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Fleet service creation in business ecosystems – from data to decisions

Fleet information network and decision-making

Helena Kortelainen | Jyri Hanski | Susanna Kunttu | Sini-Kaisu Kinnunen | Salla Marttonen-Arola

VTT

VTT TECHNOLOGY 309

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ISBN 978-951-38-8580-9 (URL: http://www.vttresearch.com/impact/publications)

VTT Technology 309

ISSN-L 2242-1211
ISSN 2242-122X (Online)
http://urn.fi/URN:ISBN:978-951-38-8580-9

JULKAISIJA – UTGIVARE – PUBLISHER

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Preface

This report summarises the main outcome of the Fleet information network and decision-making project. The research project is a part of the DIMECC Service Solutions for Fleet Management (S4Fleet) program (2015–2017). The S4Fleet program is to research the variety of possibilities that technological breakthroughs enable in the service business. The program explores the opportunities and challenges related to applying the available technologies towards a global, distributed customer base. The DIMECC S4Fleet research projects were carried out in close co-operation between participants from Finnish universities and ICT and manufacturing companies.

The Fleet information network and decision-making project aims at advancing companies' abilities to create novel knowledge-intensive services especially for life cycle management, maintenance and operations support. The basic reseach question - *How can companies with complex fleet processes upgrade accumulated data into valuable knowledge that can be used in decision-making?* - guided the reseach work that lead to concepts and models for Data to Business Knowledge (D2BK), sharing data and supporting decision-making in business ecosystems, and to extended asset service development.

The Fleet information network and decision-making project was conducted through an inter-disciplinary research consortium consisting of the VTT Technical Research Centre of Finland Ltd (VTT) and the University of Lappeenranta (LUT). This report collects the work of researchers from both organizations.

The authors wish to thank all the people and organizations involved in this project; the project management group, the case companies and all the people who were interviewed, who participated webinars and workshops, and otherwise enabled the success of this project, and the financiers who made this project possible. Our sincere thanks to the case companies presented in this report for their collaboration, insightful discussions and comments as well as for their assistance in data acquisition during the research. We give our warmest thanks to Dr. Susanna Horn from Outotec, Hannu Niittymaa from IBM and Pasi Kivinen from HUB Logistics.

09.10.2017

Authors

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Appendix B: Overview of the findings in the case companies

Abstract
Tiivistelmä

List of definitions, abbreviations and acronyms

B2B	Business to Business
B2C	Business to Consumer
BI	Business Intelligence
CBM	Condition Based Maintenance
CM	Condition Monitoring
CMS	Condition Monitoring System
CMMS	Computerized Maintenance Management System
CPS	Cyber-Physical System
DaaS	Data as a Service
DIKW	Data, Information, Knowledge and Wisdom
DIN	German Institute for Standardization
D2BK	Data to Business Knowledge
EAM	Enterprise Asset Management
EOL	End-Of-Life
ERP	Enterprise Resource Planning
FMECA	Failure Mode, Effect and Criticality Analysis
Hazop	Hazard and operability study
IaaS	Information as a Service
II	Industrial Internet
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
KaaS	Knowledge as a Service
KIBS	Knowledge-Intensive Business Services
KIS	Knowledge-Intensive Services
KPI	Key Performance Indicator
OEE	Overall Equipment Efficiency

OEM	Original Equipment Manufacturer
O&G	Oil and Gas
O&M	Operation and Maintenance
PHM	Prognostics and Health Management
ROI	Return on Investment
RUL	Remaining Useful Life
WaaS	Wisdom as a Service
WMS	Warehouse Management System

1. Introduction

1.1 Motivation

Global product manufacturing companies have shifted their focus from product delivery to value adding asset life-cycle services. Servitization of manufacturing has emerged as a way of responding comprehensively to customer needs, and gaining novel competitive advantage. Moveover, industrial services produce typically stable cash flows which supports product fleet management. (Oliva & Kallengerg 2003). Industrial services are information-intensive and require data collection also on customer sites. Customer asset systems are typically complex and expensive, and they are characterized by high profitability, efficiency and safety demands. From the service provision point of view, not only the service content but also the service experience is important (Liinasuo et al. 2016, Liinasuo et. al 2017). Data collection and analysis open up new possibilities not only for typical fleet services like maintenance but also for new business models, 3rd party services and even novel digital product lines.

Competition in international markets has led to a situation where industrial services (e.g. maintenance and information services) are outsourced to a greater extent. Many regional clusters have fragmented into global value chains, in which geographically scattered companies specialize in specific activities. As such, the competition has transferred from taking place between individual companies into competition between business networks or, as the increasing interest in sustainability and industrial ecology suggests, between industrial ecosystems (e.g. Ashton 2009, Baldwin 2016). These kinds of developments can be seen to have a vast business potential for e.g. equipment manufacturing companies or information service providers both in consumer and business-to-business markets (see e.g. Gubbi et al. 2013).

The Internet of Things (IoT) comprises a network of smart objects connected to the Internet. In the context of industry, the term of Industrial Internet (II) is often used alongside IoT. Applications utilizing IoT technologies are increasing as enabling technologies are developing and becoming less expensive. IoT is transforming businesses, and it has been described as an industry revolution taking place right now (Porter & Heppelmann 2014). Companies are developing new applications and innovative uses for IoT technologies. IoT technologies have been applied to numerous environments, such as logistics, manufacturing, security, and healthcare. Hence, the applications vary from inventory control and condition-based maintenance CBM to e-Health applications.

Global manufacturing companies are in the middle of a transformation process driven by rapid information technology development. Data, information, knowledge and analytics, and the use of data in decision-making and processes, are in the core of this transformation process. The manufacturing industry is currently learning to exploit more and more data and information in their business. The new IoT-based service concepts can introduce smart, automated products to the manufacturing business (Pletikosa & Michahelles 2011).

However, so far the adoption of new IoT-based technologies and service concepts has not met the high expectations. The technical and economical life-cycle data of the fleet is vast, multifaceted, and usually fragmented in the industrial ecosystems. The production equipment is more complex than ever, requiring state-of-the-art knowhow to keep production from stopping due to machine breakdowns (see e.g. Xia et al. 2011, Taracki et al. 2009, Kumar et al. 2006). It is not feasible for each company in the ecosystem to process all of the data by themselves. Hence, there is a need to develop innovative solutions to enable better integration, gathering, sharing and exploitation of fleet life-cycle data.

1.2 Fleet information network and decision-making - project scope and objectives

The Fleet information network and decision-making project (see **Appendix A** for details) concentrates on the life-cycle management and utilization of fleet information, on the relationship between fleet service solutions and asset management, and also on building a model to assess the value of shared information in the network. The project aims at finding new ways to gather, analyze and understand and then utilize information in fleet level operations in a value network and create extended service solutions around information. **Figure 1** presents the scope and the research setting of the project.

The focus of the Fleet information network and decision-making project is on extending service delivery to the long-term co-operative development of physical assets in close collaboration with the end customer. The project aims at answering the research guestion:

- *How can companies with complex fleet processes upgrade accumulated data into valuable knowledge that can be used in decision-making?*

The project aims at also looking beyond current service delivery and seeks solutions to the question:

- *How to extend the service offering beyond maintenance and spare parts? What could the new knowledge-intensive services be?*

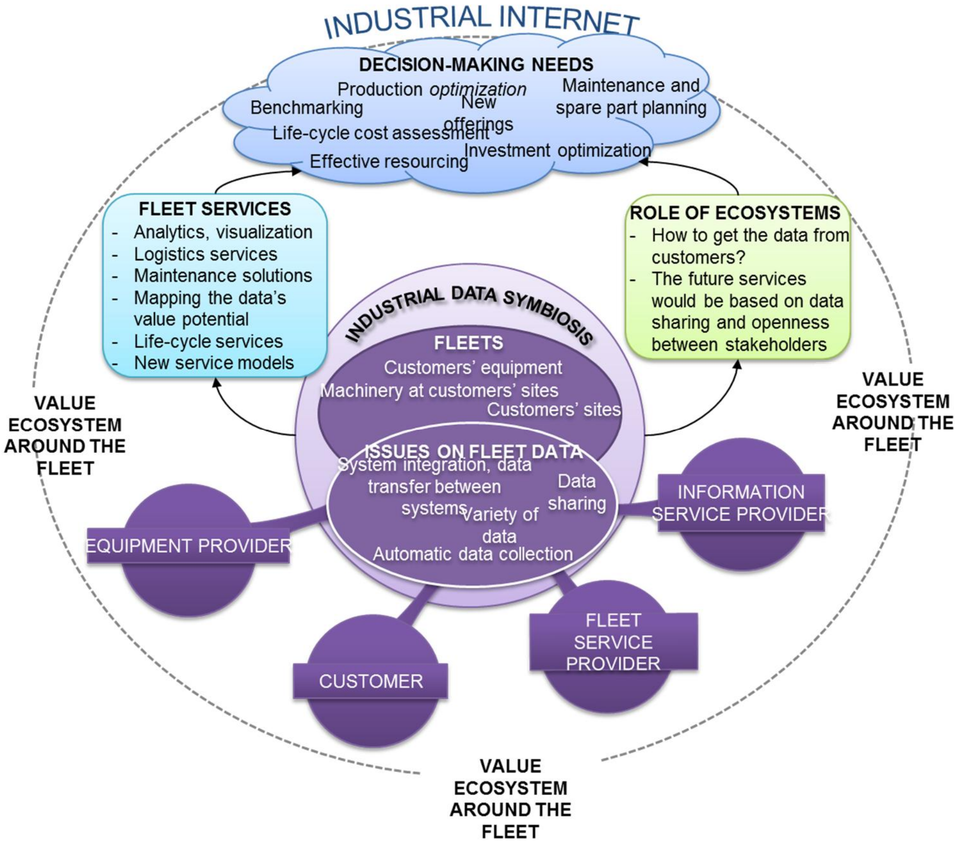


Figure 1. Research setting for constructing new solutions out of fleet-based life-cycle data in a value network context.

1.3 Purpose of this document

The report **Fleet service creation in business ecosystems – from data to decisions** collects the main outcomes of the Fleet information network and decision-making project. Chapter 2 summarizes the research methodology and data sources. Chapter 3 presents the state of the practice in turning data to business knowledge. It is based on the first project deliverable *"Data to Business Knowledge Model (D2BK) – Data Sources and Decision Making Needs*" (Kortelainen et al. 2015) that identified the different phases in the process of turning multifaceted data into business knowledge. The research project has two major outcomes, namely the Data to Business Knowledge (D2BK) model presented in Chapter 4, and a set of knowledge-intensive service concepts that are collected in Chapter 5. Both chapters are based on the second project deliverable, "*Knowledge Intensive Service Concepts for Fleet Asset Management*" (Hanski et al. 2016), that extends the perspective from that of one company to inter-organizational business transactions through a focus on services. The chapters also draw from the third project deliverable, "*D2BK Data to Business Knowledge Model, results in case companies*" (Kinnunen et al. 2016), that provided an analysis of the case companies from the ecosystem and value perspectives and an overview of the connections of the D2BK model to the management of fleet data in the case companies. Chapter 6 deals with implementation pathways for the D2BK model and fleet services. Chapter 7 offers a market review addressing the opportunities available and the market need for data and knowledge-based solutions. The chapter is based on the research project deliverable "*Implementation pathways for the D2BK model*" (Kinnunen et al. 2017). Finally, Chapter 8 summarizes the results, draws conclusions and addresses the needs for further study.

1.4 Definition of key terms

One of the key terms in Fleet management is the concept of 'fleet'. **A fleet** shall be viewed as a set of systems, sub-systems and components. Common characteristics among units allow the definition of three types of fleet composition: identical, similar and heterogeneous fleets. (Medina-Oliva et al. 2014). Fleets may consist of equipment and machinery, but also of e.g. people, customers and platforms. 'Fleet' is used in practical applications to describe a set of similar or nearly similar entities[1]. The concept of 'Fleet management' has been extended to address the **installed base**, i.e. globally supplied products of a machinery manufacturer (Ahonen et al. 2010a).

Fleet management also implies that the asset owner, fleet operator, maintenance organization or product manufacturer has an interest for such considerations and that fleet management could bring economic or other benefits (Kortelainen et al. 2015). With current technology, machinery manufacturers and suppliers can collect data from - and even control or operate - a globally distributed installed base of machines and other items as a fleet.

In the recent international standard (ISO 55 000), **asset management** refers to the coordinated activities of an organization to realize value from its (physical) assets and achieve its business objectives. This definition covers the activities in the operation, maintenance and improvement of assets required for optimal life-cycle management and economic sustainability. Typical tangible assets are equipment, machines and systems in manufacturing and process industries, mining, construction and the infrastructure sector. ISO standard (ISO 55 001) also states that the organization should determine the **information needs** related to its assets, asset management and asset management systems. Issues to be considered include e.g.:

[1] see e.g. http://www.nafa.org/about-nafa/nafa-foundation/

- The value of the information to enable decision-making and its quality relative to the cost and complexity of collecting, processing, managing and sustaining the information;
- The participation of relevant stakeholders to determine the types of information required to support decision-making as well as to ensure the completeness, accuracy and integrity of the necessary information;
- The alignment of the information requirements for different levels and functions within the organization;
- The establishment of data collection processes from internal and external stakeholders (including contracted service providers); and
- The data flow and integration of information sources into planning, operational and reporting technology systems, appropriate for the size, complexity and capability of the organization.

The asset management standard takes also the various stakeholders into consideration, not only as suppliers but also as collaboration partners. The trend towards networked collaboration models could give rise to new business ecosystems. The **business ecosystem** could be defined as "an economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world" (Moore 1996).

The concept of '**maintenance communities**' (Ahonen et al. 2010b) also refers to business scenarios in networked environments with a holistic view and common value creation targets. These scenarios call for a new and more broadminded way of thinking from each individual service provider in the community as well as shared tools, technology, models and trust between community members. What is called for as well is the ability to move from single partnership (service provider - manufacturing company) into coherent networked decision-making that is based on joint and customer-oriented planning and coordination.

Performance indicators are necessary to control the effective use of assets and optimum operation of the network over the life cycle. **Key performance indicators** (KPIs) represent a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization (Parmenter 2010). Typical indicators are overall equipment effectiveness (OEE), availability performance and maintenance costs (EFMNS 2012), but the number of possible KPIs is huge (see e.g. Kunttu et al. 2010).

The product '**life cycle**' can be defined as the time period beginning with the first idea and ending with the disposal of the product (DIN ISO 15226). In capital-intensive industries, production assets typically have long life cycles and major changes may occur in all the exogenous or internal factors (**Figure 2**). Actually, a system (e.g. production line or plant) and/or a fleet (e.g. centrifugal pumps, filter equipment or drilling machine) may consist of items that are in different life cycle phases.

