D6.3 Digital Twin based Industrial Service Business Models

WP 6

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Abstract

This deliverable describes the outcome of Machinaide Task6.3, Digital twin-enabled service business models and related monetization scenarios. This deliverable focuses on describing the different industrial manufacturers' and software providers' business models that are possible by utilizing the Digital Twins. Findings are based on the consortium companies' digital twin-based service offering and service processes, defined in the earlier Task6.1 and Task6.2. Task6.3 included company workshops that highlighted the service business models and modernization scenarios. As a result, the next generation business models were identified and analysed.

Digital twins can have an enabling and supporting role in modern manufacturing industry operations, but mainly in operation & maintenance phases. The earlier task Task6.2 suggested, in the operative environment, the main purpose of the digital twin is to ensure and support Overall Equipment Efficiency (OEE). Here, Task6.3 have identified in which kind of business model OEE can be done. Traditionally by selling the product itself and support operations with the maintenance contract. However, digital twins can offer real timed view to machine and therefor Machine-as-a-service (MaaS) type of business model can be realized. Within the monetization scenarios, the MaaS can have many options, based on the outcome or utilization rate (e.g., tonnage, amount of something, utilization hours or other outcomes). Meanwhile, software providers have a critical role by ensuring date operations in practice. In many cases, manufacturers do not have competencies to develop digital twins by themselves. Maybe in the future, new kind of Smart Factory Orchestrator is needed in the ecosystem of multiple digital twins. Deliverable summarizes the different business models and monetization scenarios for Smart Factory environment.

Change log

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1. Introduction

This deliverable describes Machinaide Task6.3, Digital twin-enabled service business models and monetization scenarios. WP6 addresses Full Project Proposal Problem Statement 5: "*New service concepts cannot be provided based on the established classical business models. Novel industrial value creation may become possible in Digital Twin based service operations in the future industrial ecosystems*". Task6.3 Digital Twin enabled Service Business Models focused on describing the consortium companies digital twin-based service offering and service processes. Insights from data and understanding generated in Task6.1 and Task6.2 were highly utilized in Task6.3. The deliverable 6.1 illustrates the current service business offerings and the existing state of industrial service business and related digitalization opportunities of the Machinaide consortium partners. Task6.2 studied and depicted the service processes of digital twin use case collaborations on two overlapping levels: inside the use cases, and also from the overall digital twin-enabled service concept level. Customer and stakeholder perspectives were highlighted in conducting the service blueprints in Task6.2, thus contributing to e.g., value proposition formation and fundamentally the service concept development of the digital twin-based services among the Machinaide consortium partners. The focus of Task6.3 was on future business models for realising digital twin value and operative processes in practice.

This deliverable is structured as follows. First, the research approach and overall method of Task6.3 are described. Secondly, the digital twin-enabled service business models and monetization scenarios are discussed. Thirdly, the future insights regarding the digital twin-enabled service businesses are presented.

2. Research approach and method

2.1. Conceptual structuring of service business models

In Machinaide project, WP6 is related to Problem statement 5 (defined in FPP): New service concepts cannot be provided based on the established classical business models. The aim of the WP6 is to provide new business models and service concepts based on the digital twins, and models how to develop digital twin-based services. On the service development, the framework of service business development presented by Hemilä & Vilko (Hemilä & Vilko, 2015) will be the basis, but that framework will be updated with digital twin and digitalization views. According to the WP 6 plan, three Tasks will contribute to Service Development Phases, as follows:

