SMART ASSET MANAGEMENT:
STORIES FROM THE WORLD
OF DIGITAL SERVICES
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OF DIGITAL SERVICES

Deliverable 3.0

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A large number of companies are currently making a transformation toward a service mind-set with digital capabilities. The exploitation of data and the development of profitable data-based business is a topical development target that involves many ongoing projects.

SmartAdvantage is a joint project that is being undertaken by the research organizations VTT and the Tampere University of Technology, as well as industrial partners. The project develops methods and models of digitalized asset management.

In the first section of this deliverable, the primary findings and observations from the earlier results of the project are presented. The second section addresses the different strategic positions in the value network that a company may take when developing digital service businesses. Section 3 introduces the fundamentals of knowledge-based analytics and business model renewal and discusses the experiences gathered during the project. The role of service integrator, which may increase in significance in light of future digital service business development, is also discussed.

The authors wish to thank SmartAdvantage’s industrial partners—Chiller Oy, Delete Finland Oy, Huurre Finland Oy, Pesmel Oy, and SW-Development Oy—for their active collaboration throughout the project. The project is funded by the Business Finland Research Benefit program, VTT, Tampere University of Technology, and participating companies.

15.12.2018

AUTHORS
1 PATHWAYS TO THE DIGITAL SERVICE BUSINESS

1.1 DIGITALIZATION PATHWAYS

There is a great deal of discussion about digitalization and its different aspects. The expectations regarding the adoption of technologies and applications related to concepts such as artificial intelligence (AI), the Internet of things (IoT), industrial Internet, and digital twin are not always realistic. Part of the problem is that the limitations, current technological level, requirements, and definitions of concepts are not always clear. Table 1 introduces definitions of digitalization and key concepts related to it.

Digitalization transforms companies, businesses, and ecosystems in several ways. Two distinct pathways can be distinguished: disruption from within by incumbent firms that gain operational benefits and from outside by new entrants to the market (Mäntylä 2017). Based on these pathways, four different scopes of digital solutions in companies can be observed (adopted from Mäntylä 2017):

1. “Customer-oriented” refers to the development of digital services via the data collected from the installed bases of machines and infrastructure items. Companies are able to access data from items located anywhere.

2. “Bottom-up” refers to the operational benefits that can be realized by IoT solutions inside a company. Sensors, machines, processes, and services continuously produce information that can be refined as knowledge for real-time decision-making and used to automate work, among other applications. “Bottom-up” digitalization is a tool that is used to increase turnover, reduce costs, improve the effectiveness of capital spending, and renew business.

3. “Value chain-oriented” has its origin in the German Industrie 4.0 initiative, which focuses on improving the efficiency and interoperability of industrial supply chains (Acatech 2013). It aims to create more value chain transparency and emphasizes not only the role of autonomous manufacturing systems but also the competencies of the people using these systems.

4. The “digital twin”-oriented bridge links real-world entities with their digital representations—that is, “digital twins.” The physical asset and its digital twin thus form a CPS (Lee et al. 2015). In future, a digital twin may already be created during the product design phase using CAD models and data contained in the PDM system (Juhanki et al. 2015).

In this deliverable, the focus is on the first three scopes of digitalization: digitalized asset management services enabled by digitalization, increased internal efficiency, and effective and transparent value chains. However, even though digital twins are not covered in this deliverable, they are considered a rising technological trend with high potential.
**TABLE 1. KEY CONCEPTS RELATED TO DIGITALIZATION**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition and examples</th>
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<tbody>
<tr>
<td>Digitalization</td>
<td>The use of digital technologies to change a business model and provide new revenue and value-producing opportunities (Gartner 2016).</td>
</tr>
<tr>
<td>Industrial internet</td>
<td>The industrial Internet brings together brilliant machines, advanced analytics, and people at work. This new way of connecting machines, facilities, fleets, and networks is combined with the harnessed power of physics-based analytics, predictive algorithms, automation, and deep domain expertise, connecting people at any time to promote design, operations, and maintenance and to ensure quality service and safety. It is the network of a multitude of industrial devices connected by communications technologies and resulting in systems that can monitor, collect, exchange, analyze, and deliver valuable new insights like never before (GE 2013).</td>
</tr>
<tr>
<td>Industry 4.0 (Industrie 4.0)</td>
<td>Industrie 4.0 (Industry 4.0) is a strategic initiative to drive digital manufacturing by increasing digitization and the interconnection between products, value chains, and business models. It supports the integration of cyber–physical systems (CPS) and Internet of things and services (IoTS) with an eye to enhancing productivity, efficiency, and flexibility of production processes and, thus, economic growth (EU 2017).</td>
</tr>
<tr>
<td>IoT</td>
<td>IoT is a development whereby “assets themselves become elements of an information system, with the ability to capture, compute, communicate, and collaborate around information” (Bughin et al. 2010).</td>
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<tr>
<td>Digital twin</td>
<td>Digital twin is an integrated multi-physics, multi-scale, probabilistic simulation of a product or system that uses the best available physical models, sensor updates, fleet history, etc. to mirror the life of its corresponding twin (Glaessgen and Stargel 2012). Digital twin consists of three parts—physical product, virtual product, and connected data—that connect the physical and virtual products (Tao et al. 2018).</td>
</tr>
<tr>
<td>Artificial intelligence</td>
<td>The term AI is currently applied in many contexts with a wide range of particular meanings; no widely accepted single definition exists. However, AI may be interpreted as a collection of technologies facilitating the “smart” operation of machines and systems through better utilization of data (Saarela et al. 2018). The autonomous and adaptive characteristics are typically linked to the applications of AI.</td>
</tr>
<tr>
<td>Machine learning</td>
<td>The algorithms of machine learning are developed to identify relationships in large amounts of data. Machine learning may be understood as an area of AI with algorithms that discover rules behind patterns in a dataset, learn these rules, and are able to apply them to new situations.</td>
</tr>
<tr>
<td>Neural networks</td>
<td>Neural networks are statistical data modeling tools, inspired by biological nervous systems, for applications for which rule-based algorithms are found inadequate. The methods are used for analyzing the complex relationships between inputs and outputs. Neural networks with multiple layers between input and output are called deep neural networks.</td>
</tr>
<tr>
<td>Business model</td>
<td>The business model is the rationale for how an organization creates, delivers, and captures value (Osterwalder and Pigneur 2010). Its main dimensions are value creation, value proposition, and value capture (Clauss 2017).</td>
</tr>
<tr>
<td>Asset management</td>
<td>Asset management covers activities that support “the realization of value while balancing financial, environmental and social costs, risks, quality of service and performance related to assets.” It can be defined as the “coordinated activity of an organization to realize value from assets” (ISO 2014).</td>
</tr>
<tr>
<td>Digitalized asset management</td>
<td>Digitalized asset management refers to the asset-related activities enabled by smart, connected products and analytics-based services. Asset management decision-making at different levels is supported using digital technologies and data-oriented services.</td>
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</table>
1.2 DIGITALIZED ASSET MANAGEMENT SERVICES