Figure 2. Item life cycle (IEC 60300-1:2014).

Logistics, maintenance, IT and facility management and guarding are typical activities that industrial companies first outsource and then acquire as services. These contracts are closed on one-to-one basis and characterized by service level agreements of KPIs. '**Extended asset services**' refers to extending service delivery to the long-term co-operative development of physical assets over the whole life cycle in close collaboration with the end customer and other stakeholders in the ecosystem (Kortelainen et al. 2015).

For knowledge-intensive services (KIS), knowledge is the main production factor and the good they offer. Knowledge-intensive business services (KIBS) form a subcategory of KIS (Schricke et al. 2012). In general terms, KIBS are mainly concerned with providing knowledge-intensive inputs to the business processes of other organisations, including private and public sector clients. Bettencourt et al. (2002) defined KIBS as "enterprises whose primary value-added activities consist of the accumulation, creation, or dissemination of knowledge for the purpose of developing a customized service or product solution to satisfy the client's needs". The economic activity sectors defined by Eurostat as knowledge-intensive services and knowledge intensive business services are presented in the following table.

Table 1. Definition of KIS and KIBS according to NACE (a European classification of economic activities) (Schricke et al. 2012).

KIS	Knowledge-intensive high-tech services	Post and telecommunications, Computer and related activities, Research and development
	Knowledge-intensive market services (excluding financial intermediation and high-tech services)	Water transport, Air transport Real estate activities, Renting of machinery and equipment, without operator, and of personal and household goods, Other business activities
	Knowledge-intensive financial services	Financial intermediation, except insurance and pension funding, Insurance and pension funding, except compulsory social security, Activities auxiliary to financial intermediation
	Other knowledge-intensive services	Education, Health and social work, Recreational, cultural and sporting activities
KIBS	Knowledge-intensive business services	Computer and related activities, Research and development, Legal, technical and advertizing

2. Research methodology

2.1 Observing the state-of-the-practice and future plans

An empirical study was carried out in the Fleet information network and decision-making project characterized by strong industrial involvement. As indicated in **Table 2**, the case companies represented machinery manufactures, technology and knowledge & service suppliers, and IT service and infrastructure providers.

The qualitative research approach was applied in the collection and analysis of emprical data. Qualitative research approaches emphasizing empirical field data are beneficial when the topic is in its early stage and extant theories are limited (Creswell 2013; Eisenhardt and Graebner 2007). Creswell (2013, p.160, 183) presents the data collection methods and analysis procedures in qualitative research, including data collection methods such as interviews and observations, and procedures from data managing as representing and visualizing e.g. with matrices, trees, and propositions. Multiple qualitative data collection methods have been used in the project. The state-of-the-practice has been observed through:

- constructing a matrix on the participating companies' presentations in the kick-off event,
- organizing a webinar for the participating companies and research institutions on the current state of fleet-level analysis tools,
- having numerous discussions and/or interviews with the individual companies, and
- observations and results from other recent research projects and literature that provided insight into the state-of-the-practice.

At the beginning of the project, a structured workshop was organized to outline the state-of-the-practice in the project. In a structured workshop, the companies were asked to present their development goals and plans related to data-based industrial services. Eleven companies participated in the workshop (see **Table 2**). During the workshop, the researchers were observers and recorded the presentations from eight complementary perspectives:

- Case - what is the company challenge to be solved in this project?
- Objective - how is the company objective stated?
- Fleet - what kind of a fleet does the company consider?
- Decision-making situation - what decision-making situations are concerned?
- Data - which data is available, which data is needed, where to get the data?
- Services - what asset services do the companies aim at developing?
- Openness - how open is the company now and how does the openness evolve?
- Network and ecosystem - who are the actors in the case ecosystems?

Table 2. Industrial partners participating in the study.

Company	Company description	Size
Analytics Cloud	Information service and infrastructure provider	SME
Etteplan	Information service provider	Large
HUB Logistics	Technology and service provider	Medium
IBM	Information service and infrastructure provider	Large
Kone	Equipment and service provider	Large
Metso Minarals	Equipment and service provider	Large
M-files	Information service and infrastructure provider	Medium
Outotec	Technology and service provider	Large
Ramentor	Information service provider	SME
Valmet	Equipment and service provider	Large
Wapice	Information service and infrastructure provider	Medium

The data collected from the case companies during the project is summarized in the form of a matrix, which is presented in **Appendix B**.

2.2 Company cases as test beds

During the research program, collaboration between researchers and companies has been multiform. The collaboration with the companies presented in **Table 2** is built through various methods, and the companies have been playing an essential role when producing research results. On one hand, the research has been led by researchers. This appies to the design of data collection in company cases, case descriptions and implementation in the company cases, and to the building of theoretical models and frameworks. The models and frameworks have been tested with companies leading to scientific achievements. On the other hand, companies have also achieved their own research and development results while the researchers have been playing a minor and observant role. In a third model, companies have laid down the current development challenge, and the co-creation with the company representative(s) and researchers has led to the result. The collision of research and practice has enabled the combination of different views and generated scientifically interesting and practically relevant research results.

Companies have participated in research by providing presentations in project seminars but also by presenting results in webinars organized with Skype for Business. Throughout the research program, various meetings have been arranged with the whole group of companies, but also separately with companies to define and elaborate the company cases. Some of the companies have also been delivering data for the research, e.g. in the form of in-house information gathered from the company systems. In addition, companies have enabled researchers to interview company representatives inside the company but also to interview the representatives of customer companies.

In addition to meetings and seminars, workshops have been organized by research institutes to enable company representatives and researchers to share and develop ideas. In all the events, researchers have been active in documenting and analyzing the meetings, presentations and workshops.

Figure 3. Digitalization and business models for asset service delivery seminar in Tampere 1.10.2015.

Companies have also participated in writing the research results and helped by providing visualization ideas and photo material. For example, the DIMECC S4Fleet monthly results have been written and published as internal publications. These monthly results present the key results achieved in collaboration between companies and research institutes. The company achievements are summarized in the final project report (Töytäri et al. 2017).

3. State of the practice in turning data to business knowledge

Decision-making in fleet management involves managing a large group of assets. The decisions that could be supported with better fleet data deal with cost savings, increasing performance and revenue, and gaining other benefits. The decision-making situations related to fleet management can vary a lot as decisions are made at different levels of hierarchy, in different working environments and in different phases of an asset's life cycle. Thus, the diverse decision-making situations have different requirements for data and analytics.

3.1 Perspectives for asset related decision-making

When exploring fleet decision-making situations, it can be noticed that all the relevant data for fleet related decision-making is not available and it is also fragmented and siloed in industrial ecosystems (Ranasinghe et al. 2011, Candell et al. 2009). **Figure 4** shows the perspectives of the asset owner and provider with respect to the assets. While asset owners are particularly calling for solutions maximizing the value extracted from the assets deployed in their systems, providers have the potential for creating value and providing value-added services for the asset owners based on fleet-level knowledge. Understanding the potential of organizations working together collecting, sharing and utilizing the data with new operational models and systems thinking is crucial in order to meet the customers' expectations towards the management of the assets composing their particular production system.

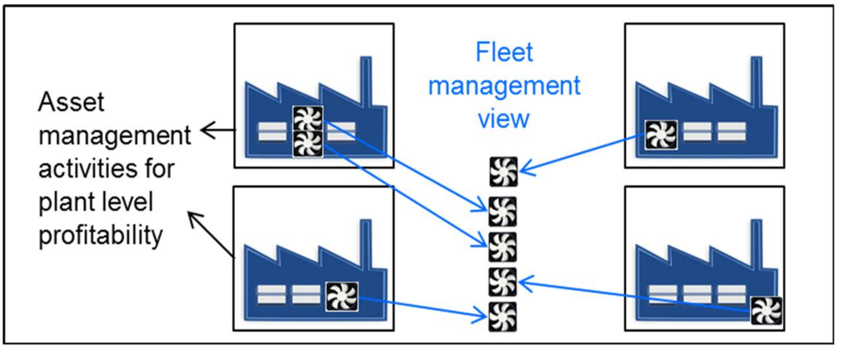


Figure 4. Asset Management vs. Fleet management view (Kortelainen et. al. 2016).

As stated by Porter & Heppelmann (2014), companies should focus on systems instead of pure discrete products. According to Davies (2004), competitive advantage is not simply about providing services, but about how services are combined with products to provide high value “integrated solutions” that address a customer’s business or operational needs. Companies will have different roles in the management of their customers’ assets and in the provision of data and analytics centric services. While companies will have to define “how they play in this new world”, the ones willing to take on a larger role will also have to build the required new capabilities related to having access to the data, analyzing it and particularly understanding the customer’s business environment for making best use of the data in order to support customer’s decision-making, and build up the collaboration in the related network.

3.2 Decision-making needs and processes in the ecosystems

Decision-making situations can be classified into operational, tactical and strategic decisions. This allows separating everyday routine decisions from decisions with longer-term effects on the whole organization. It needs to be noticed that at the same time, the decisions can be reactive, real-time, proactive, or strategic decisions by nature. Another approach to classifying decision-making situations especially in asset management is presented by Sun et al. (2008), who classify decision-making situations using the relevant time scale as criteria. The classification of decision-making situations at fleet level is further discussed by Kinnunen et al. (2015).

While asset management for the fleet considers aspects related to operations, maintenance, investments and other means of improvement related to the assets in order to realize optimal value from the assets (ISO 55000-55002), one can adopt these aspects as a framework for considering the needs for information in supporting related decision-making. From the fleet data management and service development point of view, a useful classification is to consider decisions for operations performance, maintenance and investment planning:

- **Operations performance**: Increased intelligence in assets allows for new features related to remote monitoring and even remote control which act as the basis for new functions of the assets but also allow for new service opportunities. For example, remote monitoring allows the making of quick and accurate short-term daily decisions such as adjusting operation parameters. Predictive analytics for asset performance and descriptive analytics for causes and effects provide opportunities for case specific support and for the identification of best practices and lessons learned. The adoption of new business models, e.g. cost per performance models, as well as the related risk management can be supported by the monitoring capabilities and analytics. Other new business models may also be invented based on the transparency of the actual use of the asset.
- **Maintenance decision-making**: Failure detection and elimination of breakdowns and unplanned downtime is particularly in the focus of capital intensive industries. However, the potential of the data and analytics is proposed

to be explored from the perspectives of all relevant maintenance strategies, namely preventive (periodic and condition-based) and corrective maintenance. Maintenance decision-making situations vary from operational to strategic decision-making, including failure detection, maintenance planning and strategies, and have short-term and long-term effects. Thus, versatile data and analyses are needed to support maintenance decisions.

- **Investment decision-making**: Compilations of maintenance and performance data for the optimal timing of strategic investments and decision-making related to the optimization of investments and modernization are called for. Demand sensing and support for new offering decisions as well as the estimation and control of costs throughout life cycles are expected. These types of decisions have long-term effects and typically require versatile data about history and predictions about future scenarios.

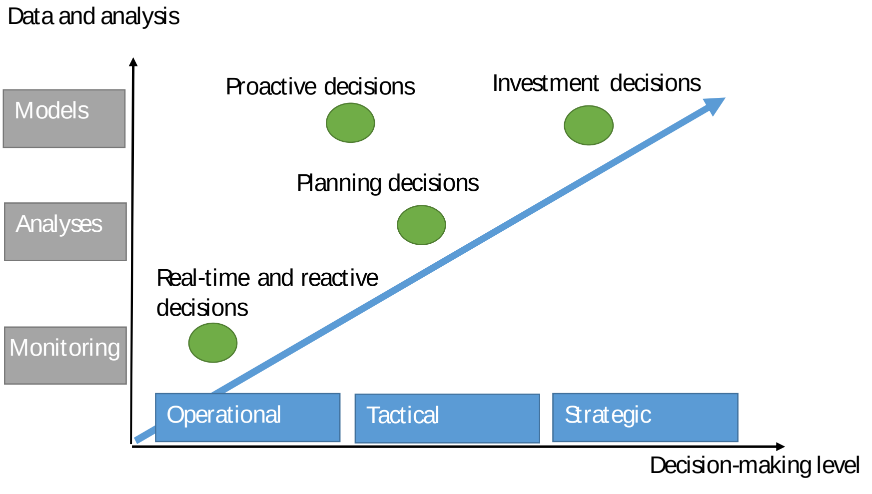


Figure 5. The nature of decision-making situations in relation to the decision-making level and the level of data and analyses.

Figure 5 illustrates the categorization into operational, tactical and strategic decisions and the role of the data and analysis level in different decisions. Often the sophistication of analyses increases along with the complexness of the decision-making situation, i.e. strategic decision-making is supported with advanced analyses and models. However, the trend has recently been that with increased amounts of data and modeling capabilities, predictive models can be developed to support proactive decisions, for example proactive maintenance tasks.

Decision-making situations can also be classified according to which phase of the asset's life cycle the decisions are made at (see **Figure 2**). The product 'life cycle' can be defined as the time period beginning with the first idea and ending with the disposal of the product (DIN ISO 15226). In capital-intensive industries, production assets typically have long life cycles and major changes may occur in all the exogenous or internal factors. (Komonen et al. 2012) Many of the strategic decisions in early design phases affect the whole life cycle of an asset. The discussion above concentrates on the utilization phase of asset life cycle as we deal with life cycle data and corresponging ecosystems. In the utilization phase, operational and tactical decisions in order to keep machinery running are essential. Furthermore, End-of Life (EOL) decision-making is increasingly important.

3.3 Data collection and sharing practices

Companies have a plenitude of sources of data - e.g. raw sensor data, event data, history data and economic data - yet the data is scattered in different systems, hindering its exploitation. In general, long-term decisions require more data and understanding of the business environment, whereas short term decisions can rely more on physical measurements. Thus data collection and analysis supporting short term decisions is easier and done more often than systematical data collection and analysis for long-term decisions. When considering the effects of short and long-term decisions, it should be in the interest of companies to develop their decision-making processes so that long-term decisions will utilize more systematic data collection and analysis methods.

3.3.1 Field data collection and sharing

In industrial plants, asset related data is collected in an O&M database. Upon performing an O&M task, whether it is part of a scheduled or unscheduled maintenance action, an O&M logbook is filled out describing the action, the component or subsystem that was serviced, and other relevant data items. This event data may be stored in several information systems, e.g. enterprise resource management (ERP) and computerized maintenance management systems (CMMS). In addition, asset data is often collected in control room diaries and in automation and condition monitoring systems. History data containing the information on the physical asset events, their upkeep and modifications is crucially important to systematic maintenance planning and valuable contribution when making tactical or strategic level decisions.

