it must be developed through standardization, customer engagement, and information and technology system support, to achieve efficiency. The results also emphasize that if external service and software providers are involved in the service processes, their role needs to be clearly specified in the standardized service delivery, to guarantee high-quality offerings.
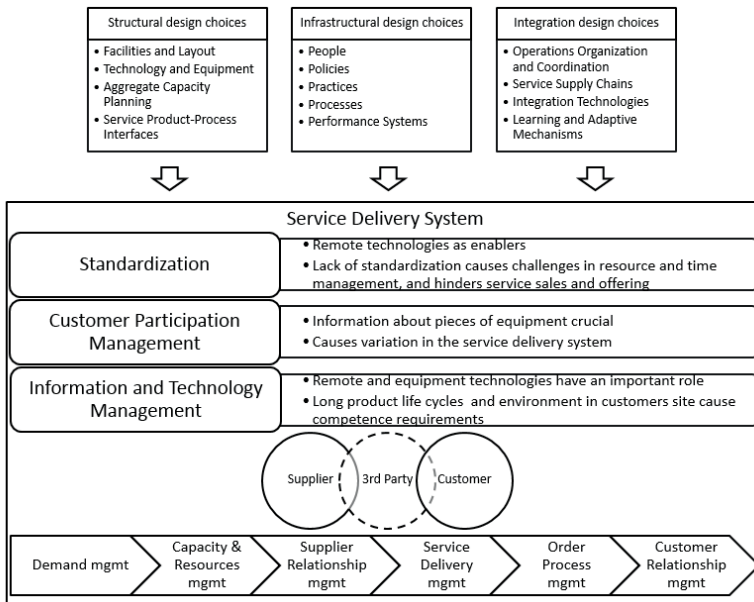
Figure 29. **Framework for service delivery systems for fleet-level industrial services**

Company impact

"During this project, we developed and introduced the Metso Metrics fleet management system. Through that system, Metso service and customers can follow their units in real time, can see possible alarms, and can start service actions faster than previously. The core of this system is an integrated service program. Through that, customers can see upcoming services proactively and can even order services. When agreed, Metso can take overall responsibility for plant maintenance, still relying on the same system."

Julius Mäkelä, product manager, Portable solutions, Metso

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Miia Martinsuo and Elina Poikonen, Tampere University of Technology

Human-to-human service experience in industrial services

Marja Liinasuo, Eija Kaasinen/VTT

Background and objectives

Globally enhanced competition sets requirements for companies to develop their services in an efficient way, without wasting investments and in accordance with true customer needs. Customers do not only assess services based on their price and utility, but it is increasingly important how they feel about the services and the company that provides the services. Focusing on customers' service experience will open possibilities to enhance business. When clarifying customers' experiences, expectations can also be perceived, answering the questions of what the customer finds valuable in the services and what the customer's beliefs and wishes are about possible future services.

Service experience is well covered in previous research, with a usual starting point being the experience related to the various customer-supplier touchpoints. In this study, the objective was to know more about the essence of the service experience, where its origins are, and what its qualities from a general perspective are. A specific practical goal was to deepen the knowledge that Fastems has about its customers, and to highlight the matters that customers find especially beneficial and the issues that should be focused on with more care.

Results

Understanding customers' service experience thoroughly has been proven to provide feedback both for the development of current services and for the creation of new services.

In-depth understanding of customers' service experience provides concrete information on the need to improve current services and the need to develop new services. Service experience also helps in understanding the various issues that affect the customer's experience of the service provider as a whole. Accordingly, the utilization possibilities of service experiences are versatile; this information supports the improvement of various aspects of current services, focusing on the specific points that customers find important, and supporting the development of new services, either by describing what the customer finds important or interesting, or by shedding light on what the customer expects from the supplier.

Regarding the essence of the service experience, this study shows that experiences of individual services form a net of experiences. The service experience does not only reflect the opinion of the service in question, but experiences of individual services affect each other and even the brand experience. Thus, the brand experience is affected by the serv-

ice experience and vice versa. Separate service experiences also affect each other: given a poorer experience related to one matter, a better experience related to some other matter may compensate for it. The service experience strongly affects the customer's intentions and decisions related to the supplier in question – their willingness to continue the partnership, willingness to buy more, willingness to invest in innovations, and so on. Furthermore, personal experiences can be strongly affected by other people. These so-called mediated experiences express how individual experiences can spread in a company and perhaps even beyond its boundaries, provided their content is easily sharable.
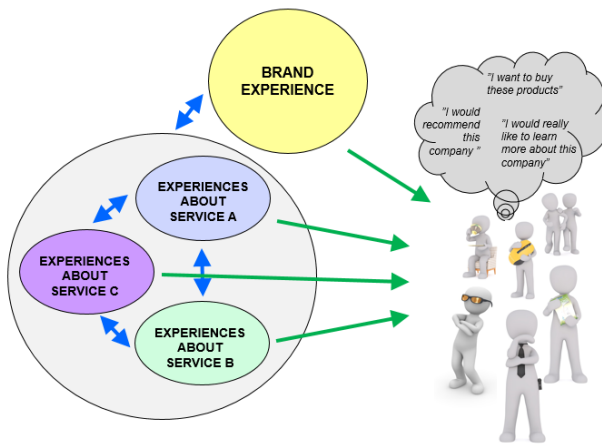
Figure 30. **Interrelations and effect of service experience**

The topics discussed in service-experience interviews covered both current and possible new services. During the interviews, the customers also raised such experiences that were not directly asked about, extending the topics to be covered in the interview. Thus, in an interview, the coverage of expressed experiences may become large. It may start from experiences related to the service touchpoints (the tendering phase, maintenance provided by the supplier, etc.) and reach any other topic important to the customer (such as the meaning of being a Finnish company, or the importance of specific personal qualities of a supplier representative in a certain role). With a good interviewer, it is possible to allow these outside-the-agenda comments to emerge without compromising the objective of the interview.

An interesting and important finding in the interviews is that, regarding new possibilities, customers do not know what they want, supposedly, unless it is defined for them within the customer company in question. None of the interviewees expressed clear wishes about services that are realizable when utilizing new solutions, such as the indus-

trial internet. It seems that if both parties, customer and supplier, are cautious, development halts, as both are waiting for the opening ideas from the other party.

Impact The methodology for studying the service experience must be well defined and of adequate quality when the objective is to clarify customers' service experience. Interviewing is practically the only means to elicit experiences; it is both difficult and time- and motivation-consuming to write down such experiences on one's own. If possible, the interviewer should represent a neutral party, as then the experiences are more likely to appear as they are, without the need to please the interviewee or complain about matters not found to be desirable.

When the service experience is taken into account when updating the service portfolio, clumsy or inadequate features in the service can be corrected to better fit customer values and expectations. In this way, frustrating elements in services can be corrected, the customer becomes more satisfied, and the brand experience is improved. Furthermore, services that have no or only little value for the customer can be removed. In this way, unnecessary costs can be avoided and resources can be allocated to investments that are more profitable. Finally, service experience-informed decisions guarantee that services that are important for customers are not removed, and are, if possible, enhanced in the direction that customers value.

Company impact

"With the study, our view of how customers envisage our service portfolio and Fastems as a brand became more evident. In addition, our knowledge about elements affecting service experience and novel value-creating service opportunities increased. By understanding more thoroughly the value-creating and value-destroying elements in our services, we can serve our customers better and shape our customer experience accordingly."

Jukka Simonen, Fastems, Service operations

PREDICTIVE SERVICE OPERATIONS FOR A DYNAMIC FLEET

Developing industrial service delivery for a complex fleet

The "developing industrial service delivery for a complex fleet" theme concentrates on the various ways to develop fleet-level service delivery. The research has observed changes needed in earning logic, as companies move toward data-enabled service delivery, and we present a rough roadmap on the key steps for changes. We then introduce an example of changes in the service delivery logic, when standardizing global service delivery. We delve into the delivery chain and show that retailers' readiness for services needs to be considered, to activate service sales through intermediaries. This section also covers the need to engage other partners, such as distributors, and develop their capabilities, to promote efficient service delivery at the level of the fleet. Finally, as a bridge toward the fleet-based data symbiosis project, we reveal clear challenges related to data management, as organizations' systems do not always offer the right kinds of data for the modern needs.

Roadmap toward new revenue logics in software-based services

Miia Martinsuo, Lauri Vuorinen/Tampere University of Technology

Background and objectives
When industrial firms develop new software-based services or change their previous service offerings, they need to consider the nature of the service and its revenue logic. Many firms are undergoing a change from product-oriented services to process-oriented and relationship-based services. At the same time, they need to determine which revenue logic they should follow. In particular, process-oriented services can enable new kinds of benefit-based revenue logics, but the transformation may be slow. The objective of this study was to identify the key steps through which industrial firms can move toward benefit-based revenue logics.

Results
We mapped the key goals and requirements when industrial firms move toward benefit-based revenue logics, through interviews with practitioners and two development workshops. Figure 31 summarizes the key steps through which firms are experimenting with and considering the move toward benefit-based revenue logics.
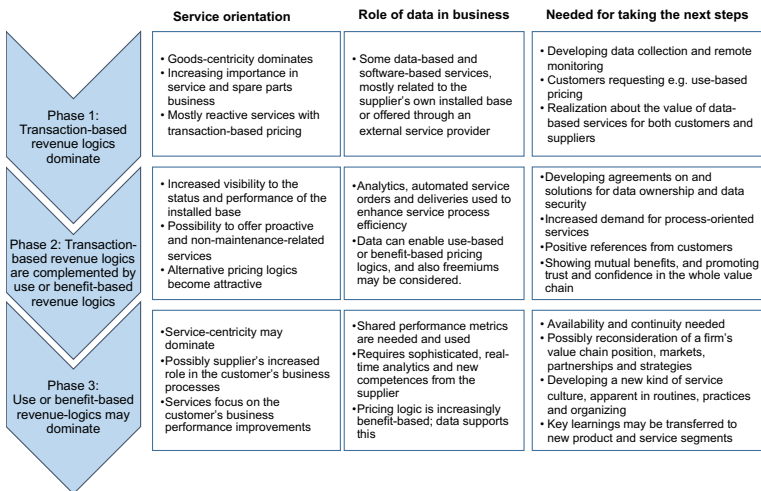
	Service orientation	Role of data in business	Needed for taking the next steps
Phase 1: Transaction-based revenue logics dominate	• Goods-centricity dominates • Increasing importance in service and spare parts business • Mostly reactive services with transaction-based pricing	• Some data-based and software-based services, mostly related to the supplier's own installed base or offered through an external service provider	• Developing data collection and remote monitoring • Customers requesting e.g. use-based pricing • Realization about the value of data-based services for both customers and suppliers
Phase 2: Transaction-based revenue logics are complemented by use or benefit-based revenue logics	• Increased visibility to the status and performance of the installed base • Possibility to offer proactive and non-maintenance-related services • Alternative pricing logics become attractive	• Analytics, automated service orders and deliveries used to enhance service process efficiency • Data can enable use-based or benefit-based pricing logics, and also freemiums may be considered.	• Developing agreements on and solutions for data ownership and data security • Increased demand for process-oriented services • Positive references from customers • Showing mutual benefits, and promoting trust and confidence in the whole value chain
Phase 3: Use or benefit-based revenue-logics may dominate	• Service-centricity may dominate • Possibly supplier's increased role in the customer's business processes • Services focus on the customer's business performance improvements	• Shared performance metrics are needed and used • Requires sophisticated, real-time analytics and new competences from the supplier • Pricing logic is increasingly benefit-based; data supports this	• Availability and continuity needed • Possibly reconsideration of a firm's value chain position, markets, partnerships and strategies • Developing a new kind of service culture, apparent in routines, practices and organizing • Key learnings may be transferred to new product and service segments

Figure 31. **Roadmap for moving from transaction-based to benefit-based revenue logics in software-based services**

Impact
A three-phase roadmap was proposed, to assist industrial firms in preparing their steps toward the new revenue logics of software-based services. A key finding was that companies cannot move to benefit-based revenue logics in their service business directly from transaction-based logics, but they first need to develop their remote monitoring systems,

data use capabilities, and customer relationships; get learning experiences of mutual value creation with selected customers; and build reliable, secure modes of operation. Different industrial firms, and even business units in the same firm, are in different phases of the roadmap toward new revenue logics in software-based services. Understanding the changes in revenue logics is central to industrial firms' transformation toward service business.

Company impact

"The service candidates with the most potential on the road toward new revenue logics have a considerable positive impact on our customer's manufacturing performance level. They do not just help our customers to save money, but to earn more money."

Harri Nieminen, Head of Innovation Development & Research, Fastems Oy Ab

"One of the big changes happening in data-enabled services deals with the business logic. I am quite sure that the orientation is toward more open business logics, seeking win-win solutions for the stakeholders involved. It will be beneficial for all parties. It is a really good direction that we are moving in, from "products" and "licenses" to "service" and "added-value"-based revenue sources, and the new analytics tools are enabling/supporting this development. We do not necessarily know what the future business logics are, but it is good to experiment with alternatives."