The recent development in wireless technologies and the growing interest in digitalization and its opportunities have rapidly increased the amount of data in industrial applications. These data offer enormous potential for value creation. In particular, applications based on the Industrial Internet and IoT are becoming ever more popular in industry, which has created a huge demand for more efficient ways of utilizing data (Da Xu et al. 2014). In general, the value gained from digitalized asset management services is usually dependent on one or more of the following aspects: faster, more inexpensive, and more comprehensive data collection; faster and real-time data analytic technologies; better opportunities to combine data from different sources; and better data availability.

Digitalization provides considerable opportunities for asset management. It enables better management of life-cycle information and better availability of sensor, equipment, and process information for the various stakeholders. Therefore, the potential new value could be in real-time optimization and predictive maintenance. Conversely, the lifetime of digitalized products and services is often much shorter than that of physical assets. This is a challenge, because companies have to prepare for new kinds of maintenance, replacement, and modernization.

Asset management services can be divided into four distinct categories (Figure 1). Product-related services digitalize the current offering by exploiting the sensor and ICT technologies. Examples of this category include preventive maintenance services and spare parts management. Production support services include failure diagnostics and information-based overall equipment efficiency optimization integrated with expert consultation. In asset optimization and risk sharing, wide installed base data is utilized to support operation and maintenance, using methods such as benchmarking and predictive maintenance. In asset and risk management, holistic digital services and intelligent products are integrated, resulting in highly automated decision-making.

Some of the key barriers to and enablers of digitalized asset management services are presented in Figure 2 (Ahonen et al. 2017a). These are based on a literature review and the results of a company workshop that took place during the pro-
ject. An exhaustive list of barriers and enablers is presented in SmartAdvantage deliverable 1 (Ahonen et al. 2017b).

The identified enablers deal with the adoption of more agile, customer-driven, and collaborative processes and activities in developing new digitalized asset management services. In addition, the utilization of new technologies as an integral part of the business model and successful examples from pioneers were considered important.

The barriers to digitalized asset management services were related to data availability, quality, security, and ownership, as well as the lack of capabilities and tools to analyze and utilize these data and communicate the value of the services to customers. Other barriers include organizational constraints such as lack of readiness for transformation and cost-driven decision criteria in regard to investing in digitalized asset management services—that is, cost-driven customers.

1.3 METHODS AND FRAMEWORKS SUPPORTING THE DIGITAL TRANSITION

In deliverables 1 and 2 (Ahonen et al. 2017b, Ahonen et al. 2018a), we presented methods and frameworks to support the development of digital services based on data from the installed base of machinery, equipment, and infrastructure. In Table 2, we position the methods and frameworks within the model for service information requirements (McFarlane and Cuthbert 2012). The methods and frameworks are positioned according to the main elements of service, which include aspects such as customer or service need, specification or use, the service offering, and the supporting infrastructure or service operation.
The determination of service need should cover the identification and understanding of key future drivers and needs, technological and market developments, customer’s processes, bottlenecks and improvement opportunities, customer’s decision-making situations, and future customer needs. In service specification, key areas include specification and satisfaction of customer requirements, specification of data management and ownership, costs and benefits, platform and analytics development and selection, and value proposition formulation. Service offering deals with service capabilities; partnerships; risk assessment; service support; resourcing; and case-specific analytics tools, methods, and models. During the service operation phase, key areas include system operation to optimize value creation, measurement of value created by services, understanding of supported functions, reliability and resilience of systems, legislation and regulation, and service infrastructure.