Machinery manufacturers providing services would also profit from field data and from data collected by end users and operators. However, they seldom have access to the end users' maintenance management systems, or the data is in such a format that it is difficult to use. Especially after the warranty period, the availability of data related to operational experience information is poor. During the past decade, field data collection has been widely studied and several solutions have been proposed. Some of the projects carried out by VTT are listed in **Table 3**.

Table 3. A selection of recent research projects and project reports dealing with reliability and maintenance related data collection.

Data type and use	Report name	Source (open access)
Reliability data collection and management to support machine design	Käyttövarmuustiedon hallinta ja hyödyntäminen suunnittelussa (in Finnish)	www.vtt.fi/inf/pdf/technology/2012/T48.pdf
Reliability and maintenance data collection for life-cycle service development	Development of knowledge-intensive product-service systems. Outcomes from the MaintenanceKIBS project	www.vtt.fi/inf/pdf/technology/2012/T21.pdf
Reliability and maintenance data collection for life-cycle service development	Customer value driven service business development. Outcomes from the Fleet Asset Management Project	www.vtt.fi/inf/pdf/publications/2010/P749.pdf
Life-cycle data collection and use in service design	Elinkaaritiedon hyödyntäminen teollisen palveluliiketoiminnan kehittämisessä (in Finnish)	www.vtt.fi/inf/pdf/workingpapers/2009/W136.pdf
Different data sources in maintenance management	Eri tietolähteiden käyttö kunnossapidon tukena (in Finnish)	www.vtt.fi/inf/pdf/symposiums/2005/S239.pdf
Reliability and maintenance data collection in the field: definition of data content, data collection process and means for data analysis and utilization	Data for better maintenance plans and investments policy	www.tappi.org/Bookstore/Technical-Papers/Journal-Articles/TAPPI-JOURNAL/Archives/2003/August/Data-for-better-maintenance-plans-and-investments-policy-Solutions-TAPPI-JOURNAL-August-2003-V.aspx

Machine manufacturers typically set the following objectives for field data collection and exploitation (Valkokari et al. 2011):

- Data is collected systematically regarding the whole life cycle of the product with clearly defined data items and objectives on how the data will be exploited.

- Existing data should be exploited more efficiently and new formulations of the current databases should support further data collection.

To achieve these objectives, systematic field data collection and exploitation processes must be defined and implemented. Otherwise the lack of important data items could occur at the data analysis phase and some important questions related to fleet management will remain as mysteries. In general, field data collection and exploitation consists of four phases:

- Design of data collection
- Implementation of data collection
- Data analysis, and
- Determination of measures.

One example of a systematic reliability data management process is presented in **Figure 6**. The reliability data of machinery fleets is an important part of field data.

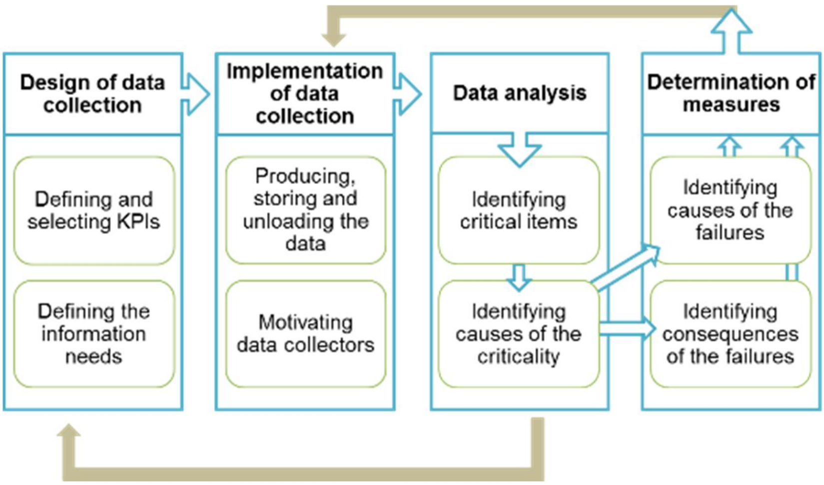


Figure 6. Process for field data collection and exploitation (Franssila et. al. 2012).

3.3.2 Business data sharing

Data sharing and information transparency between people and organizations are needed for the ecosystem-level fleet management to work properly. However, sharing data with other companies requires a considerable amount of mutual trust. As discovered by Ylä-Kujala et al. (2014), companies may not be ready to disclose data on the level of business networks/ecosystems but prefer dyadic transparency coordinated by a focal company (usually the customer). According to Ahonen et al. (2010b), companies do not see central systems as feasible solutions for inter-organizational information management due to the different natures of the partners' businesses. Instead, for example adapting the interfaces for the different companies involved, supporting dynamic decision-making and improved work management could be backed by the companies.

Figure 7. Data sharing steps.

Data sharing steps are presented in **Figure 7**. Data sharing adds transparency and can create new business models. The main barrier to sharing data seems to be the strong sense of ownership of data. However, the barriers are balanced with opportunities as **Table 4** shows.

Table 4. Opportunities and barriers for data sharing in ecosystems (adapted from Janssen et al. 2012).

Opportunities	Barriers
• transparency • more participation • creation of trust • access to data • new services • stimulation of knowledge development • economic growth • stimulation of competitiveness • new innovations • improvement of processes/products/services • new products and services	• unclear values (transparency vs. privacy) • no policy for publicizing data • no resources • no process for dealing with user input • lack of understanding the potential of data • no access to original data • no explanation of the meaning of data • information quality • complex data format and data set

Opportunities	Barriers
• availability of information • creation of adding value to the economy • reuse of data • creation of new data by combining data • validation of data • sustainability of data • access to external problem-solving capacity	• fees for the data • lack of knowledge to handle data • privacy • security • license and limitations to using data • lack of information • non-valid data • too much information or information missing • data not in a well-defined format • no support • fragmentation • no systems for publicizing data

The businesses could share their data and information to each other through secure channels, but that could cause security threats and privacy infringements. Another choice is to publish the data openly to the public, ensuring that the data does not contain critical information about the business itself. Usually when data is opened, more and more effort is put into the quality of the published data, which inadvertently causes scrutinization and a better overview of the data.

3.3.3 Open data collection and sharing

Open data is data that is shared for anyone to use, reuse and re-distribute, even for for-profit businesses. As such open data makes for an interesting and powerful business resource, since it can be harvested with no costs and analyzed. This data can be collected from different portals, websites, and other forms of data storage, from usually public sources, such as governments and municipalities. The open data itself can be practically anything that has been decided to disclose to the public. There has also been varying interest towards open data in different industries, ranging from software industry to more traditional companies, such as mechanical design and coffee shops (Herala et al. 2016a). Although there is interest towards open data, especially for application development and data analytics, the use of open data has not been realized in a wider sense. Some organizations use open data for their businesses, but it is usually used to enhance some particular solution instead of creating solutions and business solely from open data.

The current status of the open data initiative is that most of the data is published by public organizations, and the community has voiced their interest towards open data from private organizations. This initiative has found resistance, since it does not agree with the current practices of companies. However, it is possible to open business data, as long as it is modified in a way that does not cause damage to the publisher (Herala et al. 2016b). Usually when data is opened, more and more effort is put into the quality of the published data, which inadvertently causes scrutinization and a better overview of the data.

The current amount of open data could be increased, if the companies with similar fleets could share their fleet data to each other and the public, enhancing their capability to predict and analyze problems and failures. This method of sharing could increase collaborative and participative actions, especially in the R&D department, when failed experimentations and the duplication of research could be decreased. The opening can also affect the competitiveness of the sharing companies: through sharing, the companies can shape the collaborative behavior of others and also discourage competition in the same technological areas. The actions towards openness also affects the whole business ecosystem of the company, since open data is usually directed to all public, tying together governments, companies and citizens.

Scientific literature shows that by sharing the data and partially the products, companies have increased the informal dialogue between each other, collaborating in monitoring, training and remediation. These arguments suggest that data should not be considered only from the viewpoint of return of investment but also of the amount of reuse when it is compared to the effort of publishing; the value of data derives from use and reuse instead of ownership.

3.4 Practical examples of the fleet data analysis

The data collected from the installed base - or “a fleet” - concerning maintenance and operation can build up a better understanding of a product’s life cycle and its critical points compared to what asset owners have, as they usually have access only to the information concerning their own sites. Some examples to illustrate the variety of practical applications of fleet data analyses are summarized in **Table 5**.

Table 5. Existing fleet services and service concepts (Hanski et al. 2016).

Service	Service description	Data collection
ABB LEAP ABB (2010)	Condition monitoring based service which aims at extending life cycle and avoiding premature failures.	Measurement data from the machinery, failure statistics, including failure causes
Wärtsilä Genius Services Wärtsilä (2016)	Optimizing daily operations, providing predictions for future asset behaviour and instant support for the users	Historical and real-time online data from equipment and machinery; expert opinion and knowledge
Services enabled by PHM based CPS Lee et al. (2015)	PHM for similarity identification to predict future behavior of the system and for peer-to-peer comparison of the assets	Data collection from the machinery; historical snapshots from the machinery or fleet of machines
Predictive diagnosis based on a fleet-wide ontology approach Medina-Oliva (2014)	Fleet-wide PHM service	Failure information on a fleet of similar engines; failure types and causes of specific failures
A control chart guided maintenance policy selection Gupta et al. (2009)	Scheme for maintenance policy decisions through a time-based control chart	Data from tests; data from records such as dates and times of failures, and equipment working hours
Optimizing Federal Fleet Vehicle Acquisitions Helwig and Deason (2007), Singer and Daley (2015)	Prioritizing and understanding trade-offs between different mandate attainment strategies, and thus identifying optimal vehicle acquisition recommendations	Vehicle inventory; vehicle availablility; geographic location to each vehicle; fuel transaction history reports
MineLens Fiscor (2015), MineLens (2016)	Equipment and performance related data for mining companies, benchmarking and asset productivity with Big Data services	Data from mining processes, e.g. equipment location and use-related data; Benchmark data set

The examples in **Table 5** cover a wide range of applications from operational issues, like analyzing the active time of an individual fleet item, studying component failure mechanisms and performance comparisons, to more strategic decisions like replacement investment planning.

Fleet management also implies that the asset owner, fleet operator, maintenance organization or product manufacturer has an interest to consider a set of items as a fleet and that economic or other benefits are gained through fleet control and optimization. In product or service life cycle, the most essential things are usually the decision-making situations like business model design, key partner selection, pricing, purchasing and network decisions, product design related issues and also all topics related to product and production maintenance. Such decision-making situations are reviewed in Chapter 3.2.

In addition to the service offerings described in **Table 5**, wider fleet management concepts and collaboration platforms that offer tools to collect, share and analyze data are on the market. Such examples in B2B context include e.g. outcome based agriculture and the Norwegian platform for the oil and gas industry. The integrated eOperations approach in the Norwegian oil and gas (O&G) industry is presented in Chapter 5.7.

Outcome based agriculture is a connected ecosystem that provides farmers guidance to optimize their yields and coordinate their investments, and access to data and analysis such as geo-location, diagnostics, crops, fertilizers and weather data, over smartphones or farm equipment. The concept brings together the different stakeholders and actors related to the farming industry (Hanski et al. 2017, WEF 2015, Juhanko et al. 2015, 365farmnet 2015). The data is collected from different actors in the ecosystem, such as farm equipment manufacturers, chemicals providers, seed producers, and a navigation satellite systems agency. This data include sensor data from the agricultural equipment, location information from the satellites, irrigation system data, soil and nutrient sources, weather, crop prices, commodity futures related information, field shape, yields and other metrics. The platform utilizes and offers the users a variety of optimization methods.

4. Data to Business Knowledge (D2BK) Model

Industrial companies often collect big databases within the organization. Building up services on existing databases should be considered before designing new data collection efforts. Although data collection can be technically simple and not so expensive, it is not free of charge. Thus before starting to collect new data, it should be considered what kind of opportunities the data already stored in the company's databases provide. Is there a real need for new data?

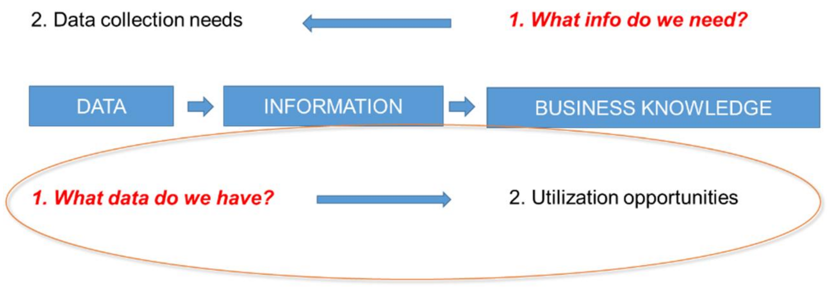


Figure 8. Before designing new data collection, the user should make the most out of the existing data.

Digital strategies at forerunner organizations go beyond technologies. They target improvements in innovation and decision-making and transform the way the business works (Kane et al. 2015). Data, information, knowledge, analytics, and the use of data in decision-making and processes is in the core of this transformation process.

4.1 Phases of the process in the D2BK model

Knowledge-intensive services are designed to provide support for decision-making. Thus, the understanding of decision-making situations and relevant alternatives is the basis for data collection and analysis. The Data to Business Knowledge (D2BK) framework (Kunttu et al. 2016, Kortelainen et al. 2015) aims at describing the content and the role of data in the context of knowledge-intensive services. The framework also illustrates the data refinement and increase in value process, in which the data is systematically converted into information, knowledge or even wisdom (see Table **6** for details).

The D2BK framework suggests that the service provider could offer new and increasing value to its customers by being able to provide knowledge and consequent actions or action plans as a service instead of mere data collecting and sharing. In this case, the service provider is capable of transforming the data and the information into knowledge that supports the decision-making of customers (asset owners) to improve their business. Such decisions could deal with daily operations, developing the assets and operations, or with long-term strategic investments, and a wide variety of other technical issues and business situations. Figure 9 illustrates the phases of the D2BK process.