Timo Lehtinen, CEO, Ramentor

"Once you can prove the real value of your software-based services, there will be opportunities for new revenue logics, including among these so-called old-fashioned industries. Globally there can be a huge difference when this will happen and what the logics will be. I still believe that software-based services alone cannot make that change happen in the near future, but if you are able to combine different kinds of services, and with the help of software-based services you are able to show the total value, it will make this change possible."

Markus Halmetoja, Raute

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Using a standardized management framework for repetitive maintenance projects
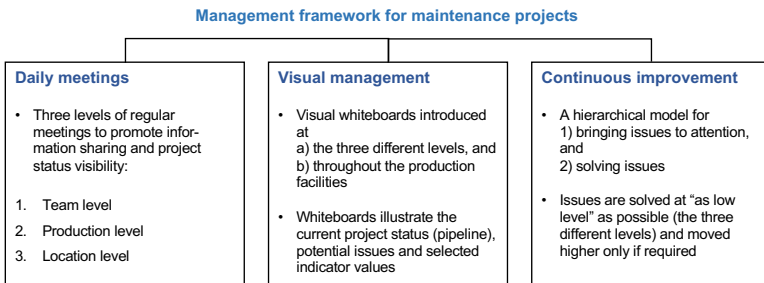
Lauri Vuorinen/Tampere University of Technology

Background and objectives

The distributed fleet of a manufacturing company consists of a diverse set of machines, delivered to customers possibly across the globe. The business relationship between the manufacturing company and the customer should not end with the machine delivery. Instead, service deliveries are one typical example of a continuous relationship between the manufacturing company and the customer, including after machine delivery. Maintenance projects are a typical group of services offered by engineering companies, and they are an excellent example of services that can be standardized.

A manufacturing company wanted to assist the manufacturing supervisors of its service centers by introducing a new management framework for standardizing its maintenance projects. The focus was on maintenance projects implemented by the manufacturing company's service centers around the globe. In the maintenance projects, parts of machines are inspected and repaired at the service centers. The parts can be from the manufacturing company itself, or from its competitors' machinery. The goal was to evaluate and collect lessons learned from using this new framework, and thereby to identify good practices in standardizing maintenance projects.

Results

Figure 32 illustrates the three core elements of the management framework for maintenance projects: regular daily meetings, visual management, and a continuous improvement model. The new management framework has two main goals: to standardize the management of maintenance projects, and to ensure and improve communication and information sharing. The results show how employees experienced the achievement of these goals.

Management framework for maintenance projects

Daily meetings	Visual management	Continuous improvement
• Three levels of regular meetings to promote information sharing and project status visibility:	• Visual whiteboards introduced at a) the three different levels, and b) throughout the production facilities	• A hierarchical model for 1) bringing issues to attention, and 2) solving issues
1. Team level	• Whiteboards illustrate the current project status (pipeline), potential issues and selected indicator values	• Issues are solved at "as low level" as possible (the three different levels) and moved higher only if required
2. Production level		
3. Location level		

Figure 32. Summary of the components of the framework to standardize maintenance projects

The new management framework was perceived to improve project visibility. Because of the lack of a nominated project team, most of the employees did not feel like they were working in a project-based business. Instead, the employees and the supervisors were more focused on individual jobs done on individual machines. With the daily meetings and the visual whiteboards, the employees and the supervisors felt that the customer-specific maintenance projects became more connected to their day-to-day responsibilities.

Another perceived benefit was improved vertical and horizontal communication. For vertical communication, the new management framework offers a hierarchy of meetings with different participants, promoting the communication of potential issues throughout the organization. For horizontal communication, the regular daily meetings bring together all the relevant parties and thus promote sharing of information.

Strongly connected to the daily meetings and communication, the new management framework was considered to improve issue management. This was linked especially to visual management with the whiteboards. The red markers on the whiteboards were considered to be clear signs for everyone that there was an issue to be handled. In particular, this information was now better available to everyone.
Lastly, the continuous improvement model was perceived as making the suggestion of improvement ideas motivating. By building a structure of decision-making, the employees felt that their ideas were really taken into account.

Impact In addition to delivery projects, many engineering companies manage their distributed fleet using maintenance projects. Especially if maintenance projects take place without a nominated project team, the "ordinary" employees and even supervisors might struggle to see the connection between maintenance projects and day-to-day responsibilities. A standardized management framework for improving the visibility of projects and promoting information-sharing can be beneficial.

"The new management concept has improved our operations. The improved communication and employees' better understanding of other working phases has improved collaboration and commitment to projects. In addition, management has a better overall view of the status of the project portfolio, which enables faster reaction to problems, as well. We have reached better delivery accuracy and we hope that the new concept will also improve employee satisfaction.

The next step is to build indicators and measurements at the location level. These indicators and measurements will enable the selection and implementation of strategic development projects. The new management concept can be considered a tactical tool, and the next improvements will be made at a strategic level."

Marko Volotinen, Director, ROL operations, Valmet,
Rolls Business Unit

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Retailers' readiness to adopt new services into their offering

Eija Vaittinen and Miia Martinsuo/Tampere University of Technology

Background and objectives

Many manufacturers distribute their offerings through a retailer network, especially in consumer markets. When equipment manufacturers broaden their solution-centric offering with services, to respond to increasing competitive pressures, reaching some of their customers can prove challenging if they use retailers in solution sales. Succeeding in service introduction requires convincing retailers, who will be responsible for promoting the service, of the attractiveness of the service. If retailers are not willing to adopt the new services into their offering for their customers, it is possible that some customers are never reached and that service sales will suffer. Therefore, it is important for manufacturers to consider the retailers' service adoption and address the retailers' concerns when developing and launching new services.

The objective of this study was to identify factors that are relevant to the retailers' readiness to adopt new services as part of their offering. The starting point was a question of why retailers would sell a manufacturer's services to their customers.

Results

The results reveal that retailers' willingness to include a manufacturer's services in their offering in addition to their technical systems and solutions depends on many factors. One of the most important aspects seems to be their perception of the quality and availability of the manufacturer's services. If retailers have heard about unsuccessful cases from their customers, they seem to be reserved about selling these services, because then these customers' service experiences would affect their image. Similarly, if retailers consider that there is not enough presence from the manufacturer even for their needs in technical system and solution sales, they might not be interested in selling their services. Additionally, the feasibility of the services is important: the service price, retailer's busyness, and how well selling the services would fit their normal work seem to affect their interest in selling the manufacturer's services. Therefore, it is crucial to ensure the proper organization of the service business and its functioning before seeking to work together with retailers in service sales. Figure 33 illustrates the position of retailers in the manufacturer's business, and factors found as important to their readiness to sell a manufacturer's services.

Should I sell this manufacturer's services?

| Retailer's perception of **quality and availability** of the manufacturer's services | Retailer's perception of the manufacturer's presence and their mutual **relationship** |

Feasibility: Prices of the services, retailer's busyness, compatibility of service sales with the retailer's current activities...

Manufacturer ◄— Handles the system deal —► Retailer — Sells own machines etc. and the manufacturer's system —► Customer

Sells services to their own customers and may not have contact to the retailer's customers

Could the retailer also sell the manufacturer's services?

Figure 33. Summary of relevant factors in retailers' readiness to sell services on behalf of the manufacturer

Impact This study investigated retailers' willingness to sell a manufacturer's services and the reasons behind this disposition. This information helps manufacturers to develop those aspects that may hinder the retailers' willingness to participate in service sales, and provides them with an understanding of their retailers' perceptions about the manufacturer's service offering. Through this additional information about their delivery chain, manufacturers can enhance their service performance. The findings provide means for manufacturers to enhance their retailer's willingness to adopt new services into their offering and, thereby, make it possible to reach a bigger share of the potential service market.

Company impact

"The origin of all value is customer value. When selling services through the retailer network, you have to be able to enable commensurate value not only for the end customer, but also for the retailer."

Harri Nieminen, Head of Innovation Development & Research, Fastems Oy Ab

Developing distributors' capabilities in the industrial solution and service business

Khadijeh Momeni, Miia Martinsuo/Tampere University of Technology

Background and objectives

Today, customer orientation is necessary in the industrial system and service business. Manufacturing firms may use distributors as intermediaries in their industrial marketing and delivery channels, and this may challenge the manufacturing firms' customer relationships in various ways. For instance, as industrial distributors become larger and more powerful, this may limit the power of the manufacturers over distributors. On the other hand, distributors may contribute to the customer relationship in very positive ways, for example by bringing in sales opportunities and offering knowledge of local markets. Building and maintaining a successful relationship with distributors is an important success factor for manufacturing firms in the competitive industrial markets. This study sought new knowledge of manufacturing firms' capability requirements for distributors, and the practices through which the distributor relationship can be developed.

Results

The results show that a manufacturing firm requires different capabilities from distributors, including business, relational, marketing, and delivery capabilities (Figure 34). As the required capabilities develop over time, the manufacturing firm needs to have distributors that are committed to developing and accepting central roles in sales and delivery in their specific markets.

The results reveal two ways to develop distributor capabilities: through systematic distributor performance improvement, and through delivery-related actions. Systematic distributor performance improvement refers to a proactive approach taken by the manufacturing firm to identify improvement areas in the distributor's capabilities and to develop them, including annual evaluation of the distributor's performance, a comprehensive training program, e-learning, seminars, and campaigns. Delivery-related development actions refer to a collaborative approach to support the distributor in delivering complex equipment, systems, and services. These actions can include joint negotiation with customers, help in preparing the proposal, and providing resources and training during the commissioning phase and after-sales services.

Impact

The study has identified several distributor capabilities, their importance to the manufacturing firm, and different ways to develop the capabilities. Our findings highlight the role of distributors as central stakeholders in the delivery chain, particularly in the industrial business-to-business

context. The study points out required actions to develop a distributor's capabilities, to enhance the success of manufacturing firms in local markets. Through these actions, the manufacturer can develop the distributor's capabilities to move them from being a wholesaler that could add some sales volume, to being a partner that can take an active role in delivering solutions to customers and providing added value for them.

Business capabilities	Relational capabilities	Marketing capabilities	Delivery capabilities
• Financial capabilities • Dedicated organization or people • Inventory management • Working with IT-based tools • Providing complementary products	• Sharing product development opportunities • Sharing market intelligence • Enthusiasm and aggressiveness • Commitment to development	• Market and industry knowledge • Customer relationship management • Sales capabilities • Geographic coverage	• Technical knowledge and skills related to products and processes • Service delivery • Customized solution/ systems delivery • Commissioning and start-up

Figure 34. **Summary of an equipment manufacturing firm's capability requirements for distributors**

Company impact

"Our distributors are not selling solely Metso products but other brands, too, such as Caterpillar. They do not have the time and knowledge to tailor service packages for each piece of equipment and customer. Instead, they have been focused on selling capital equipment. Now, we are able to package our services and offer through Metso Metrics, and make them easy to sell, just like capital equipment. This provides a huge opportunity for our and our distributors' growth. In this project, we also identified and calculated the growth potential."

Julius Mäkelä, product manager, Portable solutions, Metso

Data management and challenges related to fleet data

Matti Hyvärinen, Henri Vainio, Jussi Aaltonen, Kari Koskinen
/Tampere University of Technology

Background and objectives

Due to the development of sensor and memory technologies, in addition to growing interest in the industrial internet and its possibilities, industrial companies are highly interested in the development of novel data-driven fleet-wide services that utilize the data collected from the fleet of machines. However, when developing holistic service solutions for fleets of machines, there is a need to acquire a variety of data from the machines and their operating environments, including machine data, process data, maintenance data, and environmental data. Therefore, the amount of available data is often huge in such applications, which causes various data-related challenges and a need for efficient data management.

Based on collaboration with industrial companies and special interest group meetings, the research focused on identifying data-related challenges and barriers in a machine fleet environment. The goal was to identify the issues that cause challenges for efficient utilization of the available data in fleet applications, from the perspectives of data collection, data transmission, data management, and the quality of available data, in order to assist the development of novel fleet-wide data-driven service solutions.

Results

The research focused on identifying data-related issues in industrial fleet applications. The identified issues are divided into two groups, based on the phase in which the challenge occurs during the data acquisition and utilization process. The groups are data collection and transmission, and data management and data quality. Figure 35 summarizes the identified challenges.

The research shows that sensor installations, for example on moving components, and environmental issues such as heat, pressure, dirt, vibrations, and interference caused by other equipment, are sources of challenges when collecting data. The transmission of machine and component measurement data is often a huge challenge, especially if more detailed measurement data with a high sampling rate is needed. In some operating environments, the connection for data transmission might be poor or might not exist at all. This causes a need to store the data in local databases before data transmission, and to optimize the data flow so that only crucial information is transmitted. However, the data storage and processing capacity on the operating site is often quite low, since the installation of expensive data-processing equipment in such an environment is avoided.