### TABLE 2. METHODS AND FRAMEWORKS FOR SUPPORTING THE DEVELOPMENT OF DIGITALIZED ASSET MANAGEMENT SERVICES

<table>
<thead>
<tr>
<th>Main elements of service</th>
<th>Methods and frameworks</th>
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<tbody>
<tr>
<td>Service need</td>
<td>Roadmapping and analysis of changes in the business environment</td>
</tr>
<tr>
<td></td>
<td>Identification of service opportunities and customer value sources</td>
</tr>
<tr>
<td></td>
<td>Understanding of the customer’s decision context</td>
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<tr>
<td>Service specification</td>
<td>Analytics</td>
</tr>
<tr>
<td></td>
<td>Formulation of value proposition</td>
</tr>
<tr>
<td>Service offering</td>
<td>Business model formulation</td>
</tr>
<tr>
<td></td>
<td>Circular economy-related business models</td>
</tr>
<tr>
<td></td>
<td>Analytics according to requirements in use cases</td>
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<tr>
<td>Service operation</td>
<td>Business model canvas</td>
</tr>
<tr>
<td></td>
<td>Measurement, assessment, and key performance indicators</td>
</tr>
</tbody>
</table>
Because it is essential for a company to define its strategic position with respect to the service business levels, a framework for strategic service business positioning is proposed next. The company can be at various levels of service business with respect to data intensity and the depth of a customer relationship. Services may vary from providing occasional support and resources to establishing a deeper partnership, whereby the company is an integral part of the customer's business and development. It must be noted that a deeper partnership does not necessarily offer greater profitability for the business; it is more important to understand what the company's position is and what it is pursuing strategically.

2.1 A FRAMEWORK FOR SERVICE BUSINESS POSITIONING

In the framework, five different levels relative to the customer have been identified (Figure 3). The starting point for the proposed framework lies in the BestServ reference framework (2003).

Product supplier: The attention of the business relationship is on delivering a piece of technology that suits the customer's technical specification.

Solutions provider: The focus of business is on the delivery of a solution—for example, a production line or software product, which is usually designed for the specific customer's needs and comprises a wider supply scope than only one piece of technology. Quite often, these solutions are delivered through projects. The need to understand the customer requirements and the duration of the delivery project leads to the increased depth of the customer relationship.

Both of these roles emphasize the provider's activities regarding the customer's investment decision, with narrow participation in the continuing life cycle of the delivered item.
Support partner: The focus of business expands to include continued supplier involvement life-cycle phases after the delivery. This role adds contractual aftermarket elements supporting the upkeep of the delivered item. These support services could include spares, consumables, and periodical maintenance. Delivering these services often leads to a contractual supplier–customer relationship. With this role, the need for data intensity grows when moving from spare parts provider toward on-site maintenance resources.

Performance partner: In this role, the supplier is closely involved with operating the customer’s technical process by taking partial responsibility for process performance by giving, for example, efficiency warranties. This role involves the supplier maintaining a continuous on-site presence, and the data intensity increases when moving from OEE optimization to operations and maintenance (O&M) services.

Value partner: The supplier is directly involved in the customer’s business, for example, through collaboratively operating and maintaining the customer’s production processes, by cocreating value through various development activities, and by playing an active role in strategic asset-related decisions. This level is very difficult to reach because establishing the relationship between the service provider and the customer requires special trust. This appears, for example, in the selling of the added value that can be achieved through development efforts, because the value could lie beyond the imaginable needs of the customer. In order to be a value partner, data intensity and cooperation are always high at the strategic, tactical, or operational level of the customer.

Figure 4 presents the levels of analytics from descriptive and diagnostic analytics to predictive and prescriptive analytics. Descriptive and diagnostic analytics methods focus on past events, whereas predictive and prescriptive analytics are forward-looking methods. The value and difficulty of the analytics method increase considerably when moving from descriptive toward prescriptive analytics.

**FIGURE 4. STAGES OF DATA ANALYTICS MATURITY (ADAPTED FROM DAVENPORT AND HARRIS 2007 AND GARTNER 2012)**
2.2 CASE COMPANIES’ POSITIONS

SmartAdvantage research partners are the following companies: Huurre, Pesmel, SW-Development, Delete, and Chiller. The companies’ positions in the service business and analytics maturity frameworks outlined in the previous section are discussed below.

**Chiller** has placed emphasis on the easy and resource-efficient installation, use, and maintenance of equipment. Furthermore, Chiller aims to maintain the technological advantage by continuously providing customers with novel technologies. The aim of Chiller’s service business is to provide customers with adequate support to maintain the time and resource efficiency of the equipment throughout the life cycle. However, the services have a supporting role and, thus, Chiller may be defined as a support partner in the hierarchy. Chiller is willing to strengthen its role in support services in order to increase its competitiveness as a technology provider. This strong position in technology will be maintained through increased collaboration with and the continuous identification of value-added partners in the market.

Regarding analytics maturity, Chiller is willing to increase the predictive analytics in its portfolio. The current exploitation of the signals from the assets is related to operational support and problem-solving, and Chiller is, thus, currently at the diagnostic analytics level in certain applications. Conversely, for optimizing the use of the assets, descriptive analytics have been implemented, and diagnostic analytics has been planned.

**Delete** is willing to strengthen its upstream capabilities (Davies 2004) by integrating novel technologies into its offering. Thus, in order to provide digitalized services to the customer, Delete needs to identify its new position with regard to both the technology and service integrator aspects.

The company has identified several roles, depending on the size of the customership. In the case of smaller customerships, there is no need for a deeper customer relationship. In the case of larger customerships—for instance, in the forest industry—the role is approaching value partner. Industrial customerships are at the performance partner level. There is a need to approach higher role levels in the framework to disengage from competing purely on price and to develop added value to customers. To achieve a value partner role, the focus of decision-making should be on disturbance-free production and longer stoppage intervals, not solely the costs. However, the company is also unwilling to let go of the conventional products, which are sometimes highly profitable.

The maturity of analytics is dependent on business, customerships, and services. In industrial applications, Delete is at the diagnostic analytics stage, and in some smaller-scale applications, it is at a higher level. In terms of day-to-day activities, the company is at the descriptive level of analytics. The company is progressing toward the predictive and prescriptive stages in regard to certain applications. However, it is not certain whether the development of advanced analytics-based solutions is in the strategic interest of the company in the long term or whether it should be more focused on its core business.