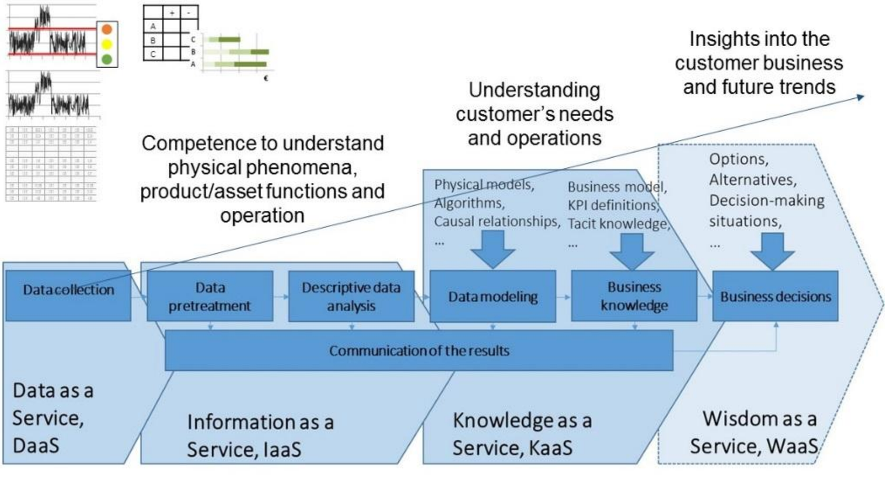


Figure 9. D2BK framework (modified from Kortelainen et al. 2017b).

Data collection has been discussed in Chapter 3.3. The following steps of the D2BK process are shortly described in the next sections.

4.1.1 Data pretreatment

Collected raw data is rarely useful as such and may require a lot of work before intended data analysis can be conducted. Data quality is crucial for any meaningful data analysis. "Garbage in - garbage out" is a well-known phrase. Thus the content of the data set must be critically assessed, because several reasons can reduce or even destroy the quality of data. The reasons can be random or systematic. Random errors, if the number of them is reasonable, are not typically crucial for data analysis because they do not cause bias to results. Random errors can be traced for example by visualizations or cross tabulations.

Systematic errors can cause bias to results. The main reason for systematic errors may reside in the data collection, either in the formal instructions or in the recording practices. To be able to recognize systematic errors, the data analyzer needs a deep understanding of how data have been collected, what information the variables really contain, who has made entries, when the entries have been made, what are the recording practices, etc. Formal instructions or recording practices tend to change over time if the data collection period is long. If data is collected by several stakeholders, there are probably also several ways to collect and record data. These discrepancies may also mean that the data set or some part of the data cannot be used.

4.1.2 Descriptive data analysis and data modeling

From a decision-making point of view, data as such is seldom useful without further processing. Data analysis - which includes descriptive data analysis and data modeling - aims at understanding the information that the collected data contains and at figuring out answers to the questions relevant to the prevailing decision-making situation. This chapter does not provide a review of existing data analysis methods, but emhasizes the importance of the system-level behavior and qualitative analysis that may support statistical data analysis. Comprehensive descriptions on data modeling and analysis are available e.g. in Pham (2006), Dalgaard (2008) and Brandt (2014).

Statistical data analysis methods can be used to compare groups, find correlations or other relationships between variables, define clusters, find normal values and anomalies, detect trends or other patterns and so on. Descriptive data analysis provides summaries of the collected data. Summaries can be basic measures (e.g. mean, median, variance) that describe the data or tables (e.g. frequencies, cross tabulations) and figures (e.g. bar charts, box-plots, spider/radar charts) presenting relevant features of the data. Descriptive data analysis creates understanding of the data content and delivers first impressions of interesting relationships between variables.

Data modeling requires different capabilities, concepts, methods and methodologies, algorithms, models and tools depending on the scope of the analysis. A suitable method depends on the problem and available data. Complex systems require complex models as they consist of different components with specific behavior and the interactions need to be understood and modeled. In order to translate patterns, anomalies and trends into predictions of the remaining lifetime or future behavior of an item, further information of the system is needed. Traditional physical models are highly complicated and require a lot of modeling efforts, or models are too simplified making it impossible to capture relevant behavior.

Data-driven models and PHM algorithms usually use pattern recognition and machine learning techniques to detect changes in system states. Also qualitative information like risk and reliability analyses, e.g. Hazop and FMECA, support the analysis phase providing essential information about the target application. These analyses could provide cause-consequence chains that connect failure indications or initiation patterns or a deviation with a certain chain of events, and link the emerging event with expected consequences (Valkokari et al. 2004). This allows the user to make predictions and to take proactive actions in time.

A further step to add value is to connect the data with business-related information like business model, key performance indicator framework, life-cycle cost and profit model, or decision-making situation. History data alone is not sufficient basis for future forecasts, but tacit knowledge, expert judgment and other data sources that help in understanding the customer's value creation have to be utilized. 'Data analysis' may then take a variety of forms and actions from benchmarking and traffic light dashboards to calculations that support long-term decisions like investments.

4.1.3 Data visualization

The human brain is not typically capable of finding out relevant information from a set of numbers which is a general form of collected data. Visualizations are one tool to present data in an understandable way. The main aim of visualizations is to condense a big amount of data into a form which supports decision-makers' or other users' attempts to understand the information included in the data. Visualizations are important tools for communicating findings between data analysists and decision-makers and can be used in different phases of the data to business knowledge model.

Data visualization is a broad branch of science and cannot be comprehensively presented in this report. Basic books about data visualization have been written by Tufte (1983) and Cleveland (1993), in addition to dozens of other books considering data visualization from different perspectives. Nowadays, as a plenitude of software tools to create figures is available, good visualizations no longer create technical problems. The main issue is to find out what kind of a figure will present the needed information in an easily understandable form.

4.1.4 Results and decision-making

Data analysis results contain information that support decision-makers' knowledge creation in the current decision-making situation. Relevant results are - once again - dependent on the case. Results can be predictions about e.g. remaining useful lifetime or expected operation costs, information on whether the current state of a system is acceptable or not, information about relationships e.g. how much of an increase in temperature increases the failure rate, etc.

The real added value arises when the data is exploited for the prediction of future behavior, for the follow-up of asset performance, for estimating remaining useful life, identifying the cause of underperforming systems and supporting planning and decision-making.

4.2 Service levels in D2BK model

Knowledge-intensive services are designed to provide support for decision-making. In addition to data processing phases, the D2BK framework in Figure 9 presents service levels. In D2BK framework, the service levels underline the value process in which the data is systematically converted into information. The theoretical background is derived from the data, information, knowledge and wisdom (DIKW) hierarchy (Ackoff 1989) or the 'knowledge pyramid' (Rowley, 2006). Table 6 summarizes the descriptions for the DIKW hierarchy and provides examples in the context of asset-related decision-making and knowledge-intensive services.

Table 6. DIKW hierarchy descriptions and examples (modified from Kunttu et al. 2016).

DIKW hierarchy	Description	Example
Data	Saved facts, i.e. values and observations about selected variables	Measured value by a technical sensor
Information	Data transferred to a form that is meaningful and useful to a human	Trends of failure rate or vibration amplitude. More generally, analyzed and processed data the meaning of which is easier to interpret over time
Knowledge	Ability to interpret trends or other signs and to recognize when actions are needed	A professional skill developed over a long time to understand the information and take actions with good results (e.g. ability to understand trends and a need for actions)
Wisdom	Ability to recognize relevant options in the current situation and to compare those as pros and cons with a skill set to utilize tools to make optimal decisions	Ability to recognize that the available vibration measurement based options are to change the component right away, or wait until the next planned stoppage, and to evaluate risks and benefits related to these options and also the skills to use, e.g. simulation tools to make an educated hypothesis of what the risks vs. rewards are in different scenarios

Based on the definitions given in **Table 6**, we suggest service levels that could be meaningful in asset-related decision-making (Kunttu et al. 2016, Kortelainen et al. 2015):

- **Data as a Service (DaaS)** is the basic level where the customer (asset owner) is provided with an opportunity for gathering asset data by means of specific technology developed and installed. At this service level, the asset owner or user takes care of data analytics and data utilization. Data services can be expanded to data storages. As a service, DaaS represents a technical competence to ensure reliable data collection in different situations. However, the service provider should be able to define which data items are relevant to the customer and to develop means of collecting most relevant data.

- **Information as a Service (IaaS)** requires that the data is further refined by the service provider. An example could be monthly reporting that is easy to understand without further elaboration by the customer. A service provider can implement this service level either by providing the customer with basic analytic tools for report generation, or by providing ready-made reports for customers. Customers do not need to disclose any data outside the company if the service includes analysis tools.
- **Knowledge as a service (KaaS)** requires that the service provider collects and analyzes information by exploiting their own capabilities and experience or by cooperating with the asset owner. The service is deeply integrated into the customer's core business and decision-making, both in the short and long term. At this level, the service provider is able to interpret and refine information into knowledge that is useful for the customer's decision-making situations. The fleet service provider can utilize the broad understanding gainded from different sites in different use environment for the purposes of interpretation.
- **Wisdom in a service (WaaS)** is not a service level in the same way as the three above. Wisdom is the ability to apply accumulated knowledge to new situations and environments and also to forecast future needs. Thus wisdom is the core issue for each company and it is not easy to outsource. In the service context, wisdom could stand for the supplier's ability to develop physical products and services needed in the future and to provide competitive edge for their customers. This requires a very deep understanding of the customer's business, and wide access to the customer's information and other business data sources.

4.3 Assessing fleet services with the D2BK-model

The D2BK framework (**Figure 9)** and the definition for service levels (**Table 6)** suggest that the service and/or product provider could offer new value to its customers by also being able to provide knowledge as a service. This would require that the service providers develop new competencies, analytical capacities and a deep understanding of the customer's value creation. The realization of knowledge-intensive service concepts also requires extensive ICT capabilities and offers ICT companies a crucial role in business ecosystems. Recently published collaboration schemes in global companies (e.g. KONE and IBM; ABB and Microsoft) support this view. The company offering in Appendix B consists of two broad categories; service concepts that enable fleet services and the fleet service concepts that are based on the systematic collection of asset data. The identified service models are summarized in **Table 7.**

Table 7. Analysis of the fleet service concepts identified by S4Fleet case companies using service models.

Company	Description of potential services based on the concept	Service level
Analytics Cloud	Technical means for IoT solutions but not capability to carry out the specific data analysis	DaaS
Etteplan	Service manager view to integrated fleet level and customer profiling information	DaaS
HUB logistics	Logistics services and material stream analyses for improved logistic processes. Providing new and better possibilities to compare and analyze processes.	IaaS/ KaaS
IBM	Analytics and platform for predictive maintenance and asset optimization solutions for fleet management	DaaS
Metso Minerals	Services for predicting equipment fails for mobile units, predictions of the units' performance and maintenance, and defining best practices	IaaS/ KaaS/ WaaS
M-Files	Offering collaboration platforms which combine data from different sources	DaaS
Outotec	Service for optimizing operations and maintenance activities, and estimating total life-cycle costs	KaaS
Ramentor	Helping customers focus development efforts to improve OEE. Using software and working practice to manage reliability and RAMS requirements.	IaaS/ KaaS
Valmet	Services for predictable and guaranteed failure free run to the customer based on using machinery and equipment related data	IaaS/ KaaS
Wapice	Platform/infrastructure service for extending the existing service from measuring the asset level to the fleet-level. Predictability information of fleet.	DaaS/ IaaS/ KaaS

ICT companies seem to focus on developing platforms and analytical tools, but do not indicate plans to incorporate substantial knowledge in their offering. Companies offering asset related services have more advanced plans for their service provision. All OEMs are large companies with a global installed base and they look for upgrading the service model with advanced service concepts (KaaS, WaaS).

From the perspective of the D2BK framework, the short descriptions for future service concepts offer the most information on the communication of results. Some companies described service concepts as enabling a wide variety of service models depending on the availability of data, the nature of customer relationships and the business model choices of the asset owner and service provider. The appropriate service model (IaaS, KaaS, WaaS) may need to be selected case-by-case depending on customer needs and limitations of available data. The choice of a service model also depends on the competitive environment, as the high-end knowledge-intensive business may be lucrative also to other service providers and third parties. In those cases, the company needs to develop competencies and acquire tools for the most demanding service offering possible to be able to maintain and increase their market share.

The acknowledged challenges include e.g. fragmented fleet data and the challenge of data sharing between various players in industrial networks. It should also be noted that the data collection environments are not equal, leading to challenges in data analysis, as well. The service concepts presented by the machinery suppliers and service providers indicate that data collection or mere information sharing is no longer sufficient but the development goals encompass a significant increase of knowledge intensity. Even technical elements for fleet services are available, the methods to extract useful information from the data and the models of value generation from the asset and fleet management perspectives require validated approaches (Kortelainen et al. 2016b).The extending service offering also covers issues on which the asset owners have traditionally had strong knowhow. This means that the service provider has to develop the excellence in refining data in a way that delivers more value to the asset owner.

5. Knowledge-intensive service concepts for extended asset services

Companies operating in the process, energy or manufacturing industry have a large quantity of different physical assets, such as machinery, equipment and infrastructure. These assets are managed in order to achieve the best possible short and long-term asset performance. The industrial ecosystem consists of a plenitude of organizations including asset operators and owners, regulatory and statutory bodies, service providers, engineering contractors, technology developers, equipment manufacturers, spare part vendors and logistic providers. Asset management calls for approaches where localized resources and capabilities are blended together with external resources and capabilities (Liyanage 2012). This also calls for customer-centric thinking as a part of service portfolio management and IoT based service business development (Hakanen et al. 2017).

Manufacturing assets typically have long life cycles and are prone to major changes due to external and internal factors (Komonen et al. 2012). To support asset management, services can be provided by several agents such as the owner of the asset, the provider of the asset, a service provider or another stakeholder. According to ISO 55000 (2014), assets should be managed during their whole life cycle with analytical approaches using multiple decision criteria and objectives. Additionally, asset management is executed at different organizational and system levels. In order to fulfill these requirements, companies delivering asset services need to establish long-term customer relationships and understand the whole life cycle of the managed assets from the perspective of all the relevant actors and stakeholders. We call the services needed to fulfill these requirements *extended asset services* (Kortelainen et al. 2017a).

5.1 Opportunities to upgrade life-cycle data to valuable business knowlege

Combining knowledge allows the collaborating parties to achieve levels of knowledge and to create outcomes they would not be capable of creating individually (Wiseman & McKeown 2010). The utilization of fleet life-cycle data enables numerous possibilities to upgrade data to business knowledge in order to support decision-making in companies. The challenges of actually using fleet data have been acknowledged; they include e.g. fragmented fleet data and the challenge of data sharing between various players in industrial networks. The case companies have identified potential possibilities of refining fleet data into business knowledge, and these possibilities are presented in **Figure 10**. Examples of the offering based on fleet life-cycle data can be found in **Figure 10**. More detailed summaries of the results can be found in **Appendix B**. The possibilities are multifold and they are suitable to many business situations from asset monitoring to new offering decisions.