Data collection and transmission	Data management and data quality
• Sensor measurement errors • Sensor installations • Environmental issues • Data transmission costs • Connection availability and quality • Data transmission security • Lack of non-site computational power	• Lack of metadata • Inconsistent data • Identification of useful information from the data • Data security and storing the data • User-defined data quality and missing entries • Lack of relevant data

Figure 35. **Data-related challenges in fleet applications, identified in collaboration with industrial companies**

In many fleet applications, there is a huge amount of available data, but it mostly consists of process and maintenance data, which includes machine operating hours, utilization rates, order information, and maintenance history and plans, which are acquired from the company's process control and enterprise resource planning systems. However, the companies have issues related to the acquisition and utilization of machine and environmental data, which includes machine information and measurements, weather forecasts, and weather history data, which are crucial for the development of holistic data-driven services. Therefore, regarding the vast amount of available data, some of the information relevant to providing comprehensive service solutions might still be missing.

The context of the data plays a crucial role when managing the data acquired from a fleet of machines. Therefore, one of the biggest challenges when dealing with the huge amount of data in fleet applications is the systematic and efficient use of the metadata, which includes the identification of the units and components from which the data is collected, information about the operating environment and location of each machine, and information about machine modifications. In particular, issues such as typos or missing data are common in manually added metadata. Furthermore, industrial companies find it difficult to find the crucial information from the data, due to the vast amount of available data. Especially when developing new service solutions, it is not always clear what part of the available data is useful.

The research indicates that data security issues are a great challenge when transmitting and managing the data in the industrial applications, because the customers are highly concerned about security issues related to data that is acquired from their machines. Therefore, the connection for data transmission should be highly secure, and once the data is transmitted, only the specified personnel should be able to access the data. The customers are often reluctant to allow their data to be

stored in cloud services provided by external service providers, and therefore, the companies that are acquiring and utilizing the data might have to invest in developing their own equipment for data storage.

Impact Our collaboration with industrial companies during the research indicates that, although companies are highly interested in industrial internet applications and the development of data-driven services, the availability of relevant data is still often a problem. The aim of this research was to identify common data-related issues when dealing with data collected from the fleet of machines, in order to enhance the development of novel data-driven fleet-wide services for industrial companies looking to broaden their service portfolios. Furthermore, the identification of data-related challenges assists in the design of the data acquisition process, since the companies are already familiar with the possible issues related to data acquisition and utilization in the fleet when designing the data acquisition and utilization process.

Company impact

"Metso has found it challenging that, while equipment provided by ourselves can be relatively easily equipped for data collection, the data does not contain all the information necessary for effective analysis. This is because the device is not a stand-alone installation but a part of a larger process. When analyzing the data, usually two missing things stand out, and the customer is not usually willing to share these, or they are not digitally available. The first is a diary of events (metadata) that on-site personnel have observed, and the second is production data, such as mass flow through the machine. Knowing the mass flow is very important for determining the operation of the machine, but it can be, at the same time, very sensitive information about production volume at a certain plant. This means that we cannot provide a good analysis result without customer cooperation and a confidential relationship."

Antti Jaatinen, Metso

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FLEET-BASED INDUSTRIAL DATA SYMBIOSIS 3

Motivation and achievements

Fleet-based industrial data symbiosis focused on producing innovative technological solutions that enable improved integration, harmonization, sharing, and standardization of fleet life-cycle data. A fleet was defined as a set of similar or nearly similar units, consisting of, for example, equipment and machinery, people, customers, or platforms. Fleet management was viewed as including the management of installed bases, that is, the globally supplied units of an equipment manufacturer. Technical and economic life-cycle data is usually fragmented in value ecosystems around the fleet, and its full potential is not often utilized. The key to novel service delivery is to process and upgrade the accumulated data into knowledge that can be used in decision-making and ecosystem-level cooperation. Two major outcomes were delivered: a data to business knowledge (D2BK) model was constructed to turn fleet-based life-cycle data into business intelligence, and an intelligent fleet management platform concept (FPC) for the future with the industrial internet was created. Models for intelligent maintenance and life-cycle solutions to optimize the fleet life-cycle and operations were presented. Figure 36 describes the research setting and ecosystem context of the fleet-based industrial data symbiosis research.

The results of the project improve companies' understanding of fleet life-cycle data, its standardization, its business potential, and the dynamics of the value ecosystems operating around fleets. When fleet life-cycle operations can be optimized, the impact is significant and includes improved efficiency, productivity, safety, and quality in a more cost-efficient way.

The D2BK model includes: a) various sources of fleet life-cycle data, b) short- and long-term decision-making situations in fleet management, c) extended service concepts as a source of customer value, and d) the value of shared information in the ecosystem. The model brings new insight into improving fleet management practices and designing new fleet-based services. The case companies developed specific tools, processes, and service concepts for their own businesses, including structured and automated processes for gathering fleet data, potential

customer needs and requirements related to data-based services, and demos and pilots of novel data-based services.
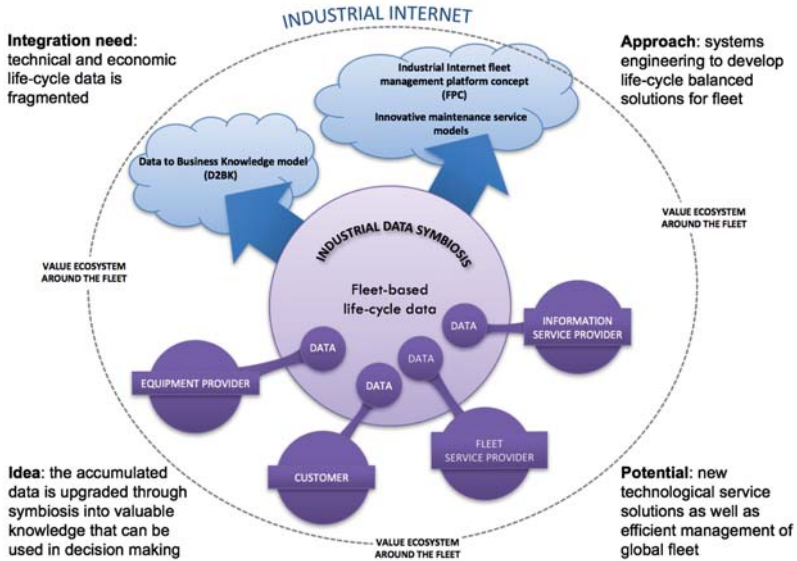
Figure 36. **Research setting for constructing new ecosystem solutions from fleet-based life-cycle data**

The FPC model a) includes a requirement specification for an internet of things (IoT)/industrial internet-based fleet-management platform for information representation, transmission, analysis, and exchange between information systems, automation systems, smart devices, and all related stakeholders; b) enables companies to build adaptive fleet management solutions for specific purposes upon shared architecture and information models; and c) supports the use of intelligent modules that enable service business analysis and fleet management optimization. The emergence of the industrial internet along with advances in sensor technology (remote monitoring) enables companies to collect operational fleet data from their equipment, in order to improve and optimize maintenance activities. Companies are able to implement advanced condition-based maintenance models as intelligent solutions. These results were utilized in more specific company cases, where the companies and research partners developed fleet management and maintenance-specific tools; solutions and concepts for their own businesses, including fleet connectivity, data collection, and online and offline analytics; and operational and maintenance optimization.

National and international collaboration was an inherent part of the project, including workshops and congresses, researcher exchanges, and joint publications. Researcher exchanges and joint publications have been realized with the University of Stavanger, the University of Sunderland, Linnaeus University, and Queensland University of Technology. The WCEAM 2015 (World Congress on Engineering Asset Management) and MPMM 2016 (Maintenance Performance Measurement and Management) conferences became the academic highlights of the project.

The essential next step is to implement the developed models and concepts in the case companies. In practice, this requires integrating the results into the existing business via, for example, the service offering, sales process, and service pricing. The companies would also need to develop their data analytics and business intelligence capabilities in order to be able to reap the benefits to the full extent.

FLEET-BASED INDUSTRIAL DATA SYMBIOSIS

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Data to Business Knowledge (D2BK) model

The aim of the "data to business knowledge" project was to examine how the fragmented data accumulated in the value network around the fleet can be upgraded into intelligence for decision-making. Accordingly, a D2BK model was constructed, based on the customers' needs and related information services when using fleet life-cycle data. The model addresses life-cycle management and utilization of fleet information, the relationship between fleet service solutions and asset management, and assessment of the value of shared information in the ecosystem. Requirements for providing fleet-related services across end-customers' business ecosystems were identified, focusing on extending service delivery into a long-term co-operative development of physical assets in close collaboration with the end-customer.

Data sources and decision-making needs

Company data used for decision-making usually comes from internal and external sources, residing in various systems and produced by machines, systems, or humans. 'Fleet data' may be quantitative or qualitative, financial and non-financial, continuous or discrete. In industrial plants, asset-related data is collected and stored in several information systems, including enterprise resource management (ERP) and computerized maintenance management systems (CMMS). The history data containing the information on the physical asset events, their upkeep and modifications, is crucially important for systematic maintenance planning and is a valuable contribution when making tactical or strategic-level decisions. There are also multitudes of technical systems that deliver continuous data. Examples are condition monitoring systems that gather

high-frequency data, for example about rotating equipment, drives, and automation systems that collect operational data. Machinery manufacturers providing services would also profit from the field data and from the data collected by end-users and operators. However, they seldom have access to the customer´s information systems, or the data is in such a format that it is difficult to use.

In addition, one of the more recent sources of data is open data sources, such as governmental and environmental data that is released for public use. Open data sets can be used to enhance the decision-making process by using non-critical open data from sources that indirectly affect actions, such as weather data in any outdoors operations. In the scope of a fleet, the weather conditions and other related open data can be used to detect anomalies and patterns that would not usually be considered. Especially in the case of openness, the combination and the use of data does not require substantial investments, and is usually easily accessible through services. This would make it a substantial resource for data analysis. Open fleet data could be analyzed, for example, from multiple manufacturers simultaneously, enhancing the user experience and the reliability of products and services.

Different decision-making situations require different kinds of data and analysis to support decision-making. Decision-making situations can be divided into two main categories: short-term and long-term decisions. Short-term decisions are operational and daily decisions on maintenance or other actions. Long-term decisions are more strategic and tactical, like investment and modernization decisions, changes in maintenance strategies, and decisions on service providers. Short-term decisions can typically be supported by measurements made on the machine or system in question, without considering, for example, the business environment. Long-term decisions require more versatile data about history, and also predictions and future scenarios, because the success of the decisions is typically dependent on the course of the future outside the company, such as the price of raw material or the demand for products. It should be in the interest of companies to develop decision-making processes so that long-term decisions utilize more systematic data collection and analysis methods.

The data to business knowledge (D2BK) model illustrates how the service provider could add value by refining the data. Translating data into insights and wise decisions is the key to effective analytic capabilities. Figure 37 below describes the phases in the process of turning fleet data into business knowledge, as well as the various levels of data-based services.
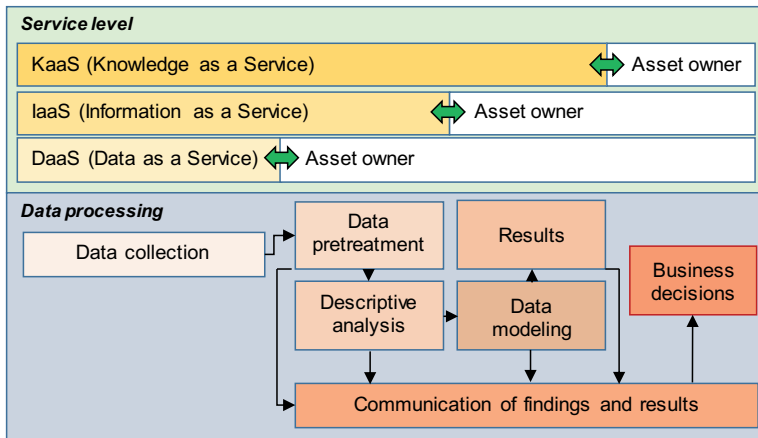
Figure 37. Schematic presentation of the data to business knowledge (D2BK) model

The aim of the data analysis is to support different decision-making at all levels of an organization. **The results** of data modeling should help organizations in predicting future behavior and following the performance of their assets, and in estimating the remaining useful life (RUL). A further step to add value is to connect the data with business-related information like business models, the key performance indicator (KPI) framework, the life-cycle cost and profit (LCC, LCP) model, or a specific decision-making situation. The history data alone is not a sufficient basis for **business decisions** that require a deep understanding of the business environment. The collected history data can be enriched by tacit knowledge, expert judgement, and other data sources that help to develop future forecasts. **Communicating the findings and results** is not self-evident. The main objective of visualizations is to condense a large amount of data in a form that supports decision-makers' or other users' attempts to understand the information included in the data.