**Huurre** has a strong global position in refrigeration and heat production technologies and services. In terms of strategic service positioning, the company has been undergoing a process of transition. A few years ago, the company was mainly a product supplier. In recent years, the company has been moving toward the roles of system provider and support partner and, in some partnerships, even performance partner. As a whole, the company can be positioned into system provider/support partner roles.

Depending on the application, Huurre is at either the predictive or the diagnostic analytics stage. In regard to cooling and heating systems, the company is at the predictive analytics stage, whereas in relation to maintenance and failure detection, it is at the diagnostic analytics stage. The goal is to move toward the prescriptive analytics stage in both fields.

**Pesmel**’s digital solutions are currently available for selected customers, enabling a continuous link to their processes and more thorough services. While the company currently has a role as system provider or support partner, with maintenance and operations support capabilities, the aim is to build capabilities with a view to becoming a performance partner. In regard to some greenfield investments, the company may already have a role of performance or value partner.

Currently, Pesmel is at the diagnostic analytics stage at the delivery project level. More advanced applications include data-based simulations if Pesmel controls the internal logistics at the customer’s production unit, which falls under the predictive analytics stage. Predictive and even prescriptive analytics are applied to machinery in some cases, but as a whole, the company is not at this level.

**SWD**’s business is project-based, whereby software can be understood as a customer-oriented product. The company is currently moving from products to services. SWD’s aim is to identify the most profitable level of service business. At the moment, the company is at the performance partner level with related analytics solutions. The goal of SWD is to become a value partner. This is a challenging task, as production planning is generally regarded as a core function from the customer’s perspective. The role of contracts is crucial in the transition. SWD strives to implement benefit-based pricing into its contracts; however, this has not been successful, even though it is appreciated by the customers.

SWD is currently at the predictive analytics stage. The company predicts sales, costs, and production capability. The next step is to utilize intelligent systems and machine learning to reach the prescriptive analytics stage.
3 OBSERVATIONS FROM DIGITAL SERVICE BUSINESS DEVELOPMENT

3.1 KNOWLEDGE-BASED ANALYTICS

3.1.1 Domain and analytics expertise

Many authors have stated that the amount of currently available data and the development of analytics approaches have resulted in numerous new opportunities. However, in many cases, the data gathered over several years have remained underexploited, and the work needed to make the data useful remains significant. While, in many cases, the potential remains unclear, the lack of commitment to new trials may also hinder the development.

The transition of machine vendors toward a value partner role requires a significant change in how data are collected, treated, analyzed, and exploited. Discussion on methodology and the generic opportunities related to big data analytics often fails to address the practical challenges. New capabilities, skills, knowledge, and resources are needed. Furthermore, the sole utilization of novel analytics models is only one piece of the equation, and one has to know how to integrate domain knowledge with the analytics capabilities. This calls for committed resources with multidisciplinary expertise.

Adrodegari and Saccani (2017) state that business model innovations, such as the shift from goods to solutions, can be regarded as the possibility for business with less competition to benefit from regulatory and technological shifts or to seize downturn-specific opportunities. Product-oriented, use-oriented, and result-oriented types of product–service systems have been identified (Adrodegari and Saccani 2017, Tukker 2004). The transitions between these roles include changes in how interactive the relationship between the customer and provider is and whether the services are provided on a transactional basis or by cocreating with the customer (Adrodegari and Saccani

<table>
<thead>
<tr>
<th>Wisdom</th>
<th>Component reliability performance optimization</th>
<th>Maintenance for availability performance optimization</th>
<th>Capacity optimization</th>
<th>Strategic asset management decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Timely machine/ component maintenance</td>
<td>Timely asset maintenance actions</td>
<td>Process and maintenance integrated optimization</td>
<td>Long-term OEE and LCC driven maintenance investment decisions</td>
</tr>
<tr>
<td>Information</td>
<td>Condition monitoring</td>
<td>Condition-based maintenance</td>
<td>Process efficiency improvement</td>
<td>OEE-driven O&amp;M actions</td>
</tr>
<tr>
<td>Data</td>
<td>Machine sensor data collection</td>
<td>Maintenance data collection</td>
<td>Process data</td>
<td>O&amp;M integrated event and process data</td>
</tr>
</tbody>
</table>

FIGURE 5. A FRAMEWORK FOR CONNECTING ASSET MANAGEMENT OBJECTIVES WITH THE DIKW HIERARCHY
Furthermore, we conclude that, when transitioning from a product-oriented business model toward a result-oriented business model, a provider needs to increasingly understand the nature of various sorts of asset management decisions. This calls for both capabilities in asset management and the creation of knowledge out of data.

Figure 5 presents the levels related to intelligent assets, asset management, and the DIKW hierarchy.

The DIKW hierarchy is used to represent the relationships between data, information, knowledge, and wisdom. Data is the first step on the DIKW model and is, thus, a requirement for creating useful results based on data. Data are the products of observation. Information answers questions that begin with words such as who, what, when, and how many. Information is inferred from data. Knowledge is know-how and is what makes the transformation of information into instructions possible. Wisdom is determined in terms of knowledge. Wisdom is the ability to increase effectiveness. Wisdom adds value, which requires the mental function that we call judgment (Rowley 2006). We have adopted the hierarchy to present the level of refinement and use of data in the asset management context. In Figure 3, the levels of the DIKW hierarchy are presented as axis Y. Axis X presents the exploitation levels for data, information, knowledge, and wisdom. The left-hand side (Smart machine) presents a physical asset-level solution, while Smart maintenance and Smart production levels are understood as system-level exploitation opportunities. The goals of Smart asset management are related to the holistic management of assets in terms of maintenance, investments, and operations at the strategic, tactical, and operational levels.