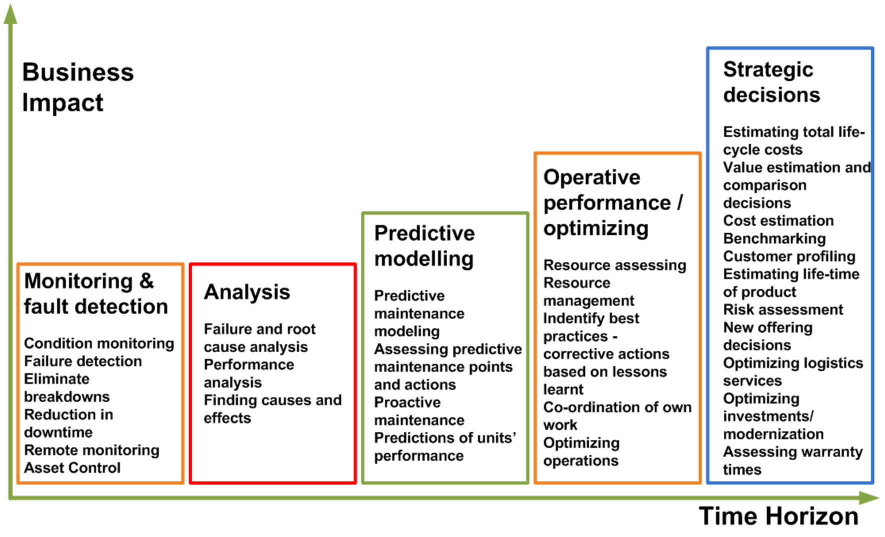


Figure 10. Examples of the offering based on fleet life-cycle data (adapted from Hanski et al. 2015).

Extended Asset Services could include features in which the service provider is capable of and has a mandate for implementing actions improving the customer's efficiency with high business impact and over a wide time horizon. With the increasing capability of transforming the data into knowledge, the service provider may take more responsibility for analyzing the data and making data-based decisions and planning for the customer (asset owner).

5.2 Modeling costs and benefits

Although the need for fleet life-cycle data as support for decision-making is recognized in companies, there is unawareness about the exact costs and benefits of refining fleet data. The knowledge and value from fleet data can be perceived as different kinds of benefits, costs savings, and other added value, such as increased customer satisfaction. The expected benefits of utilizing fleet data, named by companies, include the following:

- Increased availability of assets, increased productivity, reduced downtime
- Cost reductions related to e.g. maintenance costs, failure detection
- Longer life-times of assets
- Improved product and service development
- Resource optimization
- Best practices and benchmarking

Therefore there is a need for modeling the cumulated costs and benefits of upgrading life-cycle data to business knowledge in order to understand the potential business value. One option for modeling cumulated costs and benefits is presented in **Figure 11**. The step chart illustrates the costs and benefits cumulated over the phases of the D2BK model from data to business knowledge (including data collection, pretreatment, analysis etc.). Option II (**Figure 12**) presents the same idea of cumulated costs and benefits with mathematical functions, where the costs are assumed to grow in a linear fashion and the benefits are expected to grow exponentially. In both approaches, the value can be defined as B–C difference or B/C ratio.

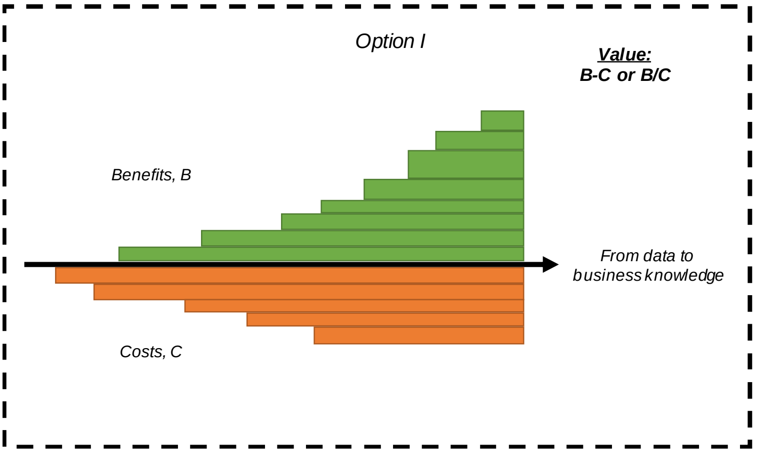


Figure 11. Step chart approach to model the cumulated costs and benefits of upgrading fleet data to business knowledge.

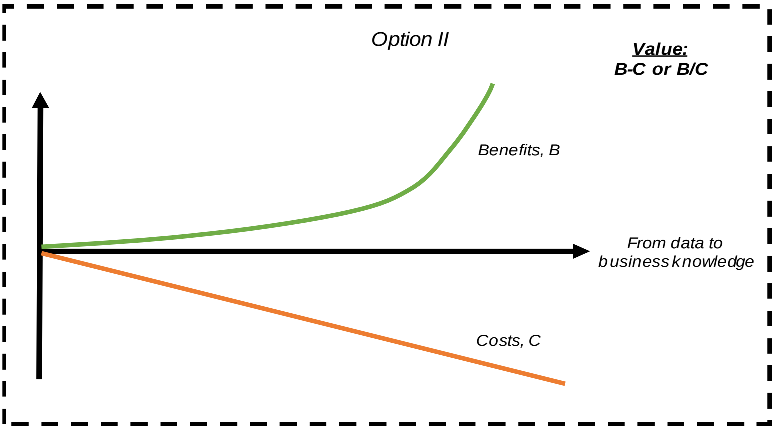


Figure 12. Linear and exponential model approach to illustrate the cumulated costs and benefits of upgrading fleet data to business knowledge.

Although IoT-based new technologies and service concepts are seen to have vast business potential, so far their adoption rate has not met the high expectations. Uckelmann et al. (2011) have described the lack of models and logics to share the costs and benefits of IoT investments between companies as one of the main reasons hindering the adoption. So far the development has been too technology-centric, and there has generally been a lack of user-centric business cases. The case companies in this research project have acknowledged this, because the customer value of the data has been highlighted in several industry-academia meetings.

When studying the value of information-based services, there are some special notions to be taken into account. Bucherer and Uckelmann (2011) refer to seven specific laws of information as an asset, originally presented by Moody and Walsh (2002):

1. The value of information is not lost when the information is shared,
2. The value increases as the information is used, and if the information is not used there is no value to it,
3. The value of information may decrease or increase over time,
4. The more accurate the information is the more valuable it is,
5. The value can increase when the information is integrated with other information,
6. Too big an amount of information decreases the value (the information cannot be processed anymore), and
7. Information cannot be consumed, it is self-generating (meaning that more information can be generated through analyzing or integrating previous information).

Thus compared to traditional (physical) assets, the value of information is a more complex concept and should be approached a bit differently. Uckelmann and Scholtz-Reiter (2011) have approached the costs of adopting the IoT through studying the costs inherent in adopting RFID. The various costs include mobile devices, aggregation hardware and software, integration to middleware and updating existing systems, training, reorganizing the business processes, new system procurement, costs of inter-organizational communication, as well as running and maintaining the system. Bucherer and Uckelmann (2011) note that *in business, customers usually expect information to be free, although it must be obvious that the costs of producing the information are then hidden in the price of the other products or services*.

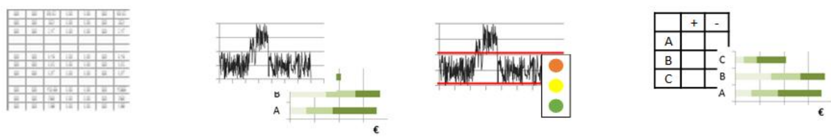
In the future, customers' willingness to pay for information might increase. In the literature, various approaches have already been presented regarding pricing IoT and data services (Niyato et al. 2015). These include e.g. market equilibrium studies, game theoretic models in duopoly and oligopoly markets, and IoT service auctions. Bucherer and Uckelmann (2011) have discussed usage based pricing, subscription fees, and information brokers in regard to pricing IoT services, and incentives to promote information sharing between companies.

5.3 Data view - data to business knowledge

The Data to business knowledge (D2BK) model in **Figure 13** presents a conceptual process for collecting data, refining the data and generating value adding services. In principle, the model applies to data from different sources, i.e. for refining continuous data (e.g. data stream from online sensors) and for creating business knowledge from event data (e.g. history data from EAM/CMMS). Similar steps for processing data have also been reported e.g. by Backman et. al. (2016).

The aim of data collection and analysis is to provide a decision-maker with information on alternatives. As discussed in Chapter 3.2, the range of decision-making situations and planning and monitoring activities is large, ranging from reliability, risk, operation and maintenance management to work and inventory management, asset level health management and state and condition monitoring. The sensor data may be analyzed with physical or statistical models in order to predict the future behavior of an item or process. The information may lead to an immediate action on an operational level, but the information may also trigger such decisions that require extensive planning.

Data as a Service	Information as a Service	Knowledge as a Service	Wisdom as a Service



Database containing data on measurements, maintenance history etc.	**Report** representing various KPIs and visualizations based on the gathered data	**Interpretation of information** by answering, for example, to questions: • when are the measurement values deviating • when does the maintenace program need to be changed • when does a need for technological changes in the fleet exist etc.	**Evaluation of alternatives** by answering, for example, to questions • how to deal with deviations • how to develop the maintenance program etc.

Figure 13. Data to business knowledge (D2BK) model (translated from Kunttu et. al. 2016).

Both the DIKW hierarchy and the D2BK framework suggest that the service provider could offer new and increasing value to its customers by being able to provide knowledge and consequent actions or action plans as a service instead of mere data collecting and sharing. In this case, the service provider is capable of transforming the data and the information into knowledge that supports the decision-making of the customers (asset owners) to improve their business. Such decisions could deal with daily operations, tactical means for developing assets and operations, or with long-term strategic investments, and a wide variety of other technical issues and business situations.

The D2BK framework also suggests that the service providers have to develop new competencies, excellence in analytical capacities and deep understanding of the customer's value creation. Service providers might have more knowledge to build these competencies on than asset owners do, as they are in a position to collect and analyze data from their installed base and from a plenitude of use environments. However, the applicability and relevance of the fleet data has to be carefully reviewed before providing predictions.

As stated in Chapter 5.2, upgrading life-cycle data into business knowledge is not free of charge but requires major investments in building capabilities and ICT. Collaboration and varying roles in the ecosystem may offer a solution. ICT companies seem to offer support to the expanding role of OEMs (Kortelainen et al. 2017b). The strategy in the digital transformation may be that not all companies aspire the same role as a "knowledge company" covering the whole range in the D2BK process. The companies may update and upgrade their role in the ecosystem as an enabler, information deliverer, asset provider or asset service provider with a limited or extended offering.

5.4 Data view - from manual activity to automated service efficiency analysis and reporting

HUB logistics has carried out the first step of the WMS (warehouse management system) project and is now on the second phase to develop business intelligence solutions on top of new data collection practices. In the first phase, the data collection practices from old manual (pen & paper and delay digitized) ways are now transferred into a more modern automated direction and almost instantly updated to computerized and active database based models. With the research collaboration between HUB logistics and LUT, HUB logistics is proceeding with new ways of operation in their customer sites, looking at the big picture, and enhancing the operations in all three fronts at the same time (digital tools, layout solutions of item locations and process optimizations).The purpose has been to enhance data collection practices to support in-house logistics process development and the determination of KPI indicators, which can further support service analysis and development. HUB logistics is continuing their work after the S4Fleet research project towards centrally monitored KPI driven customer site management models, which will be based on the real-time field and supply network data.

Just as machinery and equipment are important to the performance of a facility, the logistics processes and tools used in the processes are vital to the performance of in-house logistics operations and therefore to the logistics operator and its customers as well. While assets in industrial environments are often machinery and equipment, the assets of logistics service operators are the systems, processes, logistics machinery and workforce working within this context. In order to optimize the safety and cost efficiency of processes, the processes need to be highly monitored and after that optimized based on collected data. In addition, the usage of workforce and equipment (e.g. trucks and forklifts) resources needs to be thought through carefully. For example, the workforce needs to be directed to tasks in which their skills are giving them the most efficient results with minimal stress. In the long run, the development goals of the person and the company should be lined up in a way that the motivation for development is self-evident, offering a good ground for fruitful work environment for the workforce to achieve the corporation goals at the same time as the person is achieving career goals. On the other hand, online data from operations enable the management of daily processes and fast and timely reactions by taking corrective actions when needed.

From a management point of view, the accurate data enables the enhancement of KPI reporting and the following of operations at customer sites. With KPI based, site-by-site comparable data, the improvement efforts, i.e. identified best practices, can be generalized and implemented in other customer fleet sites as well. This data-based verification of best practices allows HUB logistics to generate logistics related gains for all of their current and future clients in the years to come.

The current work continues in phase two, where the aim is to optimize logistics processes with the aid of Business Intelligence tools. Data-based analysis tools enable the support of process development, including layout changes, item relocations, optimized personnel work rotations etc. Development work continues in terms of the utilization of online data to optimize the cost efficiency of in-house logistics operations and e.g. the maintenance costs of truck fleets. In addition, the enhanced data collection practices enable the development of monitoring and reporting capabilities, including KPI specifications, which makes it possible, for example, to monitor the status of customer sites and to benchmark the sites and processes for further improvements. Now that the basis for better data utilization is developed, the data analysis and utilization for decision support needs to be developed further. In addition, data gathered through WMS enable taking advantage of big data analysis tools in the future.

5.5 Service view - extending service delivery

Extended asset services refer to the extending of service delivery to long-term co-operative development of physical assets over the whole life cycle in close collaboration with the end customer and other stakeholders. The potential for extended asset services emerges along the value chain. One method to identify gaps in companies' service portfolios and highlight the potential for completely new services potential is to make use of holistic frameworks.

Examples of such frameworks are e.g. the Total Cost of Ownership (TCO) (Keys & Chen 2009) and the Closed loop life cycle framework (Valkokari et al. 2016a). The TCO and closed loop frameworks represent important future development pathways for extending current asset services; TCO monetizes the benefits and costs, and the closed loop framework enhances the sustainability and circular economy practices of asset services (**Table 8**). The assessment framework helps the technology and service providers to better understand *which actions the customers carry out*, and which cost and value elements drive their actions.

Table 8. The phases in the Total Cost of Ownership and the closed loop life cycle frameworks (adapted from Kortelainen et al. 2017b).