The D2BK model starts with data collection and reiterates the importance of data pre-treatment and the critical assessment of data quality. However, the core is in the data analysis and modeling. Descriptive data analysis provides summaries of collected data through basic measures (mean, median, variance), in data, tables (frequencies, cross tabulations), or figures (bar charts, box-plots, spider/radar charts). Data modeling requires different capabilities, concepts, methods and methodologies, algorithms, models, and tools, depending on the scope of the analysis. Various data analysis methods exist, and they are dependent on the specific problem and the available data.

In addition to basic steps for making data-based decisions, the D2BK model (Figure 37) suggests four service levels that describe the increasing importance of tacit knowledge in the service proposition. The data, information, knowledge, and wisdom (DIKW) hierarchy is widely accepted as a basic model describing levels of understanding of issues under consideration. Service providers can support asset owners with different services based on their experience, knowledge, and analytics capabilities. These data-based services could be classified as service levels, according to the DIKW model, in the following way:

- **DaaS** (Data as a Service) is the basic level in which the customer (asset owner) is provided with an opportunity to gather asset data by means of a specific technology. As a service, DaaS is mainly a technical issue, but the service provider should have an understanding of which data items are relevant to the customer.

- **IaaS** (Information as a Service) requires that the data is refined to some extent by the service provider. The service provider can implement the service level either by providing the customer with basic analytical tools or by delivering ready-made reports for the customers. As a service, IaaS consists of data refined into a format that is easy to understand and use in daily business.

- **KaaS** (Knowledge as a Service) requires that the service provider collects and analyses information, exploiting its own capabilities and experiences, but also those of the asset owner. The service is integrated deeply into the customer's core business and decision-making, in both the short and long term. At this level, the service provider is able to interpret and refine information into knowledge that is useful in the customer's decision-making situations. A fleet service provider can make deeper interpretations based on broader understanding from different sites in different operating environments.

- **WaaS** (Wisdom as a Service) is not a service level in the same way as the previous three levels. Wisdom is the ability to apply accumulated knowledge to new situations and environments, and to deal with future needs. WaaS is more dependent on the providers' ability to develop the physical products and services needed in the future and to provide a competitive edge for their customers. This requires deep understanding of the customer's business, based on information and knowledge gathered from customers and other business data sources.

Asset owners typically gather data from the assets, as well as maintenance actions and operational parameters, and use this data for decision-making and planning. However, the trend toward networked collabora-
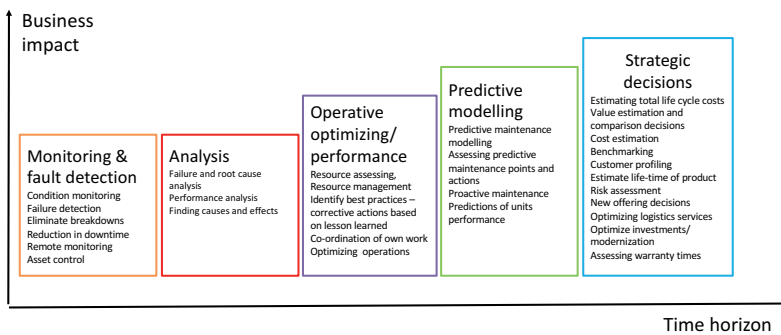
tion models is giving rise to new business ecosystems. A business ecosystem can be seen as a business community of various organizations and individuals, operating and interacting for collaborative value creation. The emergence of ecosystems calls for a new way of thinking, as well as shared tools, technology, models, and trust between the ecosystem members. Accordingly, new technological solutions and services can be identified based on information-based collaboration by equipment providers with asset owners and other partners, such as various information, fleet service, and material management providers in the ecosystem. The role of information service providers is to integrate, harmonize, and upgrade data into valuable information, while fleet services include various maintenance, logistics, or asset management services needed in the ecosystem to support continuous and uninterrupted operations. Equipment manufacturers and service providers can support asset owners with different services, based on their experience and knowledge about their own products.

Knowledge intensive service concepts for fleet asset management

The state-of-the-art in value-based asset and fleet management services reveals a variety of **knowledge intensive service concepts** and offerings that address different service levels from DaaS to KaaS. Some of the concepts may also enable the delivery of WaaS. As an example, the following services were recorded:

- Data for analysis and possible identification of optimal recommendations, prioritizing tradeoffs between different mandate attainment strategies and optimizing vehicle acquisition
- Data for analysis and possibly identification of optimal recommendations
- Collecting and storing data and possibly analyzing it to identify the current and predicted state of the assets
- Condition assessment to extend the life-cycle and avoid asset failures
- Fleet-wide prognostics and health management as an expert-based service
- Decision support for maintenance policy decisions through a control chart monitoring failure processes
- Benchmarking the parameters, analyzing the results, and providing expert advice and predictions
- Providing benchmark databases and possibly suggesting improvements

The utilization of fleet life-cycle data enables numerous possibilities to upgrade data into business knowledge in order to support decision-making in companies. **Extended asset services** refer to extending the service delivery toward long-term cooperative development of physical assets over the whole life-cycle, in close collaboration with the end-customer and other stakeholders. Thus, extended asset services should include KaaS or WaaS features and capabilities, and a mandate to implement actions improving the customer's efficiency with high business impact over a wide time horizon. The S4Fleet Project 3 case companies identified data-based service possibilities, which are presented in Figure 38. With an increasing ability to transform the data into knowledge, the service provider may take more responsibility for analyzing the data, making knowledge-based decisions, and planning for the customer (asset owner).

Business impact

Strategic decisions
Estimating total life cycle costs
Value estimation and comparison decisions
Cost estimation
Benchmarking
Customer profiling
Estimate life-time of product
Risk assessment
New offering decisions
Optimizing logistics services
Optimize investments/ modernization
Assessing warranty times

Predictive modelling
Predictive maintenance modelling
Assessing predictive maintenance points and actions
Proactive maintenance
Predictions of units performance

Operative optimizing/ performance
Resource assessing, Resource management
Identify best practices – corrective actions based on lesson learned
Co-ordination of own work
Optimizing operations

Monitoring & fault detection
Condition monitoring
Failure detection
Eliminate breakdowns
Reduction in downtime
Remote monitoring
Asset control

Analysis
Failure and root cause analysis
Performance analysis
Finding causes and effects

Time horizon

Figure 38. **Examples of fleet life-cycle data applications identified by the case companies**

Fleet services are also provided by companies and organizations that are not traditional manufacturing companies, service providers, or asset owners. The key issue is access to the data. The emerging **platform thinking** is also reflected in services like 365FarmNet (www.365farmnet.com/en/), the integrated eOperations approach of the Norwegian oil and gas industry and SSAB SmartSteel. All of these services incorporate a wider ecosystem for co-creation of the services. These kinds of ecosystem-based services could be applied in a wide variety of fields and form the basis for completely new fleet-based services.

365FarmNet is a free field-mapping service for managing the entire agricultural business, from manufacturers to every branch of the industry. The platform offers all the information from cultivation planning to harvest, from field to stable, from documentation to operating analysis. The users can access the software for free, but extra modules are avail-

able for a charge. In all, 27 agricultural partners from machine manufacturers, plant protection and manure product producers, breeders, and feed suppliers to equipment manufacturers for livestock farming, support 365FarmNet with their know-how and by making further intelligent components available.

The Norwegian oil and gas industry has implemented an integrated eOperations approach, in which the onshore support activities are connected to the offshore operations both internally and across organizational boundaries. The system is called Secure Oil Information Link, and it is a secure information network operating based on IoT, seabed-laid fiber-optic cables, radio and satellite communications, and a variety of applications and databases. The unified integrated eOperations approach has already created tangible benefits for the whole ecosystem, and for individual companies operating in it. In addition, the possibilities for novel ecosystem-level service concepts are vast.

An example of an information platform is the recent development of SSAB SmartSteel, a digital platform that enables steel to be loaded with knowledge. A unique identity code in the steel plate, connecting the plate and information, provides customers and their machinery with appropriate data and instructions to help them to select and use SSAB steels, regardless of their application. The idea is to share expert knowledge in steel with customers, and SSAB is now inviting more customers, process equipment manufacturers, and other actors to further explore the possibilities of the SmartSteel platform.

Results in case companies

Here, the relevant results in the case companies are presented from the perspective of the D2BK model. To support the perspectives of various data sources, decision-making needs, and knowledge-intensive service concepts, as addressed above, ecosystem and business views of fleet data are discussed. The case companies are analyzed from the perspectives of potential fleet service concepts, their role in the ecosystem, and the specific features related to the costs and benefits of providing the services. Table 5 gives an overview of the case companies and their connections to the D2BK model.

It can be seen from the table that, although various service time horizons and data-refining levels are well represented, joint ecosystem-level databases or shared platforms are still scarce. In practice, the companies design new services based on whatever data they have inside their own organization. For most equipment providers, this means that the service offering focuses on the installed base, while the offerings of many IT service providers are more generic, related to business analytics and in-

creasing intelligence in decision-making. Thus, understanding the roles of different organizations in the ecosystem is a necessary step in creating new services, let alone understanding the value creation dynamics or sharing the benefits and costs.

Costs are incurred during each phase from data collection to decision-making. However, some of the organizations have smaller roles in the process while others might have a lead role in several phases. In addition to observing the costs and benefits at the level of individual organizations, it is thus necessary to assess the total costs and benefits at the level of the whole ecosystem. To sustain competitiveness in the long term, it is vital to be able to create value for the ecosystem as an entity, but also for each individual organization. None of the companies should be in an indefensible position while others are harvesting all the value. This is emphasized in the benefits created by the services, as they can profit the service providers themselves, but first and foremost the service customers. Balancing the incurred costs with the achieved benefits through feasible pricing logics will be of critical importance in the future.

Table 5. **Case companies and the connections to the D2BK model**

Com-pany	Potential services	Service level	Primary role and focus in the eco-system	Notions on the benefits and costs
Analytics Cloud	Technical means for collecting IoT data	DaaS	Business intelligence and analytics services, data management and architecture, data integration	Costs from data management, integration, development of the service concept. Benefits for the customer: efficiency, productivity, reduced downtime and costs.
Etteplan	Service manager view of integrated fleet-level information	DaaS	Data linkage and integrity, task propositions	More service-process automation, higher price, higher quality, more benefits. Competitive advantages, speed and effectiveness in service processes, life-cycle management, added value, savings and quality as benefits for the customer.
HUB logistics	Logistics services and material stream analyses, analyzing processes	IaaS / KaaS	Fleet-level decision making, data collection processes	Costs of developing best practices at a test site, implementing and applying best practices to other sites. Benefits include efficient resource utilization and better quality.

Company	Potential services	Service level	Primary role and focus in the ecosystem	Notions on the benefits and costs
IBM	Analytics and platform for predictive asset fleet optimization	DaaS	Internet of things, business intelligence, analytics, cognitive analytics	Benefits for the product supplier: improved product development, maintenance, new service models, selling data to third parties, improved customer satisfaction, overview of the whole life-cycle. Benefits for the asset owner: improved maintenance, reduced costs, developed decision process
Metso Minerals	Predicting equipment failures, performance, maintenance and best practices for mobile units	IaaS / KaaS / WaaS	Services to support fleet decision-making, fleet services for asset owners, view of the state of the fleet	Benefits for all areas of business, including supply chain management, maintenance, process control, sales, and customer support. Costs include service development.
M-Files	Collaborative platforms combining data from different sources	Daas	Developing repository agnostics information management, improving data availability	Benefits for the customer: better data accessibility, data quality, coherence and reliability. Costs include platform development costs.
Outotec	Optimizing operations and maintenance, estimating total life-cycle costs	KaaS	Data preprocessing, data classification, statistical analysis, correlation analysis, decision support	Benefits: reduced production losses, reduced failure risks. Benchmarking tool to support and optimize operations and maintenance activities.
Ramentor	Improving overall equipment efficiency, managing RAMS requirements	IaaS / KaaS	Predictive analytics, preventive maintenance. Data linkage, preprocessing, integrity check, and analysis	Risk assessments, reliability and availability. Cost scenarios for warranty and service contracts based on failures. Benefits for contract period length-setting and pricing. Aim of profitability and customer satisfaction.
Valmet	Guaranteeing failure-free run based on equipment data	IaaS / KaaS	Supporting decision-making, preventive maintenance, and planning with probabilities and real-time data.	Benefits: reliability analysis and identifying the most critical faults help to plan and analyze maintenance. Savings in maintenance costs.
Wapice	Predictability information of fleet (e.g. KPIs)	DaaS / IaaS / KaaS	Platform/infrastructure for fleet-level business decision-making. Alarms, reports, dashboards, analytics	Benefits for the customer: real-time operational insights, improved employee productivity, resource management, reduced ooperating costs, better asset utilization, reduced maintenance costs, better services.