At the level of Smart machine, a company could focus on 1) measuring selected phenomena (machine sensor data collection), 2) monitoring the conditions of the components, 3) refining the maintenance information into knowledge with which to further develop the timing of the maintenance actions, and 4) optimizing the component reliability based on the reliability information gathered from the assets.

At the level of Smart maintenance, a company could focus on 1) system-level maintenance data collection; 2) condition-based maintenance solution development, whereby asset managers are given information on the conditions of the system's assets; 3) maintenance actions made at the system level with optimized time intervals; and 4) maintenance optimization with respect to needs and situations in production (need-based approach with, for example, opportunistic maintenance).

At the level of Smart production, a company could focus on the 1) collection of process data, 2) improvement of production efficiency by identifying development targets supported by data, 3) integrated planning of maintenance and operations, and 4) optimized capacity through proper maintenance and operations decisions.

At the level of Smart asset management, a company could focus on 1) integrating the data from maintenance and operations; 2) optimizing quality, performance, and availability (OEE) through improved data exploitation; 3) optimizing the maintenance of investments according to OEE impacts and life-cycle costs; and 4) managing the assets in the long term while paying attention to strategic investments.

3.1.2 Machine learning-based services providing added value for customers

Modern industrial Internet- and open data-based solutions enable the analysis of the big picture—in other words, the environment and process in which a machine operates and how these conditions affect its operation. Analysis at this level enables the optimization of the use of the machine based on the conditions it is expected to face. The data sources needed for this include enterprise process data, IoT sensor data, weather data, and other case-dependent data. The fusion of these data, aided by analytics, modeling, and simulation, creates new levels of knowledge that can be used to support existing industrial services and to create new ones.

The question of where this data fusion should be executed and by whom depends on the intended use of the data. From the industrial services point of view, the focus of the data fusion is to create knowledge that can facilitate the customer's efforts to get the most out of his or her machines.

In the case studies conducted at Huurre (see, e.g., Hanski et al. 2018), data fusion was used to explore the possibilities for energy consumption optimization, failure signal detection,
and defrost schedule optimization. These services save customers money and time and make their cooling and heat recovery systems operate more efficiently and without unnecessary pauses. The key to creating these services, along with the data fusion, is to have an in-depth understanding of the operation of the system being serviced, which is something that Huurre can offer to its customers. The customers instead have difficulties incorporating understanding of the operation of the system into their own data fusion systems.

Another use case is internal: Huurre is able to develop its own algorithms through models, simulation, and data analysis arising from the collected and fused data. This enables the delivery of better, more fine-tuned services, as well as the development and testing of services that would have been too complex to create in the past.

3.1.3 Creating Knowledge-Based Analytics

Creating a knowledge-based service support model begins with analyzing the system and identifying the important parameters and interactions present. This analysis can be performed in part using data analysis methods but relies heavily on the experts who understand the system, as well as the process of which it is a part. Once the objectives of the model are clear, its type and structure can be chosen. This further drives the choice of data preprocessing methods, which, in turn, create training data for machine learning models. Along with machine learning models, an analytical model can be developed to enhance the level of system knowledge. After the models have been trained successfully, the entire pipeline from data gathering to analytical output can be deployed and used to create knowledge to aid decision-making. The models must be maintained during their life cycles. They must be updated regularly as new data are created, and new model structures or new models altogether must be added if new relevant data sources become available. All of this implies that knowledge of the system is available along with the measurement data. The process of creating and maintaining service support analytics is illustrated in Figure 6.

A knowledge-based analytics system was created in cooperation with Huurre. The objective of the modeling was energy consumption optimization in cooling. In practice, this means modeling the behavior of individual evaporators in a cooling system and the compressors that drive the coolant through the system. The work began with the use of unsupervised learning methods to examine the strongest correlations and most important data sources. The results were discussed with system
experts and were found to be correct, thereby proving the usability of the data. Thereafter, the most useful data sources were selected. The modeling methodology was chosen to be a hybrid model of the simple analytical model and a deep convolutional recurrent neural network. This approach enabled the capturing of the effects of both internal and external phenomena on the evaporator behavior. These choices and the model structure were reviewed with system experts. Data preprocessing functions were created to supply the model with training data, and the first test models were trained. The method was found to be viable and entered the iterative loop of corrections to make the models even better.

3.1.4 Discovering the requirements for unlocking the full potential of the data

The effectiveness of the data fusion and the resulting models depends on the amount of data and knowledge available during their creation and use. Without data, the models rely on theoretical principles but are unable to fully capture the phenomena that are actually experienced by the machine in its environment. Without knowledge, the models become black boxes that form no clear distinction between causality and correlation. In an industrial service case, the knowledge often resides with the manufacturer of the machine, while the data are the property of the machine’s user. It can be argued that it is easier for the manufacturer of the machine to use data with preexisting knowledge to create data fusion, modeling, simulation, and services than it is for the machine’s user to learn the knowledge and create these elements on their end. The user is likely to be concerned with their process instead of complex modeling operations. Therefore, if the user of the machine is willing to provide data and acquire these services from the service provider, the operation of the machine will be enhanced. This requires deep considerations of data ownership and security.

In light of the results of this case work, it is clear that the more the user is willing to share.