Life cycle phase	TCO framework cost elements	Phases in the closed loop life cycle framework
Beginning of life	Ownership costs - Delivered price - Facilities capital costs - Miscellaneous ownership costs	Design and development
		Realization - Resource processing - Suitable R-strategies (e.g. reuse, re-realisation, redesign, recycling)
		Distribution
		Sales
Middle of life	Explicit operating costs - Energy - Operator's wages	Utilization - Service + Enhancement - Suitable R-strategy
	Implicit operating costs - Maintenance - service - Maintenance - repair - Out-of-service lost revenue - Wearing parts cost	
End of life		End-of-Life or retirement - Collection - Suitable R-strategy - Waste

An analysis of the service descriptions from **Appendix B** confirm the assumption that service offering development focuses on the utilization phase of asset performance with the emphasis on reducing maintenance costs. There are plenty of untapped service potential and "gaps" in the service offering, e.g. in the area of explicit operating costs and EOL services (Kortelainen et al. 2017b).

5.6 Service view - demonstrating value by benchmarking

In global operations, service sites are seldom comparable: the installed base (fleet), environmental conditions and processed raw materials can vary significantly – among other operational parameters. Service companies have a strategic focus on providing the customers with the highest value services to improve their asset performance. Customer value, however, is case-specific – the solutions provided to one customer might not be as valuable to the next, due to e.g. customer-specific competences or external constraints.

A commonly applied benchmarking procedure is the comparison of the average values of the particular industrial sector with the company's own values (Komonen et al. 2011). As the focus is on the development of maintenance service offerings, benchmarking should categorize the sites or plants according to their operational or maintenance environment. "Maintenance environment" collects together the data arising from sites similar enough with respect to external aspects affecting maintenance activities (Kunttu et. al. 2017, Valkokari et al. 2016b). The maintenance environment describes features that affect the requirements of the maintenance function and includes maintenance policy and maintenance activities. Such features include for example: the availability of competent employees, climate effect on maintenance conduction, the life cycle phase of equipment and the maintainability of equipment. From a service provider's point of view, these aspects are external and cannot be controlled by a service provider. An example of the benchmarking process is presented in **Figure 14**.

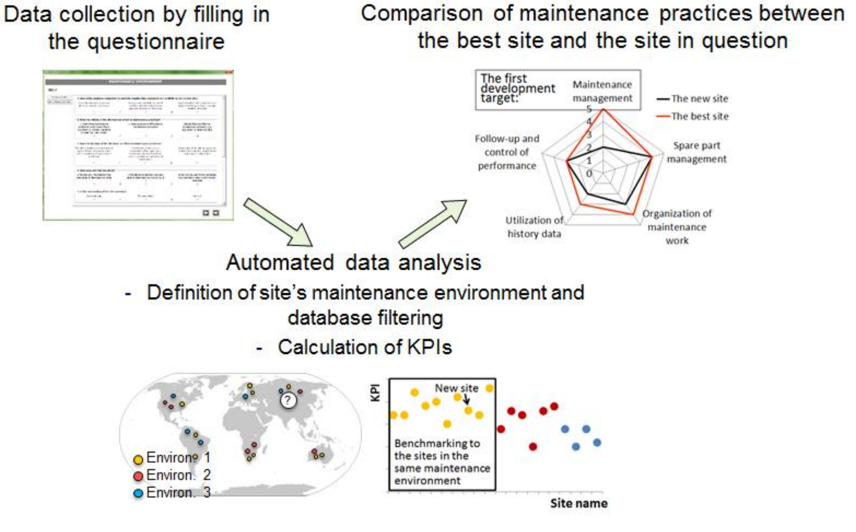


Figure 14. Example of benchmarking results pointing out development targets in a new site (Kunttu et al. 2017).

The benchmarking tool helps in identifying and visualizing the potential sources of value. With this approach based on categorizing sites to comparable units and benchmarking them against each other, the service provider is able to improve its capability in:

- Showing improvement potential in asset management and making recommendations of applicable asset management policies,
- Facilitating sales by optimizing the customer specific product and service offering, and
- Concretizing the customer value of the service provision.

5.7 Ecosystem view - common platforms

As a response to declining competitiveness, Norwegian oil and gas producers, supported by the Norwegian government, initiated an industry-wide program in 2003, the aim of which is to gradually change over from the conventional mode of operation to integrated operations (IO) (Liyanage et al. 2006; Liyanage & Langeland 2008; Liyanage 2008). IO is introduced in two phases; the first phase (approx. 2003–2011) concentrates on bridging the gap between onshore support and offshore operations, while the second phase (approx. 2006–2018) is targeted at improving inter-organizational collaboration and transparency (Norwegian Oil and Gas Association 2007). IO brakes down former silos and emphasizes the role of the ecosystem.

Successful ecosystems are founded on common platforms of services, tools or technologies the members of the ecosystem are able to use to enhance their own performance (Iansiti & Levien 2004). The Norwegian oil and gas industry is not an exception as an integral part of the transition to IO has been the implementation of an ICT infrastructure known as the Secure Oil Information Link (SOIL) (Liyanage et al. 2006; Liyanage & Langeland 2008). Data transmission in SOIL between onshore and offshore activities relies on fiber-optic cables laid on the Norwegian seabed complemented with radio and satellite communication as illustrated in **Figure 15**.

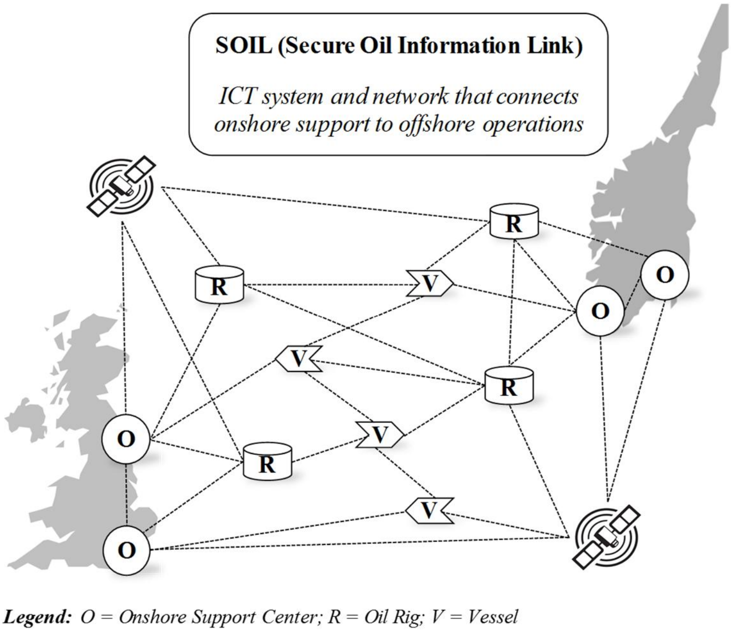


Figure 15. Secure Oil Information Link (SOIL): the common platform in the oil and gas industry (adapted from Liyanage et al. 2006; Liyanage & Langeland 2008).

As the industry's common platform, SOIL is the 'neural network' that improves communication in both intra- and inter-organizational domains. In addition to SOIL itself, a multitude of Internet of Things (IoT) technologies are required in the collection, pretreatment, refinement and analysis of data and information (Liyanage et al. 2006; Liyanage & Langeland 2008; Liyanage 2008). The offshore environment is saturated with sensors, actuators and remote controlling capabilities. CCTV and wearable devices are utilized to monitor the assets' condition in oil rigs and vessels. Onshore support personnel take advantage of e.g. virtual workspaces and conferencing facilities. Diagnostics and prognostics are increasingly carried out online, while 3D visualization and simulation are becoming commonplace in the drilling planning.

According to Rong et al. (2015), IoT-based ecosystems follow three distinctive patterns; high-open, medium-open and closed. High-open ecosystems are still emergent, which means that focal companies invite other stakeholders to add value to the common platform so that the ecosystem would co-evolve. Once ecosystems mature to medium-open, their common platforms are being controlled by focal companies, but still refined collaboratively. In closed ecosystems, common platforms are already considered as dominant designs. By adopting this characterization of Rong et al. (2015), the Norwegian oil and gas ecosystem lies somewhere between medium-open and closed. SOIL is a dominant design, but the producers allow other stakeholders, such as service providers, to develop the industry's IoT toolbox.

5.8 Ecosystem view - sharing data

Cloud services offer a practical solution for data sharing between companies. The cloud service provider represents a third party who has no own interest in the data content but a strong interest in securing data. In case machinery manufacturers and component users have contracts the terms of which are based on actual performance, e.g. availability or overall equipment efficiency, data stored in the cloud ensures consistent data and calculations for both sides. An example of cloud-based data sharing in an industrial ecosystem in
Figure 16 consists of a platform for data collection and sharing and provides an identical view of contract terms and Key Performance Indicators to all stakeholders.

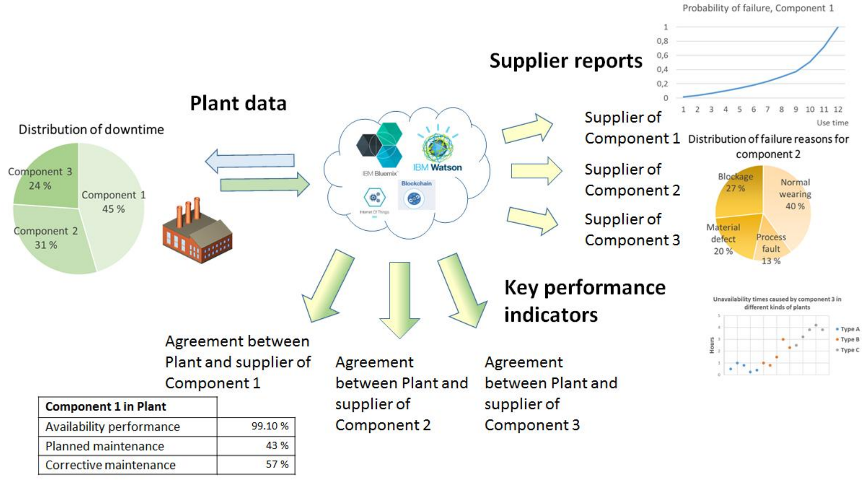


Figure 16. Cloud service concept where the end user plant has the leading role (Kinnunen et al. 2016).

Technical and economic data on geographically scattered fleets is vast, multifaceted, and usually fragmented into various companies. It is not feasible for each company to process all of the data by themselves. Hence, data sharing would have several positive impacts on business, e.g. through motivating collaborative decision-making and by increasing transparency from the provider side.

Trust itself is the key ingredient in making sharing possible. Pekkarinen and Ali-Marttila (2016) suggest that data sharing could be first piloted for a sub-process. This would allow the operations to develop and collaborative practices to establish. Step by step as the collaboration level increases, the data sharing level could also be increased within the relationship. The cloud service concept illustrated in

Figure **16** aims at overcoming challenges related to trust and the fact that component users do not get any direct benefits from data sharing. The concept consists of three main stakeholders: a component/system supplier, plants using components in their production line and a cloud service provider. In addition to traditional data collection, analyzing and sharing through a cloud, the concept presents the idea of using the collected and analyzed data in contract verifications. The calculations of key performance indicators used in terms of contracts, e.g. availability or overall equipment efficiency, can result in different values if the source data varies. Thus if KPIs are calculated from data stored in a cloud, the results should be consistent for all stakeholders.

5.9 Pricing IoT-based fleet services

Data-based fleet services are a feasible way for various manufacturing companies to create more cash flow and support their equipment sales (see e.g. Oliva & Kallenberg 2003). According to the 2015 financial statements of certain big manufacturing companies, an extensive share of their revenues are created through services (for example Xerox with 56%, Rolls-Royce with 50%, and Konecranes with 44%).

As one aspect of the D2BK model, we have developed an analytical model for pricing new IoT-based services in the context of industrial equipment fleets. Here a brief introduction to the model is presented; more details can be seen in Marttonen-Arola et al. (2016). The model suggests that the optimal price of a fleet service depends on the life cycle of the service, the required rate of return, the size of the fleet, and the economies of scale in fleet service development.

Let us assume that a fleet manufacturer develops (or purchases) IoT-based solutions to support their core product. R&D costs are incurred and the company hopes to gain revenue through installing the service concept for its customers. The R&D costs of the IoT technology (C) can be calculated as a function of the size of the fleet (q), and technology-related economies of scale parameters a and b:

$$C = aq^b. \tag{1}$$

The unit cost (C/q) is thus assumed to decrease when the size of the fleet increases. This is congruent with e.g. the four-layer structure of the IoT presented by Niyato et al. (2015), the tiers being: 1) devices, 2) communications and networking, 3) platform and data storage, and 4) software layer for data management and processing. Out of these four layers, at least two (platform layer and software layer) can be seen as sources of fixed costs that are not directly dependent on the size of the fleet. Rayport and Sviokla (1995) emphasize that the emergence of virtual products and services changes the whole notion of economies of scale and scope. However, so far empirical research on the exact economies of scale in digital services has not been presented.

The R&D costs of the novel IoT technology (C) can be further divided into several cost components. Existing literature usually assesses the costs of adopting the IoT based on the costs inherent in adopting e.g. radio-frequency identification (RFID, see Uckelmann & Scholz-Reiter, 2011). Adopting this view, it can be said that

$$C = \sum_{d=1}^{9} C_d, \tag{2}$$

Where

C1 = the cost of mobile devices
C2 = the cost of aggregation hardware and software
C3 = the cost of integrating to middleware and system updates
C4 = the training cost
C5 = the cost of reorganizing the related business processes
C6 = the procurement cost of new systems
C7 = the cost of inter-organizational communication
C8 = the cost of running and maintaining the system
C9 = other possible costs (Uckelmann & Scholz-Reiter, 2011)

For the sake of simplicity, our model assumed that the R&D costs are accrued during one single year. The cost is then divided along the life cycle of the service with the annuity method. The price of the service (B) can be presented as

$$B = \frac{i \sum_{d=1}^{9} C_d}{1 - (1 + i)^{-n}}, \tag{3}$$

where i represents the required return of the investment, and n the targeted life cycle of the service. When equation (1) is inserted in equation (3) we get

$$B = \frac{i * aq^b}{1 - (1 + i)^{-n}}, \tag{4}$$

Finally, the service development can be addressed from the perspective of the payback period (C/B), with an objective criteria of

$$C/_B \leq n. \tag{5}$$

It should be noted that in practice a payback period very close to the length of the service life cycle would seldom result in feasible profitability. In most cases, the payback period has to be significantly shorter than the life cycle for the company to create profit.