Implementation pathways

The D2BK model helps companies to improve their fleet management practices and enables them to provide new services for their customers, so that various stakeholders can benefit from fleet-wide data and analysis. However, in practice, the tools and service concepts developed in the case companies need to be implemented, utilized, and developed further in order to achieve the expected benefits. Table 6 below describes some examples of the typical company results created in the project, and addresses some of the potential next steps in implementing them. The implementation pathways are based on the insights of some of the case companies, and are supported by the academic findings of the participating researchers.

Table 6. **Potential directions for the implementation of the project results**

Examples of project results	Next steps to implement the results in the ecosystem
• **Structured processes** to gather fleet data, automated solutions to achieve a **real-time view** of the status of the fleet • **Demos and pilots** on new data-based products and services • Insights on **potential value sources** from the perspective of the customer	• Integrating the developed tools to e.g. the **sales process** to gather more customer data, as well as finding similar ways to **reach the data** residing in the rest of the ecosystem • Developing the **existing product and service portfolio** from the perspective of the new demos and process models • Learning to **analyze and exploit the fleet data** in a way that produces additional value and best practices for the customer • Designing **feasible pricing logics** for the new data-based services

Although the markets for new IoT and industrial internet-related applications have been assessed to be vast, it is very difficult to give a specific monetary estimate of the fleet service solutions—a market that would be relevant to this project and to the service concepts developed by the case companies. However, the globally identified major drivers for future trends and business are congruent with the themes addressed in the project, including efficient use of real-time data and predictive decisions based on historical patterns. This supports the project consortium's notion of the significant business value of the developed concepts, models, and processes.

Next, some more concrete examples of the results created in the case companies are presented. The selected examples include Outotec's

benchmarking method to produce knowledge about suitable asset management for various operational sites, IBM's cloud services for sharing information in the ecosystem, and Hub logistics' automated service efficiency analysis and reporting. These are presented briefly in the sections below.

Benchmarking for matching the offering to customer challenges

Outotec's benchmarking method compares different customer sites based on their operating contexts. For example, the installed base and operating conditions vary from site to site, making it difficult to compare data and construct optimal asset management policies for each site. The aim is to use a systematic assessment framework to provide customers with the highest value services, and to be able to concretize and visualize the customer value. The benchmarking method enables categorizing customer sites in comparable units.

The project's basic assumption is the notion that Outotec's customer base is a large and heterogeneous group of mining companies, metals and chemicals producers, and energy providers. The challenge is that customer sites are not comparable to each other, and thus it can be difficult to make a conclusion about what levels of maintenance are better than average or worse than average, or whether certain productivity levels can be achieved within certain maintenance environments.

Outotec Service Business Development is a function that has been actively looking for new ways of providing value to the customer. By developing the benchmarking concept in cooperation with different departments within the company, as well as with certain customer sites, the development team has been able to structure the data-gathering process. Moreover, it is able to better utilize installed base knowledge, as well as to understand the potential value sources for the customer, on a very concrete level. The benchmarking tool can be used as a sales tool for the services business for an entire site or for sub-processes or process islands. It enables a value-based sales process and, more specifically, the matching of Outotec's service offering against the customer's actual needs, as defined in a detailed site assessment. Furthermore, it enables a transparent sales process, which can be defined in close cooperation with the customer. Finally, Outotec will be able to use the tool and its results in internal product development, seeing the key challenges faced by the customers. Addressing the service product portfolio accordingly will give Outotec insight into what types of services the customers most demand.

Sharing data in a company network

IBM's service concept would offer solutions for sharing the information traditionally available inside just one company to the supplier network in the industrial ecosystem. The cloud service concept especially addresses the challenges created by a lack of trust and benefit-sharing between organizations. The concept includes three main stakeholders: a component or system supplier, plants using the components in their production, and a cloud service provider. The cloud service can be led by a customer plant when the suppliers collect data from several clouds. On the other hand, a supplier can also lead when plants need to join several clouds. The cloud service provider would have no business interest in the content of the data, but would focus on making the data secure.

The data-sharing concept developed in the S4Fleet project offers a starting point for a functional demo that IBM is now planning. The focus is now on connecting current products and services to the concept. Such items include IBM Maximo, IBM Watson, and BlueMix, and new components such as block chain. The IBM service development unit is constantly looking for new concepts for demonstration, and the data-sharing concept would offer them a wider business framework beyond sensor data collection and visualization. The functional IBM demo will be based on the data-sharing concept, and it will include some existing solution components and visualization tools.

Manufacturing industries is one of the main customer sectors for IBM. Manufacturing industry companies are also a main target group for IoT solutions. Data sharing opens a new, solutions-oriented view that complements or even replaces the current product-centric view. A broader scope is necessary, as many manufacturing sector companies do not have a clear IoT strategy. In the future, the data-sharing concept could offer a tool to present IBM solutions to industrial sector customers. The functional demo is a necessary starting point that will support sales, especially in Nordic countries. Further spreading is possible if the concept finds acceptance in Nordic industrial companies operating globally, and leads to commercial results.

Automated logistics service analysis and reporting

HUB logistics developed a solution for transferring from manual data collection to modern automated collection of fleet data from highly automated processes, machines, and operations. Data availability has been a challenge because data has usually been in the IT systems owned

by customers. To improve the efficiency and safety of their customers' outsourced logistics operations, the data from operations needs to be continuously analyzed, and operations need to be re-developed regularly. The aim of the operator and its customer companies is to get online data from operations. This online data enables the management of daily processes and fast and timely reaction by taking corrective actions when needed.

Integrating the data collection of automated processes with data collection from operations done by humans in in-house logistics processes is the basis for improving service analysis and fulfilling the given customer promises. With increased accuracy of in-house work process data, automated data collection helps HUB logistics in verifying the actual realization of gains, compared to the implemented improvement efforts. In fact, it works in quite the same way as fleet management works for a machinery fleet, but in this case the machine is replaced by work steps in in-house logistics operations. Understanding the impact of different work phases on the whole process enables an operator to find inefficient work phases. After that, better work conditions (e.g. tool and item relocation, machinery to support work steps) can be implemented.

The purpose has been to enhance the data-collection practices to support in-house logistics process development and the determination of KPIs, which can further support service analysis and development. One customer site can work as a feasibility test site for new ideas, and with good results, the ideas can be tied to actual KPIs. This enables the benchmarking of customer sites and the identification of best practices. HUB logistics is now focusing on developing new KPIs and reporting to support decision-making at fleet level.

FLEET-BASED INDUSTRIAL DATA SYMBIOSIS

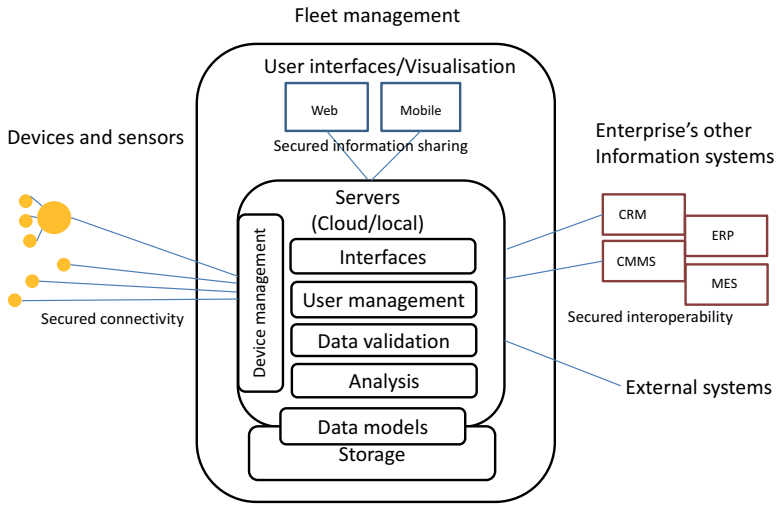## Fleet Management Platform Concept (FPC)

The main aim of our research was to generate an intelligent platform concept to take the initiative in adopting the changes in ICT required by the emergence of the industrial internet. A new fleet service platform concept requirement specification for information representation, transmission, analysis, and exchange between information systems, automation systems, smart devices, and all related stakeholders was specified. The fleet service platform concept enables companies to build adaptive fleet management solutions for specific purposes upon a shared architecture and information models. Furthermore, it supports the use of intelligent modules that enable service business analysis and fleet management optimization. These results were utilized in more specific company cases.

Another aim was to create intelligent maintenance solutions to better optimize the fleet life-cycle. Models and methods were developed for the optimization of customer-specific maintenance service programs, to achieve the required availability and safety with minimum costs in fleet-service business. A suitable platform to support the maintenance of scattered product fleets, in order to enable a condition-based maintenance (CBM) service business scenario, was defined.

The following subchapters present an overview of the specified Fleet Management Platform Concept and some examples of the company case results relating to it.

Requirements for the new Fleet Management Platform Concept

Jere Backman, Heli Helaakoski, Janne Väre, Seppo Rantala, Pasi Ahonen/VTT

Background and objective

Global service business has become increasingly competitive, and in order to stay in the leading position in this area, companies have to face the latest challenges and opportunities related to the growing importance of data-driven services in GDP (gross domestic product). One successful survival strategies for the manufacturing sector seems to be related to better exploitation of the installed base, or in other words, the global product fleet. This signifies that companies need cutting-edge exploration and innovation in service and fleet management solutions. The solutions require a platform on which these solutions can be implemented.

The main aim was to generate an intelligent platform concept to take the initiative in adopting the changes in ICT required by the emergence of the industrial internet. A new fleet service platform concept for information representation, transmission, analysis, and exchange between information systems, automation systems, smart devices, and all related stakeholders, was defined.

Results

The requirement specification was defined for fleet management systems (FMS) set by companies. Figure 39 presents the concept at a high level. The specification defines a technical framework for the fleet management solution (Fleet Management Platform Concept - FPC) and the functions that FMS should support. Above this, the specification also includes case-study definitions by each participating company. Some of these company case results are presented in the following subchapters.

Impact

The specification/concept is available as the basis for companies' new fleet management solutions. The project created solutions around the concept, which was about to fundamentally reform fleet management and information-based services. The requirements have been used as a framework for selecting suitable FMS platforms to be used in real use-cases by companies. Each company, whether it is an actual fleet management provider or a support service provider, could assess and define their specific use-case and available platforms against these requirements. We expect this framework to be a valuable complement in the ongoing IoT/industrial internet reference architecture work by different organizations, and because of that, the results were also published in a scientific conference and professional omnibus.

Figure 39. **Fleet Management Platform Concept**

Defining interfaces and standards for fleet data connectivity

Jere Backman, Janne Väre/VTT
Heikki Kettunen, Tatu Pitkänen /Valmet

Background and objective

Streamlined web-based fleet data management is required for efficient maintenance planning, management, and operations. The potential of a comprehensive maintenance management system is large and will benefit the whole life-cycle. To implement this kind of solution, one needs to determine standards, interfaces, and data formats to integrate data from different sources and to provide it to different targets. Streamlined web-based fleet data management is required for efficient maintenance planning, management, and operations. When implementing this kind of solution, the first step is to determine standards, interfaces, and data formats to be able to integrate data from and to different sources (Figure 40).
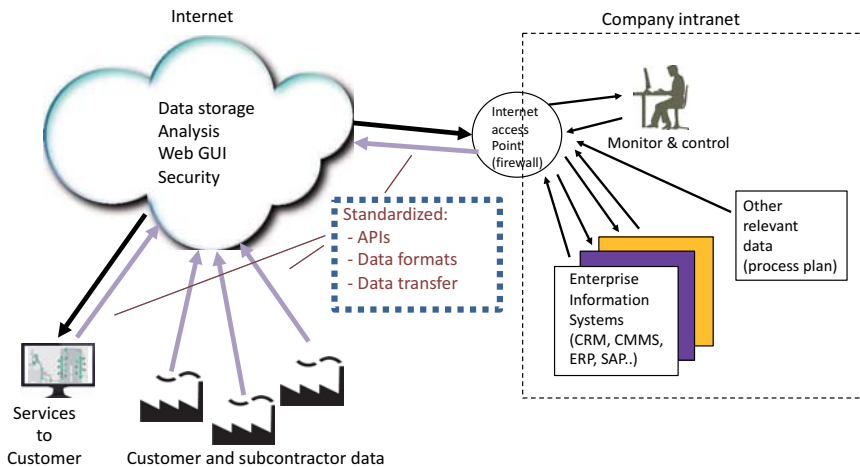
Figure 40. **Need for standards, interfaces, and data formats to be able to integrate data from and to different sources**

Results

We studied what standards, interfaces, and data formats could be used in integrating data for roll maintenance management. Potential implementation possibilities were assessed through discussions with experts from different domains. The results state that the Open Messaging Interface (O-MI) and Open Data Format (O-DF) Open Group standards can be

used in integrating data for roll maintenance management. Semantic integration can be utilized to convert legacy data formats into Open Group standards-based target ontologies. Enterprise Application Integration (EAI) can be used for internal messaging.