3.2 BUSINESS MODEL RENEWAL

The business model is the rationale for how an organization creates, delivers, and captures value (Osterwalder and Pigneur 2010). Its main dimensions are value creation, value proposition, and value capture (Clauss 2017). Rethinking the value proposition is the core task of digitalized asset management services. For instance, the use of modern analytics for the entire life cycle of assets and the development of digital twins to provide lifetime support are drivers of business model transformation. The main categories of digital service concepts for asset management are identified from the perspective of their value propositions:

- **Service platform and enabling technologies**: Providing technological capabilities from measurements to user interfaces—for example, the provision of standard reports for customers' O&M functions
- **Analytics-based services**: Providing analytics models and related capabilities—for example, diagnostics, problem solving, predictive maintenance, and predictive performance management
- **Asset performance services**: Providing a means of managing customers’ assets to maximize the value created in customers’ processes—for example, the combination of analytics capabilities and domain knowledge related to customers’ production and business environments to determine best practices

Traditionally, manufacturers have focused on producing a physical product and capturing value by transferring ownership of the product to the customer through sales. The owner of the product is then responsible for the costs of servicing the product. Digitalization allows for a radical change of this traditional business model. Access to product data and the ability to anticipate, reduce, and repair failures provide new opportunities to
affect product performance and optimize services (Porter and Heppelman 2015). This enables the creation of new business models for capturing value. The main challenges related to business model development include the following (Nicolescu et al. 2018): the lack of reliable models for the economic, social, and environmental values of IoT systems; the lack of reliable methods for identifying the costs of IoT systems’ life cycles; the poorly understood trade-offs between technical and social capabilities and economic costs; the need for better understanding regarding the risks and opportunities of IoT technology fragmentation; and the bridging of the value gap between theoretical designs and actual implementations.

For business model renewal to be successful, it is essential to analyze and understand customer needs. It will be important to identify which types of services the customers would be willing to pay for. Digital products and services require the rethinking of the value proposition. The entire life cycle of products and services must be considered. The optimization of customers’ processes is an area in which digitalization creates new opportunities. Data analytics provides information that can be used to improve the efficiency of processes.

New services that are based on data require the service provider and customer to agree on data-sharing principles. Furthermore, the parties need to arrive at a mutual understanding of the value creation opportunities. Focusing solely on articulated customer needs does not allow for adequate emphasis to be placed on long-term development needs. An understanding of the customers’ business is, thus, needed to foster developments that will enable a future competitive edge.

Data-based business models transform customer relationships from individual transactions into continuous partnerships. New customer segments can be reached with digital products and services. It is important to work jointly with customers to define and agree on the KPIs that will be monitored to ensure the quality of service. Digitalization also provides new opportunities to reach customers through direct channels, also globally.

Companies need to use approaches that enable them to better understand and communicate the value of the developed services. The value spectrums of different services may be visualized to cover all the essential aspects of value creation. Furthermore, more quantitative approaches may be utilized, where relevant. Life-cycle cost and profit models, for instance, are used to evaluate the value created based on assumptions regarding the effects of the service on the factors identified. Lack of data is a common challenge for the calculation models; however, expert judgment-based evaluations are often adequate for demonstrating and communicating the values. The primary objective is often to reach a common understanding regarding value creation.

The implementation of new data-based business models will require information technology (e.g., ERP, CRM, and demand management), operational technology (e.g., control systems, sensors, and smart machines), and engineering technology (e.g., 3D models, catalogs, and analysis) to become integrated and to work together seamlessly to provide added value. This integration is demanding, and issues such as different data formats and semantics, differences between software providers, software versions and the hardware installed, need to be resolved (World Manufacturing Forum 2018).

The implementation of digital twins can have significant impacts on companies’ business models. According to Frost and Sullivan (2018), business impacts and benefits can include the following:

- Quality: The digital twin solutions enable users to predict and detect quality trends and defects much sooner than before.
- Maintenance and repair: The digital twin contains knowledge about installed equipment and its configuration, thereby proactively enabling servicing of the machine to avoid machine stoppage.
- Operational cost: Monitoring operational activities will improve product and production quality. The digital twin will also be capable of accepting engineering and design changes based on the simulation and virtualization of the new product. This will improve productivity and overall performance and reduce process variability.
- Market lead time: A digital twin solution will reduce new product lead time due to the capability to simulate design and product manufacturing processes prior to production.
3.3 SERVICE NETWORK INTEGRATION

For several years, many technology providers have been moving toward more service-oriented business in order to ensure more stable cash flows. This transformation in a company’s mind-set is reported by many sources to be challenging in terms of how to develop services when the existing competencies are on the side of new technology development.

Service companies could face a reverse challenge if they are seeking real value-added services. Quite often, these companies are exploiting technology that is available from retail shelves to execute their service activities. This means that service companies either do not possess or have minimal competence and resource reserve allocation to develop technologies.

To create a new value-added service, a service company might need to move more strongly toward the role of technology developer. In this case, forming a new kind of network could be a quicker and more cost-efficient way for the company to make technology development competencies available than establishing its own development department. Therefore, to overcome this challenge, assuming the role of a service network integrator is a viable alternative.

As presented in Figure 7, the following are service network integration tasks:

i. Define services through interactions in the complex B2B service network
ii. Link various resources successfully
iii. Support value cocreation between the parties involved

In the context of the SmartAdvantage project, the implementation of the framework for service network integration and management has been realized on the following levels:

i. The service company has been successful in defining a new added-value service concept
ii. The service company has been successful in linking various resources in order to develop an enabling technology and the application required for the new service concept
iii. The potential value elements of the end customer have been identified to support value cocreation

Achieving the full implementation of the framework is challenging, especially from the value cocreation point of view. In the case study of SmartAdvantage, the service provider is aiming to reach the value partner level (see Figure 3) based on a new service concept. Overcoming the challenges related to end-customer intimacy requires more time, mutual understanding, and goal setting, particularly between the end customer and the service network integrator.
3.4 APPROACH TO DIGITALIZED ASSET MANAGEMENT SERVICE DEVELOPMENT

Today, agile development approaches have become popular in both digital service development and the manufacturing sector. Agile development has the potential to quickly produce so-called minimum viable products (MVPs), which are services that have only basic functionalities. MVPs can be quickly and relatively economically tested and modified in practice. Product and service concepts that do not show potential in agile testing can be discarded more quickly than the more traditional product or service development processes.