Figure 1 Service Development Phases and Task contribution

Task6.1 studied the visionary thinking of companies, how they strategically are aiming towards the DT services (SDP1). There are many frameworks for strategy formulation, but that is not included in Machinaide studies. The product and its features (SDP2) are the core of analysis. Within the Machinaide, case studies are looking DT opportunities in machine level, production line level, factory level and even in ecosystem level (see more details about Digital Twin Web in other Machinaide WPs). Customer understanding and customer needs (SDP3) have been studied in Task6.1 but continued in Task6.2. DT services are not typically requested by customer, but rather offered by machine manufacturers. However, understanding of how customers are using machines, how they operate (HMI studies in WP4) and finally customer journey is critical for the successful development and implementation of DT. Product lifecycle (SDP4) is typically shared in phases 1) design 2) sales 3) install 4) operate 5) maintain 6) modernization 7) replace. From service business point of view companies need to decide in which lifecycle phases they are offering services. For example, some companies do not offer installation services. Machinaide case studies have different level of detail in these lifecycle phases, but DT can have role on each of these phases and DT based services can be offered in many lifecycle phases. Service ideas and offering must be innovated (SDP5) along the product lifecycle. Task6.1 started service innovations and work have continued in Task6.2, where the series of workshops have been used for defining service innovations and practical service processes. Service offerings can be modular and packaged as service packages for the customer (SDP6). A service offering packaged in modules can provide full product lifecycle support for the customer. Then the customer can focus on their own core business and be sure that the machines are working as needed. For the machine manufacturer, service packages are a way to make them even stronger in the markets, with a fully covered product lifecycle with services. SDP7 was the core of the Task6.2, as the service processes and needed roles were identified. Here, Task6.3 focused on the SDP8, earning logics. SDP9 was already partly covered in Task6.2, as the sales and marketing phase of machines were included in the studies. Task6.3 finalized the marketing and sales view by defining how to concretize digital twin value to customers. SDP10 service launch and SDP11 follow-up and improvement were not included in the studies as Machinaide is research project, not developing ready to market offerings. As a summary, the entire business model includes all SDPs. Here the focus is on analysing what is the business opportunity and operation model for future smart factories utilizing digital twins.

2.2. Method for forming service business models

WP6 included three main stages that aimed for constructing and conceptualizing digital twin enabled service business models and monetization scenarios (Figure 2). Task6.3 is strongly utilizing results from earlier tasks Task6.1 and Task6.2.

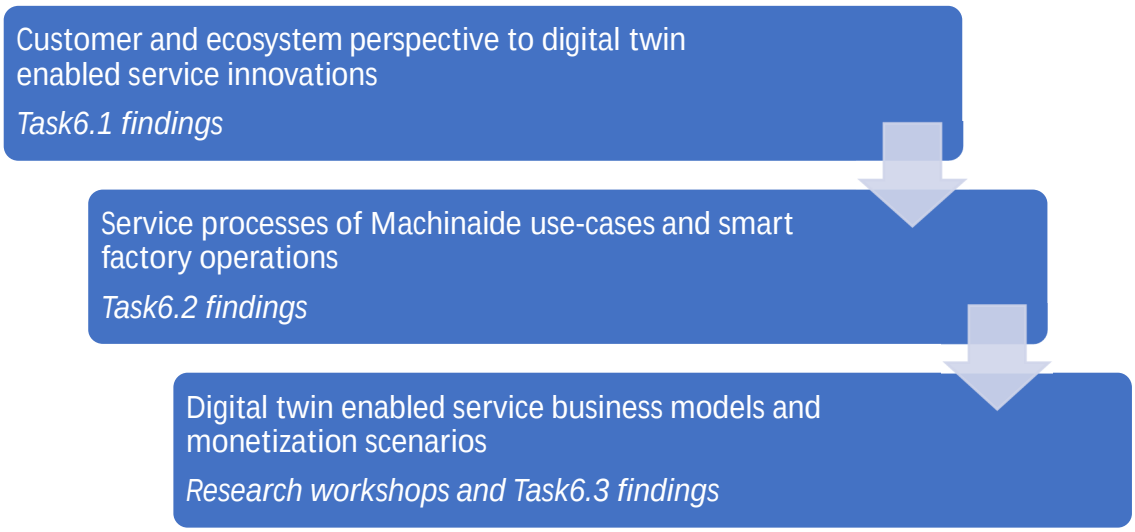

Figure 2 Overview of WP6 methods.

The findings of Task6.1 company interviews were used as a basis for understanding the current stage and the future business potential of the digital twin enabled services in the Machinaide consortium companies. Next in Task6.2, several workshops were conducted to map the service processes of the Machinaide use-cases in three consortiums: Finland, Turkey, and The Netherlands. The workshops were held remotely using Microsoft Teams due to the still ongoing COVID-19 situation and the limitations to travel and meet in person caused by the situation.

As a results of earlier tasks, the several business model candidates and related monetization scenarios were identified. As defined in Machinaide KPIs, project need to deliver nine business models and five monetization scenarios. Therefore, following eleven Business models were planned to be studied, seen on the right column of the next Table 1.

Table 1 Business Models to be studied in Task6.3.