6. Implementation pathways

The Fleet information network and decision-making project resulted in a number of analysis tools and service concepts for decision support that will be further developed by the participating companies. The developed tools and service concepts enable the gaining of additional monetary and non-monetary benefits. Benefits which the companies expect from the developed tools and service concepts are presented in detail in **Table 9**. Monetary benefits can be, for example, cost savings related to maintenance costs and reduced production losses. Cost savings can also be achieved with improved resource utilization. Improved resource utilization can be related to the utilization of machinery and equipment as well as to the utilization of workforce. Fleet-wide analysis enables improved efficiency because of real-time operational insights and employee productivity. Tools may also enable the improvement of maintenance planning and the consideration of the whole life cycle of assets.

In addition to the monetary benefits, the developed analysis tools turn up better services. Better services can manifest as better service quality, satisfied customers, longer service contracts and added value for customers. The analysis tools developed in the project improve fleet management practices in companies and enable the provision of new services for their customers in order for different stakeholders to benefit from fleet-wide data and analysis.

The service concepts are also bound with costs as discussed in Chapter 5.9 and shown also in **Table 9**. The concepts need to be implemented in the organization. Three examples of implementation pathways are presented in Chapter 6.1.

Table 9. Overview of the expected costs and benefits arising from the proposed service concepts in the case companies (modified from Kinnunen et al. 2017).

Company	Description of potential services based on the concept	Costs and benefits
Analytics Cloud	Technical means for IoT solutions but no capability to carry out the specific data analysis	Costs from data management, integration, development costs of service concept Benefits for customer: increased efficiency, increased productivity, reduced downtime, reduced costs, discovered opportunities
Etteplan	Service manager view to integrated fleet level and customer profiling information	Costs: N/A Competition advantages, speed and effectiveness in service processes, life cycle management, added value, savings and quality as benefits to customer, more service process automation, higher price, higher quality, more benefits
HUB Logistics	Logistics services and material stream analyses for improved logistic processes. Providing new and better possibilities to compare and analyze processes.	Costs of developing best practices at a test site, implementing and applying best practices to other sites Benefits are efficient resource utilization, better quality
IBM	Analytics and platform for predictive maintenance and asset optimization solutions for fleet management	Costs: N/A Benefits for product supplier: improved product development, maintenance, new service models, selling data to third parties, improved customer satisfaction, overview of the whole life cycle. Benefits to product client (asset owner): improved maintenance, reduced costs, developed decision process.
Metso Minerals	Services for predicting equipment fails for mobile units, predictions of unit's performance, maintenance and defining best practices	Development costs of the service Benefits for all areas of business, including supply chain management, maintenance, process control, sales, customer support etc.

Company	Description of potential services based on the concept	Costs and benefits
M-Files	Offering collaboration platforms which combine data from different sources	Platform development costs Benefits for customer: better data accessibility, data quality, coherent and reliable foundation for decision-making
Outotec	Service for optimizing operations and maintenance activities, and estimating total life-cycle costs	Costs: N/A Benefits: reduced production losses, reduced failure risk, benchmarking tool to support and optimize operations and maintenence activities
Ramentor	Helping customers focus development efforts to improve OEE. Software and working practice to manage RAMS requirements.	Costs: N/A Benefits for contract period length setting & pricing, profitability & customer satisfaction
Valmet	Services for predictable and guaranteed failure free run to the customer based on using machinery and equipment related data	Costs: N/A Benefits: most critical faults → reliability analysis helps in planning and analyzing maintenance; Savings in maintenance costs
Wapice	Platform/infrastructure service for extending the existing service from measuring the asset level to the fleet-level. Predictability information of fleet.	Costs: N/A Benefits: increased efficiency, cost savings, better service

6.1 Examples of implementation pathways

6.1.1 Implementation pathways at Outotec

Within the S4Fleet project, Outotec has developed in cooperation with VTT a benchmarking concept and/or tool for categorizing and benchmarking customer sites (see Chapter 5.6). The project's basic presumption is the notion that Outotec's customer base is a large and heterogeneous group of mining companies, metals and chemicals producers as well as energy providers. According to Outotec, the challenge is that customer sites are not comparable against each other and thus it can be difficult to come to a conclusion on which levels of maintenance are better than average or worse than average, or whether certain productivity levels can be achieved within certain maintenance environments.

The 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 understanding on 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 allows 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 allows 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 also in internal product development being faced by the key challenges of customers. Addressing the service product portfolio accordingly will give Outotec insight into what types of services the customers demand the most.

6.1.2 Implementation pathways at IBM

IBM has developed a Data sharing concept together with VTT (see Chapter 0). For IBM, the concept offers a starting point for a functional demo IBM is now planning. The focus is now on connecting current products and services to the concept. Such items include e.g. IBM Maximo, IBM Watson and BlueMix, and new components like Blockchain.

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 manufacturing industry is one of the main customer sectors of IBM. Manufacturing industry companies are also the main target group of 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 for presenting IBM solutions to the industrial sector customers. The functional demo is a necessary starting point that will support sales especially in the Nordic countries. Further spreading is possible if the concept finds acceptance in the Nordic industrial companies operating globally, and leads to commercial results.

6.1.3 Implementation pathways at HUB logistics

HUB logistics has carried out the first step of the WMS (warehouse management system) project and is now on the second phase to develop business intelligence solutions on top of new data collection practices (see Chapter 5.4 for details). In phase one, the data collection practices from old manual (pen & paper and delay digitized) ways are now transferred into a more modern automated direction and into almost instantly updated database models (see Kinnunen et. al 2017 for details). With the research collaboration between HUB logistics and LUT, HUB logistics is proceeding with new ways of operation in their customer sites, looking at the big picture, and enhancing the operations in all three fronts at the same time (digital tools, layout solutions of item locations and process optimizations).The purpose has been to enhance data collection practices to support in-house logistics process development and the determination of KPI indicators, which can further support service analysis and development.

Just as machinery and equipment are important to the performance of a facility, the logistics processes and tools used in the processes are vital to the performance of in-house logistics operations and therefore to the logistics operator and its customers as well. While assets in industrial environment are often machinery and equipment, the assets of logistics service operators are the systems, processes, logistics machinery and workforce working within this context. In order to optimize the safety and cost efficiency of processes, the processes need to be highly optimizedand the usage of workforce and equipment (e.g. trucks and forklifts) resources needs to be efficient. For example, the workforce needs to be directed to tasks in which their skills are giving them most efficient results with minimal stress. Online data from operations enable the management of daily processes and fast and timely reactions by taking corrective actions when needed.

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7. Understanding the market

The digitalization of industrial enterprises and activities is expected to bring major benefits to the European industry. PriceWaterCoopers (PwC 2014) has estimated that European industrial companies will invest on average 3.3% of their annual revenues in industrial internet solutions. This is equivalent to an annual sum of more than €140 billion and nearly 50% of the planned new capital investments. A German study (BMWi 2015) indicates similar prospects but reminds that most German companies estimate that the investment costs could be higher on a mid-term basis than the expected company growth in terms of turnover. Frost & Sullivan (2016) are also cautious with the market opportunities and point out that operators want to see immediate value and Return on Investment (ROI) before they invest, as margins in manufacturing are small. This fact sets challenges to the market introduction of IoT-based services. The S4Fleet companies also recognize the need to address both costs and benefits when considering implementation pathways (see **Table 9**).

The service business offers global product manufacturing companies high growth potential and a steadier and more continuous turnover than the capital business. As an example, a machine with a 30-year serviceable time and annual maintenance costs of 10% of the acquisition price generates service business income that is three times higher than the initial capital investment. Most Finnish manufacturing companies developing digital services for "fleet management" consider first monitoring and maintaining their products, i.e. the installed base in customer sites (Hanski et al. 2016, Kortelainen & Koskinen 2016). This is in line with international market studies. For instance, Frost & Sullivan (2016) suggest that real-time monitoring and predictive maintenance of industrial equipment are two of the best use cases demonstrating immediate benefits and ROI.

Several surveys in Europe (e.g. EU 2016, KPMG 2015, EFNMS 2012, Kunttu et al. 2010) indicate that the average maintenance spending in different industrial branches is around 5% of the plant turnover. This figure does not include lost revenue arising from lower product quality or production losses. Extending the scope of knowledge-based solutions beyond maintenance activities towards a variety of operation, efficiency, predictability and life-cycle support options on customer sites might open new business opportunities to fleet service providers, as well. McKinsey (2015) estimates in its report "*The internet of things: mapping the value beyond the hype*" that IoT in a worksitessetting can have a global economic impact of $160 billion to $930 billion per year in 2025. In this context, "a worksite" refers to a custom production environment, such as a mine, oil and gas extraction site, and a construction site. According to McKinsey, improvements in operations from IoT applications could be worth more than $470 billion and improved equipment maintenance potentially more than $360 billion per year. However, the calculation base is unclear. These figures could make sense when compared to the rough estimate of annual maintenance spending 403 Mrd € in Europe (KPMG 2015) and to the fact that European countries represent 15–20% of the world economy (IMF 2016).

The Industrial Internet or IoT in general (see **Figure 17**) contains features that open a relevant market view also in our context. IoT solutions are regarded as a platform for an ecosystem capable of capturing data and performing analytics. According to Frost & Sullivan (2016), major drivers for the next 3–4 years are:

- Improving efficiency through the availability of real-time information,
- Reducing downtime and maximizing revenue through predictive decision-making, and
- Identification of historical patterns shaping decision-making.

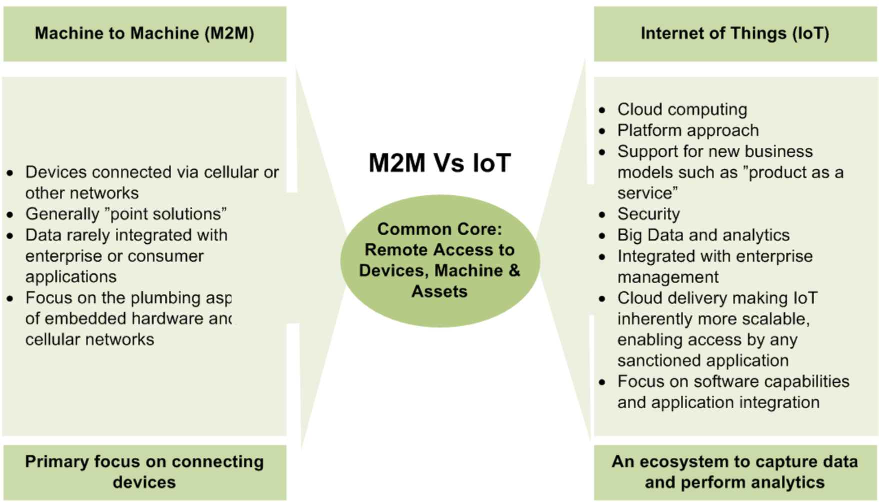

Figure 17. IoT solution as a platform for an ecosystem capable of capturing data and performing analytics (Frost & Sullivan 2016).

Companies offering IoT platforms as marketplaces offer another view to the market. Ecosystems are highly valued in B2C products (Alstyne et al. 2016), and there are multiple examples of large-scale platform enterprises in consumer business. It is more than likely that same phenomena will occur in the B2B sector, as well. One example of a B2C/B area is 365FarmNet (365FarmNet 2017). It is a free field mapping service for managing the whole 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 available for charge. 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 webpage does not reveal the company earning logic, but fees for “extra modules” seem to be at least a part of the cash income flow.

An example of an information platform is the recent development of SSAB SmartSteel, a digital platform that enables steel to be loaded with knowledge (SSAB 2017). 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 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.

8. Summary and conclusions

The Fleet information network and decision-making project focused on producing innovative solutions that enable the 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 e.g. equipment and machinery, people, customers, or platforms. Fleet management was considered to include the management of installed bases, i.e. 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. The *Data to Business Knowledge (D2BK)* model was constructed to turn fleet-based life-cycle data into business intelligence. 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) value of shared information in the ecosystem.

The model brings new insight into improving fleet management practices and designing new fleet-based services. The model also offers tools for determining the costs and benefits of fleet level information and for pricing fleet-based IoT services. The significance and different roles of actors in the value creation of fleet data at ecosystem level are discussed.

The new fleet-based services reach beyond the current service offering which typically consists of monitoring and maintaining the installed base in the customer sites. *Extended asset service* refers to extending the service delivery to a long-term co-operative development of physical assets over the whole life cycle in close collaboration with the end customer and other stakeholders. The potential for extended asset services emerges along the value chain.

The new ways of gathering, analyzing, understanding, and then utilizing information in fleet level operations in a value network form the key competence when designing extended service solutions around information. One method of identifying gaps in companies' service portfolios and highlighting the potential for completely new services is to make use of frameworks and philosophies that help in understanding the customer's operation and business in a holistic way. As an example, the Total Cost of Ownership model opens up the customer's cost structure and helps in identifying the value elements of the service. The closed loop framework broadens the scope to the operation ecosystem and emerging issues of sustainability. Companies may update and upgrade their role in the ecosystem as an enabler, information deliverer, asset provider or asset service provider with a limited or extended offering.

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. The Industrial Internet, Industry 4.0, and digitalization in general will cause major changes in the European industry. It will change supply chains and the ways of working in a crucial way, and change roles in the ecosystems maintaining industrial assets. A plenitude of data will be available, and the understanding and utilization of the information in fleet level operations in a value network will offer a competive advantage. Services for fleet management are one possible specialization area in the wide IoT context, and so it offers possibilities of competitive advantage also for small nations like Finland.

At the moment, business networks are still struggling with collaboration, and a systematic approach to value creation in ecosystems and fleet management is needed. Typically ecosystems or business networks are poorly managed, and there is huge hidden win-win potential. It needs to be acknowledged that the era of individual machines and companies is transforming into networks and ecosystems. Technological IoT solutions are available, but their full potential cannot be reached if willingness and maturity to collaborate are not taken to the new level.

Acknowledgements

The research leading to these results has received funding from Tekes – the Finnish Funding Agency for Innovation. The authors gratefully acknowledge Tekes for the financial support that made this study possible.

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Appendix A: Service solutions for fleet management (s4Fleet) program Key Characteristics

The Fleet information network and decision-making project is carried out as a part of the Service solutions for fleet management (s4Fleet) program coordinated by DIMECC. The purpose of the DIMECC S4Fleet program (2014-2017) is to research the variety of possibilities of technological breakthroughs enabling service business. The objective is to explore and exploit the possible managerial possibilities and challenges related to applying the available technologies towards a global, distributed customer base. A strong research consortium can lead the way for Finnish industry renewal. This collaboration and multidisciplinary accomplishments can have a remarkable impact on the competitive advantage of Finnish firms and their position in international trade.