The reasons for the adoption of agile approaches include the increasing complexity, data, and service intensity of manufacturing companies and their products. However, in focusing solely on agile development, companies may lose the strategic focus of their development activities, and individual experiments may remain disconnected. There is a need to connect the strategic level, the customer’s decision-making context, and the business model development to support service development (Figure 8).

To support strategic decisions, such as the development of new digital asset management services, companies need to understand the development of their business environments. Roadmapping produces the strategic framework for the service development process. It results in a development path that visualizes the means for reaching the company’s strategic goals and its desired role in the customer’s business.

Companies often develop solutions from the perspective of what they think is valuable to their customers. However, their view of customer needs and limitations might differ from the views of the users of the solutions. Many solutions that make

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**FIGURE 8. APPROACH TO DIGITALIZED ASSET MANAGEMENT SERVICE DEVELOPMENT (ADAPTED FROM AHONEN ET AL. 2018B).**
sense from the perspective of a service provider are not successful because of limited consideration of customers’ decision-making contexts. Therefore, when developing digital services, there is a need to understand the customers’ decision situations at different decision-making levels (strategic, operational, or tactical) and to connect these to the service. For instance, at the operational level, decision situations typically occur frequently and decisions must be made quickly, whereas at the strategic level, they are typically highly complex, have long-term implications for business profitability, and are supported by various decision-support methods.

Companies work in increasingly complex networks in which partners’ roles are complementary. In regard to the creation of new service offerings, ecosystem partners share the risks and are able to significantly shorten the time to market through efficient collaboration. The selection of development targets is crucial at both the company and network levels. Particularly in SMEs, where resources are scarce, the strategic fit and commitment of the resources need to be ensured.

Many of the service business frameworks have been interpreted from the perspective of the transformation from product-based business to service business. However, as Davies (2004) states, the strategic positioning of a company will be as an integrator role, and the transition may be either downstream or upstream. Thus, not all companies should take the steps downstream and adopt a wide perspective of services, rather they should build their businesses based on their known and potential capabilities. However, the key challenge relates to how a company can manage the capabilities required by the larger role. The case studies of the SmartAdvantage project have addressed both downstream and upstream transitions. Due to these changes, companies are no longer able to cover all the competences internally, and their value chains have been changing into value networks, which support companies’ transformations.

The identification of future service opportunities is not always an easy task for developers. Customers may not necessarily see the need for a service that will become topical only after a few years and which may need to undergo some changes before becoming relevant. The question, therefore, is whether the company is completely wrong about the idea or whether it is simply too soon to pursue it. However, it is crucial to involve the customer in the development work from the beginning. An understanding of the new opportunities can be achieved together.
3.5 OBSERVATIONS FROM THE COMPANY PERSPECTIVE

SmartAdvantage is a parallel project for which research organizations and companies have their own projects. During the project, a series of joint workshops was organized, and companies were able to collaborate, find answers to important questions, and discuss the focal topics surrounding industrial service business development. For each of the companies involved, the joint events have resulted in new ideas that could be implemented in their own businesses. Company-specific research case studies were carried out in collaboration with researchers and company representatives. Each company brought its challenges to the table as the basis for collaboration. Among the criteria for the topics covered in the case studies was that the results should be exploitable within a wide range of industries and should not include too many case-specific focus areas.

During the project, it was discovered that many data sources remain underexploited if a systematic approach to utilization is lacking. For example, a set of maintenance event data gathered over 15 years was analyzed to identify its exploitation potential. It was noted that the quality of the data is to a great extent dependent on the type of service contract agreed upon with the customer. In many cases, this shows that the exploitation of the data has not been predetermined and that only the necessary items have been collected based on the customer’s expectations. In order to exploit their full potential, the collection of field data should be guided by consideration of the questions that need to be answered. In our example, maintenance recommendations for selected component types could be updated based on the data collected and analyzed. While utilizing the existing sources of data, one should adopt a need-based approach to future data collection activities. Thus, one should think carefully about additional information needs from the design, maintenance, operations, and end-of-life perspectives.

The realized potential of data-based services has so far been largely limited to cost savings, and real breakthroughs related to new earning models with new value elements have not emerged as predicted. There is, thus, a need to search for more potential use cases in which novel customer value is created.

Table 3 presents some observations from digitalized asset management service development at the case companies. The companies’ current statuses and future visions are analyzed based on their stage of analytics maturity, strategic business positions, asset management objectives, and examples of digitalized asset management service offerings.

This framework can be utilized to identify companies with similar characteristics, focuses, and visions related to digitalized asset management service development. It is crucial for companies to identify their current roles and positions in the framework, their strengths and weaknesses, and their desired positions in the future. From the business perspective, it does not always make sense to strive for more advanced levels in analytics or deeper customer relationships. A company's role and service portfolio are dependent on, for instance, the sector or industry in which it is operating, the importance of its customership, and the criticality and impact on its customer's business from the customer's perspective.
### TABLE 3. DIGITALIZED ASSET MANAGEMENT SERVICE DEVELOPMENT AT CASE COMPANIES