Based on the performed interface study and expert interviews, the conclusions were the following. The O-MI and O-DF Open Group standards can be used for integrating data for roll maintenance management. There are no expected challenges using O-MI and O-DF, because these require support for only Extensible Mark-up Language (XML) and Hypertext Transfer Protocol Secure (HTTPS) technologies. Roll maintenance-related external sources usually have XML format data and have the possibility to implement a network transfer using XML and HTTPS. Those two technologies are also widely supported and used for data transfer in various domains. For legacy data, semantic ontology-based data integration can be utilized to convert legacy data formats into Open Group standards-based target ontologies. However, if the organization has EAI available, this should be utilized for internal messaging and legacy data conversions. In special cases where data is available only in analogic format from older sources, it can be input to the system manually by utilizing portable devices in the field, by implementing the same standardized software in the device.
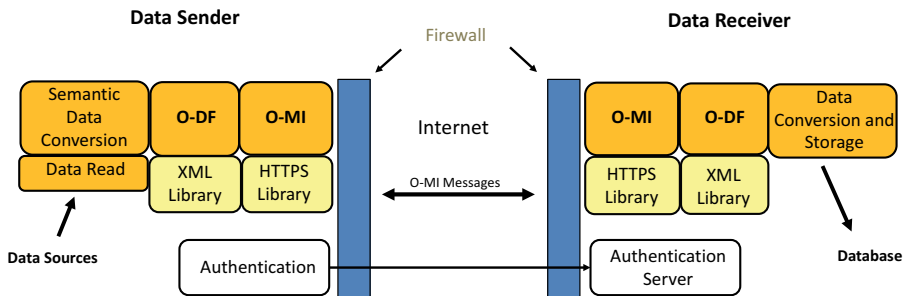
Figure 41. An example implementation with a sender and a receiver O-MI node in an industrial setting

Impact The results in general can be utilized in different domains and used for different integration purposes. In roll maintenance, a web-based integrated solution can: a) improve work efficiency by systematic development of roll maintenance, b) enable better planning of purchases with dynamic information on available spare rolls with their condition and location, c) streamline planning with information of upcoming roll maintenance events, and d) lead to better cost predictability and easier budg-

eting for roll maintenance. In addition to this, the solution can give a visual outlook of maintenance needs, roll positions, and so on, and can provide access to data for all users that need it.
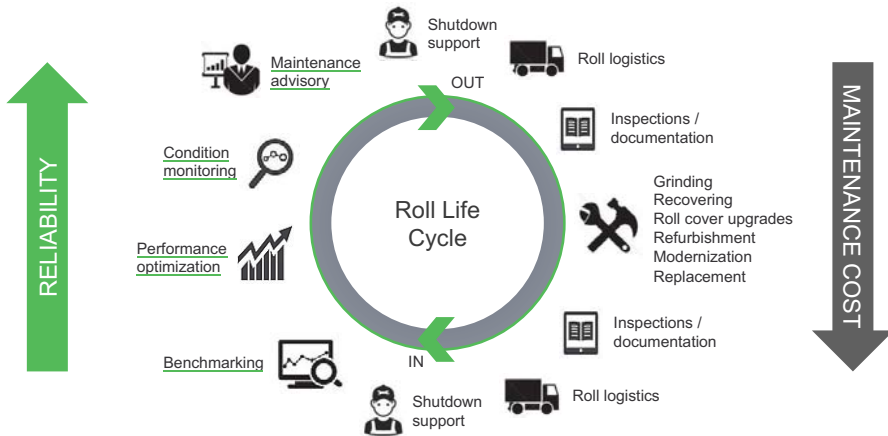

Figure 42. Roll life-cycle

Streaming analytics signal status recognition

Seppo Rantala, Marina Eskola, Jere Backman/VTT
Kai Anttila, Kati Kekäläinen/Outotec

Background and objective

When dust accumulates in the electric furnace off-gas line, the gas flow is obstructed. Blockages in the off-gas line cause production losses and even serious explosion risks. At the moment, there are no clear indicators to operators or best practices to classify the severity of dust accumulation. The higher-level knowledge derived from process data can be used for many supervisory tasks, such as process monitoring, diagnosis of process malfunctions, and detection of mode change. To minimize erroneous decisions and overload, there is a need for approaches that can automatically capture and interpret knowledge, which will reduce the real-time decision-making burden on the operator. Figure 43 presents an electric furnace and its off-gas line.
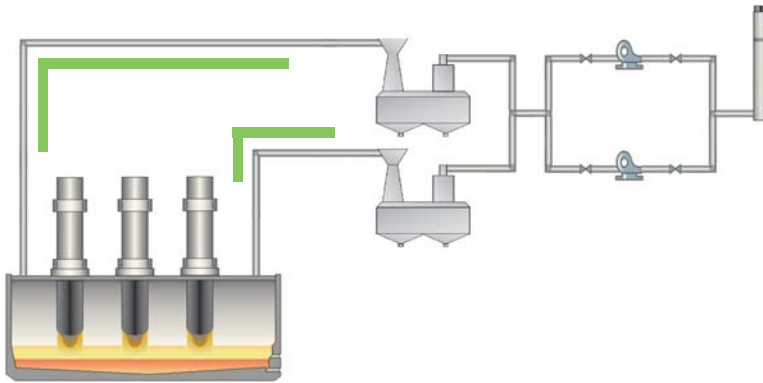
Figure 43. **Electric furnace and off-gas line**

Results

The sensor signal analysis chain was proposed to improve the sensor signal data interpretation. The signal analysis chain involves several signal analysis phases, which in turn involve a number of signal analysis methods, which were investigated during the project. To recognize the status of the electric furnace off-gas line, comprehensive data analysis was performed. The data analysis chain included data pre-processing, data classification, statistical analysis, and correlation analysis. As a result, gas flow dynamics changes can be recognized well beforehand. Dust accumulation in the off-gas line can be identified eight hours before it becomes critical. This phenomenon can be identified in Figure 44.

220EF202-PC-04C/C.MV#Value
Furnace pressure setpoint
CO-Gas to CO-Gas Fan Furnace 1 Pressure Control
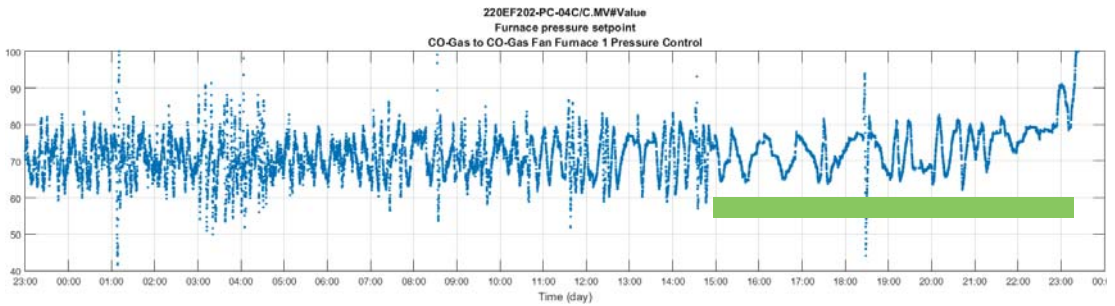
Figure 44. Dust accumulation in the off-gas line can be identified before it becomes critical

Impact   Due to the results achieved, the electric furnace off-gas line status can be recognized, gas flow dynamics changes identified, and dust accumulation predicted before critical events occur. According to the results, a risk-level indicator can be implemented and tested on the site. A universal solution for electric furnace off-gas lines could also be implemented in the future.

Further information

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Ultimate service tool

Meri Kailanto, Juho Koro, Ossi Nykänen/Tampere University of Technology
Jouni Ojala, Sampsa Guenat/Etteplan

Background and objective

The objective was to define a concept, the main components, and requirements for an ultimate service tool (UST). The UST is a context-aware service tool that provides service technicians and managers with smart access to technical documents and relevant information in a service process. The work was done through a research and business showcase jointly carried out by Etteplan and Tampere University of Technology.

The work consisted of the following main parts:

- UST concept definition:
  - context definition: information and process models, stakeholders
  - prototyping: a laboratory prototype in a real company context
- Information design
  - Service information model
  - information maturity model
- Business plan with commercial indicators

As a high-technology engineering company, Etteplan works intensively as part of the fleet-based value networks of its global customers and sees significant business potential in the area of industrial service business and related technologies. The results of the S4Fleet program are estimated to enable remarkable additional revenue for Etteplan in the long term. This will affect the profitability of the consultancy business by heightening the extent of value added to the services provided to the industry. Additionally, this enables the company to create more information-intensive services with increased usability and user experience.

TUT Department of Mathematics studied semantic modeling, analyzing and processing fleet-level technical information related to the Fleet Platform Concept. The techniques enable, for example, efficient, context-specific management and use of technical documentation.

Results

UST concept: We approached defining the UST requirements through interviewing and observing actual service personnel from management and development, as well as field workers in one case company. The ecosystem that affected the UST context consisted of fleet operations, maintenance and repair, the product line, and technical information.

In a case study with the real customer company, we developed the concept of UST further and made a limited laboratory prototype implementation to demonstrate the concept in practice. In the pre-study phase, we identified related information products and systems, roles, and process phases. The gained information was used as background for the laboratory prototype and simplified semantic models.

Semantic modeling helps to deal with complex information networks. As real processes are human-centered, they are complex and dynamic and can only partially be modeled and controlled through information systems. Semantic modeling helps in building semantically solid information architecture and providing understanding on different phenomena. This limited laboratory implementation showed some of the possible benefits that the UST concept can provide.
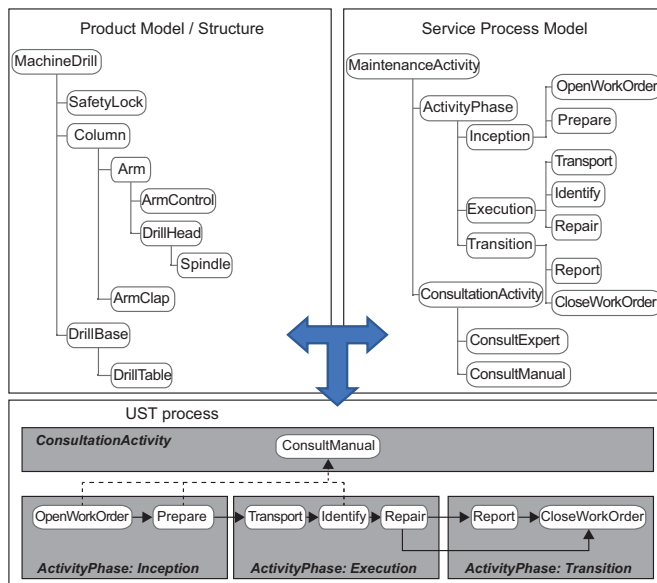
Figure 45. A simplified example of how product and process model ontologies can provide context awareness to automatically collected event log data during service processes

Basic idea and benefits: UST provides smart, context-aware access to timely technical documentation and information for different stakeholders (technicians, managers, technical information providers, product line, etc.) through a single user interface. It bridges state-of-the-art technical documentation; maintenance, repair, and operations (MRO) activities; and the related information. Many field service management (FSM) tools provide similar functions, but the key difference in the UST concept is

that it takes the information and system integrations a several steps further, which is the basis for the benefits it provides.