--Reseach consortium

Companys	*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 institutions	*Aalto University, Lappeenranta University of Technology, Tampere University of Technology, University of Vaasa, VTT Ltd.*

S4Fleet program projects and subprojects:

- P1: Strategic Intelligence in fleet management
    - Strategic service business intelligence
    - Service offering
    - Profitability-driven service business renewal
    - Service transformation
- P2: Predictive service operations for dynamic fleet
    - Dynamic service delivery systems for distributed fleets
    - Managing manual fleet data and enhanced service experiment for operational excellence
- P3: Fleet based industrial data symbiosis: information based value network

    P3 SP1 Fleet information network and decision-making

    P3 SP2 Fleet Platform Concept

More information:

http://www.dimecc.com/dimecc-services/s4fleet/

Appendix B: Overview of the findings in the case companies

Table B1 Overview of the results of the D2BK model in the case companies.

Company	Description of potential services based on the concept	Service concept description (if applicable)	Service level	Primary role in eco-system	Economy of scale from fleet data
Analytics Cloud	Technical means for IoT solutions but not the capability to carry out the specific data analysis	*Data collection and pretreatment:* Tools are offered for collecting data from customer's fleet of machines and operations *Data analysis and modeling:* Technical means are offered on which the IoT services can be built *Communication of results:* Increased production output, elimination of breakdowns, predictive maintenance modeling, reduction in downtime, optimization of logistics services	DaaS Providing technology for DaaS/IaaS/ KaaS	BI & analytics service, data management and architecture, data integration Capture – Analyze - Visualize	Fleet is the assets of the customer
Etteplan	Service manager view to integrated fleet level and customer profiling information	*Data collection and pretreatment:* Machine unit info and various other information sources *Data analysis and modeling:* *Communication of results:* Service manager view to integrated fleet level and customer profiling information. There is a need for making information available to field service and maintenance management personnel.	DaaS Providing technology for DaaS/IaaS/ KaaS	Data linkage and integrity Task propositions	Fleet is the assets of the customer

Company	Description of potential services based on the concept	Service concept description (if applicable)	Service level	Primary role in eco-system	Economy of scale from fleet data
HUB logistics	Logistics services and material stream analyses for improved logistic processes. Providing new and better possibilities to compare and analyze processes. Service enables resource assessing, savings (time and money), identification of best practices and corrective actions based on lessons learned.	*Data collection and pretreatment:* Customers' sites and logistics based data. Solution/method for automatically gathering and analyzing data from different sources instead of manual work. *Data analysis and modeling:* - *Communication of results:* Resource assessing, savings (time and money), identifying best practices, corrective actions based on lessons learned	IaaS/KaaS	Fleet level decision-making, data collection processes	Size of customer fleet
IBM	Analytics and platform for predictive maintenance and asset optimization solutions for fleet management	*Data collection and pretreatment:* Customer's fleet based data, other data sources *Data analysis and modeling:* Tools that enable the advanced analytics of maintenance/service management (focus on asset and maintenance optimization) *Communication of results:* Predictive maintenance and asset optimization solutions for fleet management	DaaS Providing technology for DaaS/IaaS/KaaS	IoT, BI, analytics, cognitive analytics	Fleet is the assets of the customer

Company	Description of potential services based on the concept	Service concept description (if applicable)	Service level	Primary role in eco-system	Economy of scale from fleet data
Metso Minerals	Services for predicting equipment fails for mobile units, predictions of unit's performance, mainte-nance and defining best practices	*Data collection and pretreatment:* Data from mobile units and other equipment, actual material flow from mining customer to delivery sites, also combining external data (e.g .Weather forecast, prediction of market shares, etc.) *Data analysis and modeling:* Benchmarking for best practices *Communication of results:* Predictions of unit's performance, maintenance services, defining best practices	IaaS/KaaS/ WaaS	Services to support fleet decision-making Fleet services for as-set owner, view on the state of the fleet	Fleet is the equipment of the user Platform for 1 000–100 000 Metso equipment, ex-plosion of data volume
M-Files	Offering collaboration platforms which combine data from different sources	*Data collection and pretreatment:* Combining data from customer's fleet and other sources *Data analysis and modeling:* - *Communication of results:* Combining maintenance information from various systems, improv-ing the validity and quality of the data	DaaS Providing technology for DaaS/IaaS/ KaaS	Developing repository agnostics information management Improving data avail-ability	Fleet is the as-sets of the customer

Company	Description of potential services based on the concept	Service concept description (if applicable)	Service level	Primary role in ecosystem	Economy of scale from fleet data
Outotec	Service for optimizing operations and maintenance activities and for estimating total life-cycle costs	*Data collection and pretreatment:* Data from customers' machinery and equipment: e.g. the machinery and equipment of mining companies *Data analysis and modeling:* Best maintenance practices (benchmarking system for different customer segments), value estimation and comparison, data analysis *Communication of results:* Optimizing operations, estimating total life-cycle costs, proactive maintenance, value estimation and comparison decisions, process optimization, spare part optimization, maintenance recommendation, cost estimation, life of mine estimation, resource efficiency	KaaS	Data preprocessing, data classification, statistical analysis, correlation analysis, decision support	Fleet is the assets of the customer
Ramentor	Helping customers focus development efforts on improving overall equipment efficiency (OEE). Using software and working practice (ELMAS) to manage reliability and RAMS requirements.	*Data collection and pretreatment:* Data from customer's fleet. Gathering data into the RAMS model. *Data analysis and modeling:* Simulations *Communication of results:* Design for reliability, risk assessment, maintenance optimization decisions, "design - analyze - optimize", maintenance planning decisions	IaaS/KaaS	Predictive analytics, preventive maintenance Data linkage, preprocessing, integrity check, analysis Real-time data can be used if the predictive model is developed	Fleet is the assets of the customer

Company	Description of potential services based on the concept	Service concept description (if applicable)	Service level	Primary role in eco-system	Economy of scale from fleet data
Valmet	Services for predictable and guaranteed failure free run to the customer based on using machinery and equipment related data	*Data collection and pretreatment:* Data from machinery and equipment at customers' sites, case rolls *Data analysis and modeling:* Data management; transferring data fluently between systems *Communication of results:* Effective co-ordination of one's own work, new offering decisions, maintenance decisions, predictive decisions, finding causes and effects	IaaS/KaaS	Support for decision-making, preventive maintenance Probabilities, real time data not supported. To support maintenance planning.	Benefits can be achieved at fleet level Fleet is the assets of the customer, e.g. rolls in paper machine
Wapice	Platform/infrastructure service for extending the existing service from measuring the asset level to the fleet-level. Predictability information of fleet (e.g. KPIs).	*Data collection and pretreatment:* Data from customer's fleet *Data analysis and modeling:* Providing SW and HW of IoT solutions and analytics tools *Communication of results:* Remote monitoring and asset control for supporting asset management decisions, benchmarking	DaaS/IaaS/KaaS Providing technology for DaaS/IaaS/KaaS	Platform/infrastructure to fleet level business decision-making Alarms, reports, dashboards, analytics	Fleet is the assets of the customer

Series title and number

VTT Technology 309

Title	**Fleet service creation in business ecosystems – from data to decisions** Fleet information network and decision-making
Author(s)	Helena Kortelainen, Jyri Hanski, Susanna Kunttu, Sini-Kaisu Kinnunen & Salla Marttonen-Arola
Abstract	Digitalization and the industrial internet are transforming business as technologies enable the gathering, processing and utilization of increased amounts of data. At the same time, technology companies have shifted their focus from product delivery to life-cycle services which are knowledge-intensive by nature. Companies are interested in developing global fleet-based industrial services, which could be seen as means to increase competitiveness. The targets of these fleet services, the customers' asset fleets, are typically complex and expensive assets, and they are characterized by high profitability, efficiency and safety demands. In order to provide value-adding fleet services, these knowledge-intensive services require data collection from globally distributed fleets. Technical and economic life-cycle data are often fragmented in business ecosystems and the full business potential of data is rarely utilized. Therefore, innovative technological and business model solutions are needed to upgrade the accumulated data into business knowledge that can be used to support decision-making and service delivery. This offers new opportunities not only for typical fleet services such as maintenance but also to support different types of fleet decision-making situations regarding different types of fleets. This publication presents and discusses the findings from the project "Fleet information network and decision-making", which is a part of the DIMECC Service Solutions for Fleet Management (S4Fleet) research program. The project addresses this issue by developing ways to upgrade the accumulated fleet data into valuable business knowledge that can be used in decision-making both on the level of individual companies and the whole ecosystem. The research is conducted in collaboration with companies involved in the research project, and the findings result from multifaceted cooperation with the case companies over a three-year period. The project results in a Data to Business Knowledge (D2BK) model, and documents pathways for industrial ecosystems to implement the model. The main ambition is to increase understanding on fleet data based services and develop ways to create value from fleet data at ecosystem level.
ISBN, ISSN, URN	ISBN 978-951-38-8580-9 (URL: http://www.vttresearch.com/impact/publications) ISSN-L 2242-1211 ISSN 2242-122X (Online) http://urn.fi/URN:ISBN:978-951-38-8580-9
Date	October 2017
Language	English, Finnish abstract
Pages	70 p. + app. 6 p.
Name of the project	Fleet information network and decision-making
Commissioned by	Tekes, VTT, Lappeenranta University of Technology and participating companies (DIMECC S4Fleet program)
Keywords	Fleet management, data management, industrial services, decision making
Publisher	VTT Technical Research Centre of Finland Ltd P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111

Julkaisun sarja ja numero

VTT Technology 309

Nimeke	**Laitekannan hallinnan palveluiden kehittäminen liiketoimintaekosysteemeissä** Tiedon hallinta ja päätöksenteko
Tekijä(t)	Helena Kortelainen, Jyri Hanski, Susanna Kunttu, Sini-Kaisu Kinnunen & Salla Marttonen-Arola
Tiivistelmä	Digitalisaatio ja teollinen internet muokkaavat liiketoimintaa, kun kehittyneet teknologiat mahdollistavat lisääntyvän datan keruun, prosessoinnin ja hyödyntämisen liiketoiminnassa. Samaan aikaan yritykset ovat siirtymässä tuotekeskeisestä liiketoiminnasta tarjoamaan tuotteilleen elinkaaripalveluja. Datan keruu kansainvälisille markkinoille levittyvästä laitekannasta (fleet) mahdollistaa tietointensiivisten, laitekannan käyttöä ja ylläpitoa tukevien palvelujen (fleet services) kehittämisen. Asiakkaan tuotantolaitteet ovat tyypillisesti arvokkaita ja kompleksisia järjestelmiä, joiden tuotto-, tehokkuus-, ja turvallisuusvaatimukset ovat korkeita. Tietointensiivisten palveluiden kehittäminen edellyttää elinkaaridatan keräämistä laajasta laitekannasta. Tämä tekninen ja taloudellinen elinkaaridata on usein pirstaloituneena liiketoimintaverkostoissa, eikä sen koko potentiaalia pystytä hyödyntämään. Innovatiivisia teknologisia ja liiketoiminnallisia ratkaisuja tarvitaan, jotta elinkaaridataa voidaan jalostaa ja siten hyödyntää palvelukehityksessä ja päätöksenteon tukena. Elinkaaridataa voidaan hyödyntää kunnossapitopalveluissa, mutta myös tukemaan erilaisia päätöksentekotilanteita ja asennetun laitekannan hallintaa. Tässä julkaisussa esitetään DIMECC:n "Service Solutions for Fleet Management" (S4Fleet) -tutkimusohjelman projektissa "Fleet information network and decision making" saavutettuja tuloksia. Projektissa on kehitetty tapoja jalostaa laitekannan tuottamaa tietoa liiketoiminnassa hyödynnettävään muotoon, luomaan arvoa ja tukemaan päätöksentekoa eri tasoilla yksittäisestä laitteesta koko liiketoimintaekosysteemiin. Projektin keskeisin tulos on "Datasta liiketoimintatietoa (D2BK)" -malli, joka kuvaa tiedon käsittelyn vaiheita ja tiedon arvon ja merkityksen kasvua tämän prosessin tuloksena. Tutkimushanke on toteutettu yhteistyössä ohjelmassa mukana olleiden yritysten ja tutkimuslaitosten kanssa. Tämän raportin tavoitteena on lisätä ymmärrystä laitekannan hallintaa (fleet management) tukevien tietointensiivisten palveluiden kehittämisestä ja tietoon pohjautuvan arvonluonnin prosesseista ekosysteemitasolla.
ISBN, ISSN, URN	ISBN 978-951-38-8580-9 (URL: http://www.vtt.fi/julkaisut) ISSN-L 2242-1211 ISSN 2242-122X (Verkkojulkaisu) http://urn.fi/URN:ISBN:978-951-38-8580-9
Julkaisuaika	Lokakuu 2017
Kieli	Englanti, suomenkielinen tiivistelmä
Sivumäärä	70 s. + liitt. 6 s.
Projektin nimi	Fleet information network and decision-making
Rahoittajat	Tekes, VTT, Lappeenrannan teknillinen yliopisto ja yritysosapuolet (DIMECC S4Fleet-ohjelma)
Avainsanat	Laitekannan hallinta, tiedon hallinta, teolliset palvelut, päätöksenteko
Julkaisija	Teknologian tutkimuskeskus VTT Oy PL 1000, 02044 VTT, puh. 020 722 111

VTT TECHNOLOGY 309 Fleet service creation in business...

Fleet service creation in business ecosystems – from data to decisions

Fleet information network and decision-making

Industrial internet enabled technologies expand machinery manufacturers' possibilities to collect data from globally distributed fleets. The trend towards networked collaboration models gives rise to new business ecosystems. **The Fleet information network and decision-making project** aims at advancing companies' abilities to create novel knowledge-intensive services especially for life cycle management, maintenance and operations support. The research project has two major outcomes: Data to Business Knowledge model, and a set of methods to extend service delivery with this knowledge.

The new ways of gathering, analyzing and understanding and then utilizing information in fleet level operations in a value network is the key competence when designing extended service solutions. The project resulted in a number of analysis tools and service concepts that the participating companies will further develop. These concepts include benchmarking, concept for data sharing, and data collection practices to support the determination of KPI indicators.

This publication is aimed at experts who have the intention of refining data to knowledge and further to knowledge-intensive services. Our aim is to give answers to the question - *How can companies with complex fleet processes upgrade accumulated data into valuable knowledge that can be used in decision-making?*

ISBN 978-951-38-8580-9 (URL: http://www.vttresearch.com/impact/publications)
ISSN-L 2242-1211
ISSN 2242-122X (Online)
http://urn.fi/URN:ISBN:978-951-38-8580-9