<table>
<thead>
<tr>
<th>Company</th>
<th>Stage of analytics maturity</th>
<th>Strategic business position</th>
<th>Asset management objective in service business</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>Current status</td>
<td>Diagnostic for problem solving</td>
<td>Product supplier and support partner</td>
<td>Smart machine</td>
</tr>
<tr>
<td></td>
<td>Future vision</td>
<td>Predictive</td>
<td>Product supplier and support partner</td>
<td>Smart machine</td>
</tr>
<tr>
<td>Delete</td>
<td>Current status</td>
<td>Descriptive and diagnostic, predictive in selected applications</td>
<td>Product supplier and performance partner</td>
<td>Smart production</td>
</tr>
<tr>
<td></td>
<td>Future vision</td>
<td>Predictive and prescriptive in selected applications</td>
<td>Product supplier and performance partner Value partner in selected custom- erships</td>
<td>Smart production</td>
</tr>
<tr>
<td>Huurre</td>
<td>Current status</td>
<td>Diagnostic in maintenance and predictive in cooling and heating systems</td>
<td>Product supplier, system provider, and support partner Performance partner in selected applications</td>
<td>Smart maintenance and production</td>
</tr>
<tr>
<td></td>
<td>Future vision</td>
<td>Prescriptive analytics</td>
<td>System provider, performance partner, and value partner</td>
<td>Smart asset management</td>
</tr>
<tr>
<td>Pesmel</td>
<td>Current status</td>
<td>Diagnostic, predictive in selected applications</td>
<td>System provider and support partner</td>
<td>Smart machine and maintenance</td>
</tr>
<tr>
<td></td>
<td>Future vision</td>
<td>Predictive and prescriptive</td>
<td>Performance partner</td>
<td>Smart production</td>
</tr>
<tr>
<td>SWD</td>
<td>Current status</td>
<td>Predictive</td>
<td>Performance partner</td>
<td>Smart production</td>
</tr>
<tr>
<td></td>
<td>Future vision</td>
<td>Prescriptive</td>
<td>Value partner</td>
<td>Smart production</td>
</tr>
</tbody>
</table>
The main findings of the project may be categorized into three dimensions: analytics, digital services and decision-making, and business model development. The main findings are as follows:

1. Analytics: Pure analytics capabilities are not sufficient to generate successful results. Domain expertise needs to be tied into the development process by inviting the company’s process and maintenance experts to bring their views on the phenomena that are being addressed. Without this knowledge, the models become black boxes that form no clear link between causality and correlation. All the relevant stakeholders need to be involved in the development process so that none of the important perspectives are neglected. Furthermore, all the relevant data sources and items need to be combined. Thus, the effectiveness of the data fusion and the resulting models depends on the amount of data and knowledge available during their creation and use. Thus, the greater the suitability of the available data and expertise, the better the results. The objective of the data-processing project should be carefully determined; however, preparations should be made to ensure that the precise goals and practices are revised and iterated throughout the project in order to achieve optimal results. Data exploitation requires in-depth considerations of data ownership. The more the company is willing to share, the better the results.

2. Digitalized asset management services and decision-making: Developing frameworks such as “strategic service positioning” and a “framework for connecting the asset management objectives with the DIKW hierarchy” helps companies to focus on and position their service development. To create a new value-added service, a service company might need to move more strongly toward the role of technology developer. In this case, forming a new kind of network could be a quicker and more cost-efficient way to make technology development competencies available than the company establishing its own development department. Therefore, assuming the role of a service network integrator is a serious alternative that can be used to overcome this challenge. An approach to digitalized asset management service development was presented in the deliverable. It combined roadmapping, understanding the customer’s decision context, business model perspective, and agile development. The transition to digital service development requires a top-down approach to digitalized asset management service development to complement the experimentation- and iteration-driven agile development.

3. Business model development: The renewal of the value proposition is a requirement for a successful business model of a new digital service. The successful renewal of business models necessitates an understanding of customer needs. Furthermore, it is necessary to identify which types of services the customers would be willing to pay for. New services that are based on data require the service provider and customer to agree on data-sharing principles. In addition, it is important to work jointly with customers to define and agree on the KPIs that will be monitored to ensure the quality of service. Data-based business models transform customer relationships from individual transactions into continuous partnerships. Approaches that enable better understanding and communication of the value of the developed services are needed. During the project, it was noticed that smart machines, digitalization, and asset management provide a means of realizing the principles of the circular economy. Further information on circular economy development is provided in the final report of the Data to Wisdom project: https://www.vtt.fi/sites/datatowisdom.
SmartAdvantage has provided companies with opportunities to share their experiences with digital service business development, with a focus on both technology development and business models. The companies did not share business ecosystems and did not work in the same industries; however, companies have reported that the knowledge acquired from other companies have been extremely valuable and have provided new insights. Even while working in a different industry, mutual concerns and development areas were found. Networking is a necessity in the changing business environment, and collaboration with carefully selected partners has boosted the companies’ development work.

During the project, the following future research areas that have considerable potential have been identified:

1. Further development of analytics-based services is important. AI has gained significant attention among researchers and practitioners, and various development activities are being prepared. The development and testing of AI-based services is considered a future research topic. The research activities will focus on the use of AI in new applications and on deepening the knowledge in previous domains.

2. The development of digital twins is a rising trend. Digital twins are currently exploited mainly in R&D and training applications. The exploitation of digital twins in decision-making over the life cycle of the technical system is the second future research topic identified.

3. There is much talk about industrial data-based services, but only a few practical success stories. Companies operate in complex ecosystems with multiple actors who could benefit from the data. In order to generate profitable data-based business it is essential to identify the value of the data and its benefits and the potential end users and customers. However, it is difficult for the data producer and the buyer to set value for the data. The third future research topic concerns assessment and realization of the value of data for different stakeholders in industrial value networks. For instance, business models, contract types, risk management and measurement and demonstration of the value are considered.
5 REFERENCES