This supports the evolution of a service-compatible (business/process) documentation model/process, and gives the opportunity to measure, analyze, and illustrate the benefits of the technical information value network. In the broader context, MRO develops and ensures the operational reliability and profitability of the machine/unit/plant and its lifetime. One key feature in UST is the feedback loop from maintenance, repair, and operations to all relevant stakeholders. The ownership of the information is a sensitive issue. Each stakeholder has their share of the process data. In order for the UST concept to achieve its full potential, the information flows should be agreed so that each partner benefits from the "open" information exchange. This requires trust between the stakeholders.
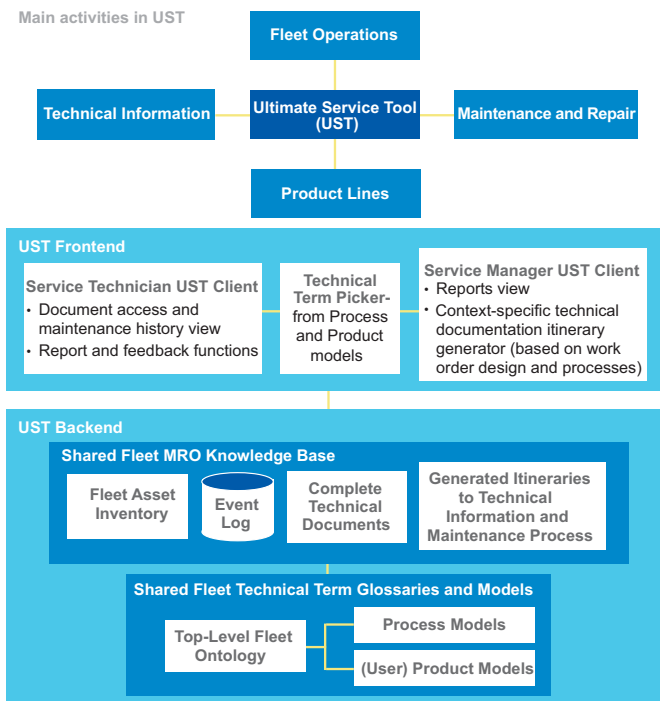
Figure 46. Components of UST

Components of UST: The main components of the front-end in UST include service technician and manager UST clients and the technical term picker to guide the user to use shared terminology. The back-end contains a shared maintenance, repair, and operations (MRO) knowledge base associated with shared term glossaries and models.

Maturity model: The re-definition of technical information maturity was an essential step in this program. By maturing information, considerable benefits and quality increases are achievable. The effect of maturity of information on technical documentation and field service processes is described in Figure 47. Typical modern technical documentation is on level four, where simplified language, purpose-made illustrations, and content management systems are used to make concise digital and single-source technical documentation products and publications. Basically, this means that the information needs to be marked up at paragraph level, and documents and document components need to contain metadata. Moving onward from maturity level four requires a new way of working. Level five is all about building the platform to facilitate the more precise control of information and the cross-connection between processes, organizations, and information.
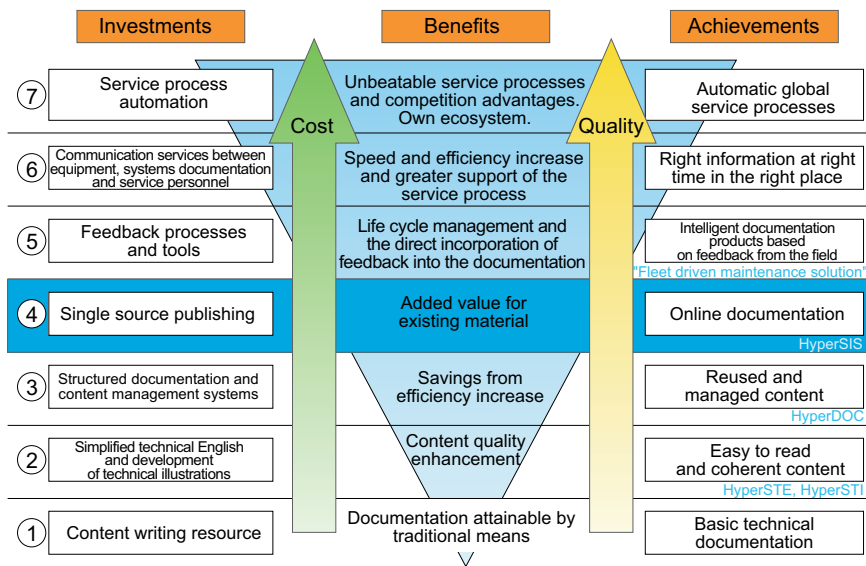
Figure 47. Technical information maturity model

Information model: The ultimate service tool project already showed us what is needed to automate field service processes and right-time information delivery. The missing function is the possibility to get proper feedback from the field, which is tied to information from several key systems.

The key corner-piece that is needed to progress, with the integration of product information into life-cycle data, is easily accessible technical documentation that integrates into the product data. The challenge in

the field is the many different production data and field service management solutions that require case-by-case integration. The basis for the system is the original design data, which is enriched by more refined technical information. The "connection-ready" information is then stored in an accessible storage place for easy integration. A general information-flow diagram is given in Figure 48, which shows the original information sources and how the original information gathers value when it is processed and linked to other information.
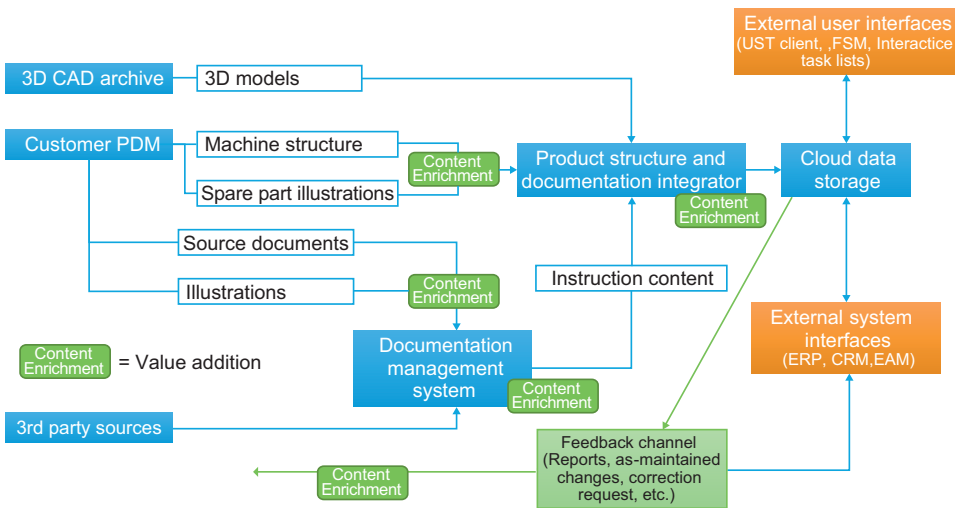
Figure 48. **Information-linking diagram for UST solutions**

Impact The main business benefits may be summarized as follows: maintenance and repair receives better, context-specific technical documentation and performs better in a more informative and safer environment. By knowing the actual needs and the priorities of maintenance, repair, and operations (MRO), technical documentation can deliver improved and more specific information products. In addition, management of rich technical documents and access to event logs enables the introduction of novel, added-value services to the UST ecosystem. Due to better documentation and maintenance, product line operations get better customer satisfaction and less reclamation. Fleet operations receive up-to-date technical documentation and better maintenance, leading to less downtime, for example. Finally, accumulation of MRO knowledge supports migrating to condition-based maintenance, which provides superior control over MRO. Achieving the benefits requires both operational and strategic actions, such as the adoption of new work practices, and

systematically aiming for higher information management maturity levels in stakeholder collaborations. In practice, the specific key performance indicators are defined in line with the process and the customer needs.

The key thing is easily accessible technical documentation that integrates with the product data throughout the whole product life-cycle. Many different production data and field service management solutions form a challenge, and they require case-by-case integration. The basis for the system is the original design data, which is enriched by more refined technical information. The "connection-ready" information is then stored in an accessible storage place for easy integration.

Fleet usage statistics and maintenance log data – risk analysis

Panu Tiittainen /Ramentor

Background and objective

Many companies have gathered considerable amounts of sensor- or counter-based usage statistics from their fleet, as well as more or less manually completed formal operational logs. There is a strong motivation to combine and refine such data to create real business value. The methods and tools to accomplish that must be flexible enough to suit various analytics needs, robust enough to deal with data of varying quality, and scalable enough to be applicable to the vast and ever-increasing amount of data.

Utilizing fleet data for maintenance optimization requires the identification of relevant predictor variables and the application of suitable risk assessment methods based on them (see Figure 49). The challenge is to find such methods that provide valuable insight and knowledge by processing vast amounts of data of varying quality in an efficient, flexible, and robust way.
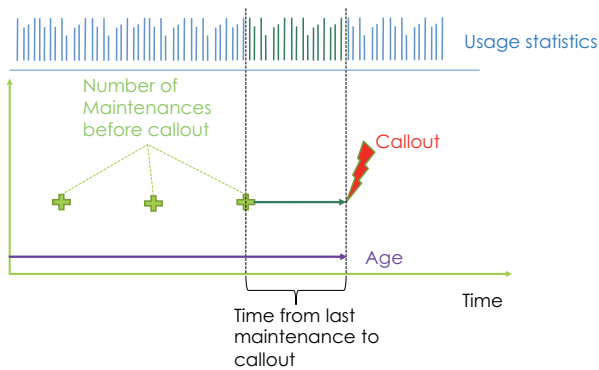

Figure 49. Maintenance optimization

Results

Combining and reformatting the usage and maintenance data into a suitable layout enables the utilization of visual association rule-mining to determine which of the numerous factors should be used as predictors of customer call, failure, and so on. With a suitably limited predictor set, it is then feasible to proceed to the Kaplan-Meier and Cox proportional hazards methods to find out the predictor effects, as well as the differences between subpopulations, both visually and numerically. The data

covers approximately 5000 pieces of equipment for a few years, totaling about 30 million data rows.

The analysis methods proved suitable for finding the most important factors affecting failure risk and the relative risk strengths from a fairly large data set. In the fleet context, this enables the study of, for example, various environmental and usage profile-related factors, in addition to traditional variables such as equipment age or operating hours. The methods are flexible, enabling an easy shift of focus between factors and subpopulations. The methods are robust, as they are able to produce reliable information on failure risks while avoiding the vulnerabilities and overheads related to distribution fitting.

The analysis was a multi-step process, with each step producing valuable results. A data integrity check and data source combination provided valuable insight into the data producing system's performance and potential from an analytics point of view. In addition, the analysis steps enabled the formation of various reusable scripts and procedures for database and analytics tools, making it easier to repeat the analysis process with new, modified, or updated data sources.

Impact The tested set of methods and tools performed well within this industry case, and refined data into real business knowledge not just in terms of analysis results, but also as insight into the data collection performance metrics. The results enable the formation of a scalable, flexible, and robust data-based risk analysis service. Ramentor plans to utilize these results to offer such a service and also, more specifically, to gain assistance in determining system failure logic and assessing failure tendencies, to be further utilized, for example, in prescriptive what-if scenario analyses.

Further information

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Fleet data collection and maintenance optimization

Manik Madhikermi/Aalto University

Background and objective

The industrial internet promises to radically change and improve many industry's daily business activities, from data collection and processing to context-driven, intelligent, and proactive support of workers' everyday tasks, such as maintenance. Within many large-scale plant-based industries, maintenance is one of the main sources of expenses and can account for as much as 40% of the operational budget. Maintaining a fleet of equipment is a daunting task, as over-maintenance increases expenses for companies and under-maintenance results in a risk of failure or even halts operations. With the emergence of the industrial internet, along with advances in sensor technology (remote monitoring), companies can collect operational fleet data from their equipment in order to improve and optimize maintenance activities. As a result, companies are able to implement an advanced maintenance model called condition-based maintenance. Condition-based maintenance requires detailed understanding of products' operational behavior, to detect problems before they actually occur, and to react accordingly. This maintenance model, in principle, should aid the optimization of maintenance activities. Despite such an efficient maintenance model, companies are still struggling to fully leverage their fleet data assets to provide reliable and cost-effective maintenance. The objective of this study is to identify the key pitfalls that hinder companies in fully leveraging their fleet data assets to provide effective and efficient maintenance services.

Results

This study is based on the data that was gathered in our previous project, FUTIS (Future Industrial Services). In the FUTIS project, our aim was to measure data quality. However, here in this research, we utilized the knowledge gathered during that project and extended it to identify and document key pitfall that hinder companies in providing effective maintenance service. The key pitfalls are described below:

Wrong or incomplete data reported: This issue is related to the maintenance reporting process, in which maintenance activities are reported, to include the work order ID, date, maintenance type, start date and time, end date and time, maintenance personnel, component with the problem (component code), reason for the problem (reason code), and action taken (action code) to solve the underlying issue. During the analysis of 45,375 maintenance reports, significant amounts of data in some fields

were either missing or incorrect. Table 7 shows the total number of empty and invalid codes. These codes provide vital information regarding commonly failing components and failure frequency, what the reasons for failure are, and how they can be resolved. This information helps the maintenance planner to plan maintenance activities and manage inventory, making maintenance activities more efficient.

Table 7. Total number of empty and invalid codes

Type of Code	Empty Code Count	Invalid Code Count
Component code	33562 (73.96%)	114
Reason code	33570 (73.98%)	162
Action code	33562 (73.96%)	26

Sensor data not logged for predictive maintenance: Sensor data gives actual insight into the machine environment and is an important indicator of the root cause of any kind of failure in the operational environment. During the field visit for the study, we observed several sensors installed on the equipment itself and on the factory floor to record equipment usage, condition, and operational environment data. However, the analyzed data did not correlate with the sensor installation because no sensor data are available in the database. Further investigation of the data indicated that only alarm and error information from these machines is logged in the database, while associated sensor data had been completely ignored. Current implementation of the sensor monitoring process in our case companies is depicted in Figure 50. As can be seen, in the current architecture, data from sensors is limited to software and is used by software only. The software is responsible for raising an alarm or error based on a computation of the sensor value from these sensors. This architecture has serious drawbacks when it comes to condition-based maintenance. One of the main issues in this architecture is that the software is based on prior knowledge of error or alarm conditions and lacks the possibility to learn new errors or alarm conditions by utilizing data generated from the sensors. The current architecture also lacks the ability to track the root cause of any failure, since deployed software only raises an alarm or error when it occurs, which might lead to a disruption in the functioning of the equipment. In addition, there is no possibility to look for sensor data to identify how an error or alarm condition has developed over time, to identify the root cause of the failure. As a result, condition-based maintenance is not possible.
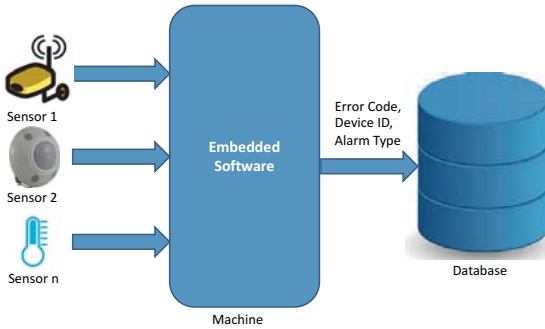
Figure 50. **Remote monitoring process**

Machine data and service reports are hard to integrate: In today's big manufacturing companies, with several organizational units working together, each unit must be properly placed and activities must be performed on time and accurately. To help manage their workflow, organizations typically rely on different processes that have all been individually developed. These individual processes and solutions give rise to problems of data silos, which can be seen in the studied cases, as well. There are different workflows and systems for carrying out maintenance and remote monitoring, as shown in Figure 51. In the maintenance workflow, the maintenance planner and technicians use the maintenance workflow management process to create and report maintenance activities, whereas in the remote monitoring process, the embedded software installed in the machine reports errors or alarms. The data from the two processes are hard to integrate, as the timestamp is the only key to integrating this data, which often results in ambiguous integration due to the occurrence of multiple errors at approximately the same time in the machines. Table 8 shows the total numbers of errors that occurred at a given timestamp.

Table 8. **Number of error at the same time**

Assembly ID	Device ID	Time	Number of Errors
1	215	2013-12-23 06:29:45.673	24
1	215	2012-11-08 15:33:31.517	23
1	215	2012-11-30 12:10:13.423	22
1	215	2012-11-29 11:19:39.780	22
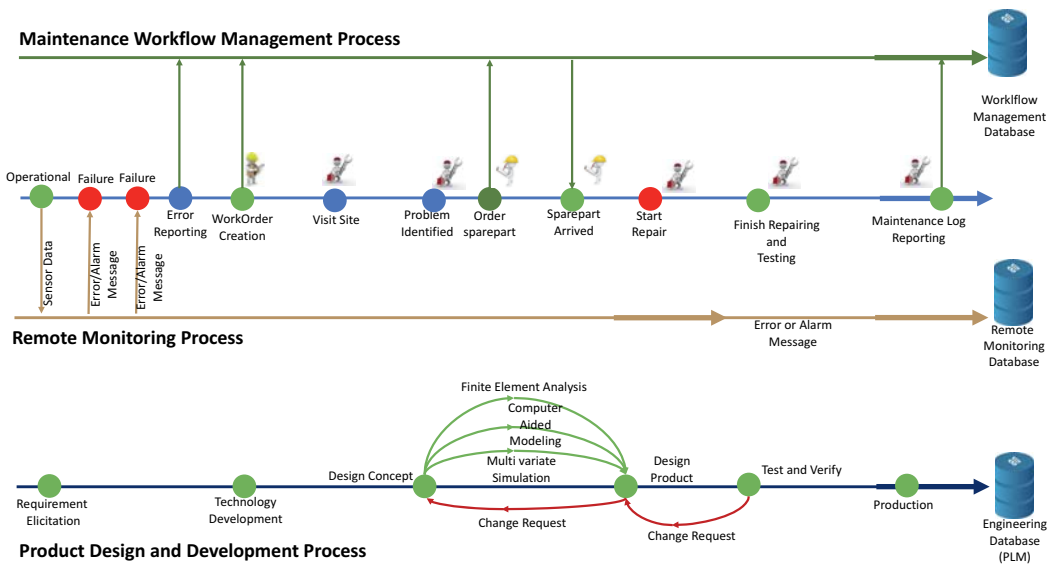
Figure 51. Data collection processes

Lack of data validation technique: One of the observations noticed in these studied cases included a lack of data validation techniques or mechanisms to check the quality of the data. This issue is also related to manual data reporting by technicians in the back-reporting tool. Table 7 shows there are several invalid codes entered by the technicians during service reporting of their maintenance work. Through further investigation, it was found that neither of the case companies practice any form of data validation process. Once the data is entered, neither does the back-reporting tool perform any validation on input data nor is there an external process or tool that helps to identify data quality errors. A proper rule-based validation process needs to be in place to prevent technicians from inputting the wrong data, which fosters the quality of reported data.

Processes are not designed for predictive maintenance: The current process architecture lacks interaction between different organizational units. There were several independent workflows and processes implemented in these case companies' organizational units, as depicted in Figure 51, where a lack of interaction between these units limited the capability of the organizations to understand and utilize available data assets. For example, the service report data and sensor information were only being utilized by the maintenance or service unit to develop the maintenance plan. However, such data can provide important information to engineering and product development units, regarding the design of new systems and the development of service strategies. These units can use the data to understand the product's operational behavior in the client

environment. Deep understanding of product behavior in real and simulated environments adds another dimension for improvement of the company's product and maintenance activities.

Impact The results of this study highlight the shortcomings of the studied cases, which hinder them in performing effective and advanced condition-based maintenance. This studied cases highlight that it is of utmost importance to integrate fleet data collection into other organizational processes, such as maintenance workflow management, in order to get the most out of the fleet data to improve and optimize maintenance activities using condition-based maintenance.

Further information

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Platform for fleet CBM service

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Unai Gorostegui/University of Mondragon

Background and objective

I t is widely accepted that the condition-based maintenance (CBM) strategy can bring vast economic benefits when compared to, for example, corrective maintenance. The rapid development of new cheap sensors, and processing power in compact and economic format, together with the penetration of IoT has created a huge potential for widening the use of CBM to support the service business that manufacturing companies are developing in order to broaden their business. The objective of this task has been to lower the cost and difficulty of implementing CBM in everyday use.

Results

In order to be efficient, the existing methodology, techniques, and standards that support the adoption of a CBM strategy have been collected and listed. Consequently, the CBM platform in this case does not represent new developed elements, but instead the best available practices. For example, ISO standard 13374 (Parts 1– 4) defines how condition monitoring and diagnostics of machines should be carried out with regard to data processing, communication, and presentation, meaning that the standard forms the basis for CBM. Based on the standard, the Machinery Information Management Open System Alliance has made available an open source solution that defines the semantics, ontology, and structure of this data. The definition of the platform for fleet CBM service follows the Open System Architecture for Condition-Based Maintenance (OSA-CBM) definition shown in Figure 52.
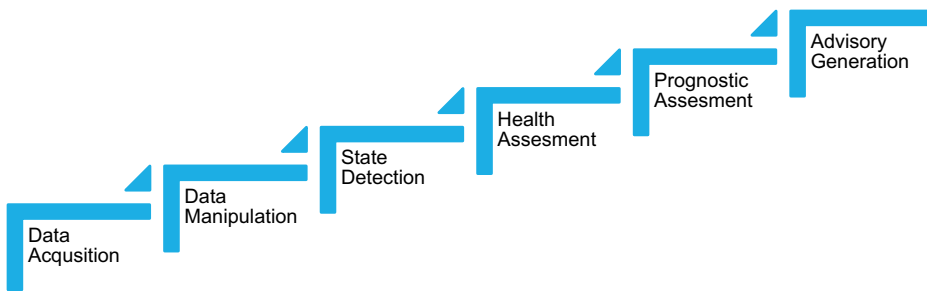

Figure 52. **Basic steps of the OSA-CBM definition**

Impact The results are generic, meaning that the collected approaches can be used in different industrial sectors in order to support the introduction of a CBM strategy and IoT.

Further information

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Early Warning System (EWS) for aircraft systems

Tauno Toikka, Jouko Laitinen, Kari T. Koskinen/Tampere University of Technology

Background and objective

Early Warning System (EWS) is a project studying and developing a system for maintenance decision support for F/A-18 aircraft (of the Finnish Air Force) maintenance procedures, based on flight data. The need for EWS comes from the fact that in complex and safety-critical systems like the F/A-18, condition-based maintenance (CBM) has an important role. CBM has an important role because scheduled maintenance and run-to-failure procedures are not applicable in complex and safety-critical systems. Complex system failure times are not age- or runtime-dependent, and thus scheduled maintenance does not improve system reliability. Run-to-failure is not a realistic option in safety-critical systems for obvious reasons. Thus, when an increase in the reliability of a complex and safety-critical system like the F/A-18 is required, effort needs to be put into improving CBM.

EWS is an effort to improve the CBM tasks in F/A-18 aircraft. In CBM, the decision about system maintenance needs is made based on the system condition. The condition of the system is analyzed in many ways, including based on human senses such as visual inspection, or on monitoring equipment like an ultrasonic defect detection system. The aim of EWS is to bring extra valuable information to the maintenance decision-maker from the F/A-18 in-flight process data.

Results

In order to receive any useful information from F/A-18 in-flight process data, the data need to be analyzed using data analysis methods. Since the F/A-18 in-flight process data is complex, highly directional, and produced by several subsystems of the aircraft, diverse data analysis methods have been studied in the EWS project. Methods from several scientific fields have been studied: probabilistic methods from the field of probability theory, machine learning methods from the field of computer science, and novelty detection methods from the field of signal processing. The basic concept of EWS is presented in Figure 53.

In this context, the applicability of machine learning (ML) methods for forecasting F/A-18 flight control surface failures was studied. It was found that unsupervised ML methods are effective tools for finding data samples indicating upcoming failures from historical flight data. The methods that were able to perform the task were self-organizing maps (SOM) and K-mean clustering. Furthermore, the capability of supervised

ML methods to classify failures, indicating healthy system data among the rest of the healthy system data, was studied. It was found that neural networks (NN), support vector machines (SVM), and radial basis function (RBF) were capable of learning the patterns of F/A-18 flight control surface failure indications, and further classifying them in new data. Figure 54 illustrates how dimensionality reduction with SOM, from high dimensional process data to 2D presentation, can reveal potential failure indicators.
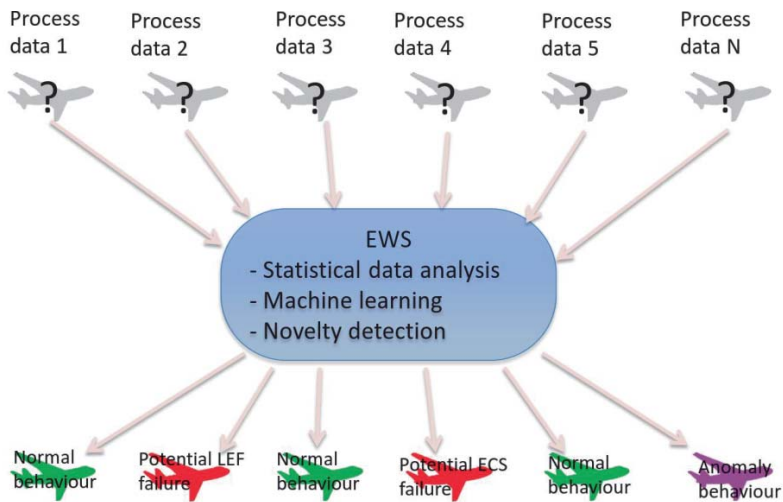
Figure 53. **The concept of EWS. The first layer presents the system process data, the second layer presents data analysis, and the third layer presents the interpretation of the system condition.**

Figure 54. **Illustration of a 2D SOM U-matrix map generated from several flight data parameters related to the F/A-18 flight control surface functions. Failures indicating healthy data samples are classified in the rest of the healthy data by SOM.**

Impact   In complex, safety-critical, and worthy systems like F/A-18, CBM has an important role. Due to the importance of CBM, the supporting information and data should be utilized widely. EWS is an effort to find valuable information in F/A-18 process data for the CBM process. Current studies have shown that F/A-18 process data encapsulates some valuable information describing the system condition, which may be further utilized for CBM decision-making.

Currently, the focus of the EWS project is on novelty detection (ND) methods established in the field of signal processing. The advantage of these methods is that they do not require data describing the failures of the system, and thus can be utilized for monitoring a never-failed system and never-seen failure modes. The tentative results are promising.

Further information

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