Case ID (Process)	Customer	Machine / manufacturer role(s)	SW Role	Consortium Partners to be studied	Related Business Models to be studied
Production line (TUR)	Automotive industry	Automotive supplier Robot manufacturer Press manufacturer	Machine DT Line DT Platform	Production Process Optimization - Ermetal (TUR) Multiple DTs – Teknopar (TUR) HMI provider SW - Dogru (TUR)	1. Optimized Production Line with multiple DTs – Ermetal (TUR) 2. Multiple DTs and Sensor data HMIs – Teknopar & Dogru (TUR)

Feeding robot (NED)	Farm	Feeding robot manufacturer	Farm visualization Robot DT	Automated Guided Vehicles (AGVs) manufacturer - Lely (NED)	3. Optimized Farm Operations with Automated Guided Vehicles - Lely (NED)
3D printing (NED)	Automotive / Aerospace industry	3D printer manufacturer	Machine DT Data Platform	Machine manufacturer - Additive Industries (NED)	4. Overall Equipment Efficiency (OEE) with DT supported Machines – Additive Industries (NED)
SW providers DT offering (NED)	Machine manufacturers Manufacturers	Machine manufacturers Manufacturers	Low-code model, Big Data collection, AI dash boarding and analytics, Formal model, PLM system, Smart Connected Factory IoT platform, Hololens UI for machine control	Smart connected factory SW - Cordis SUITE, TNO, KE-works (NED)	5. Smart connected factory SW (NED)
Virtual Factory (FIN)	Factory	Crane Roll grinding machine	Crane DT Roll grinding machine DT Industrial IoT Data platform Plant simulation SW	Machine manufacturer - KC (FIN) Machine manufacturer - Roll Research (FIN) HMI provider SW - KC (FIN) Industrial IoT Data platform - Remion (FIN) Plant simulation model - IDEAL-PLM (FIN)	6. Machine as a Service - KC & Roll Research (FIN) 7. Smart HMI for machine operations and training - KC (FIN) 8. Industrial IoT Data platform - Remion (FIN) 9. Plant simulation model SW - IDEAL-PLM (FIN)
Material handling platform (KOR)	Factories	Manufacturers	Material handling platform AMR control, 3d visualizati	SW Platform provider – ETRI, CIP (KOR)	10. Material handling platform for AMR operations with modern HMIs – ETRI, CIP (KOR)

			on, 2d minimap		
Smart Factory Orchestrator	Factories	Multiple Machine manufacturers Smart Factory Orchestrator	Smart Factory SW MachineDTs FactoryDT	New concept	11. Smart Factory Orchestrator

Unfortunately, project partner LELY did not join to workshops, so their Feeding Robot case is not included in business model analysis.

Additionally, to business models, five monetization scenarios were identified to be studied, as indicated in following list:

1. Pay-per-use of Machine (Micropayments per use)
   - Shared use in multi-user environment
   - Pay per use models: per tons, per hours, per amount of lifts
2. Total Care of Machine (Full-service model supported by DTs)
3. Minimized maintenance fee with optimized operations
4. Machine will be sold separately, service fee for maintenance operations
5. OEE ensuring / Process optimization benefit sharing (Revenue for SW provider from manufacturing operation / maintenance savings)
6. DT Platform operations (SW fee for platform)
7. Smart Factory Orchestrator

In the Task6.3 part of the workshops were held in person, but unfortunately still some travel restrictions forced us to have partly meetings in Teams format.

Following Table 2 summarizes Task 6.3 workshops.

Table 2 The company workshops, themes and participants

Business Model	Date	Participants
Machine as a Service	4th October 2022 (Telco)	Thomas Widmaier, Roll Research
Material handling platform for AMR operations with modern HMIs	11th October 2022 (in person)	Yo Hun Lee, CIPSYSTEM WankSik Choi, CIPSYSTEM Wookeun Jeong, CIPSYSTEM Daesub Yoon, ETRI Yangkoo Lee, ETRI Youngjae Lim, ETRI Jaejun Yoo, ETRI
Smart connected factory SW	15th November 2022 (in person)	Bas Huijbrechts, TNO Jeroen Broekhuijsen, TNO Benno Beuting, Cordis Jeroen Keiren, TU/e

Overall Equipment Efficiency (OEE) with DT supported machines	15th November 2022 (in person)	Roland Smits, Additive Industries Niels Hoppenbrouwers, Additive Industries
Multiple DTs and Sensor data HMIs	21st November 2022 (Telco)	Özlem Albayrak, Teknopar
Industrial IoT Data platform	22nd November 2022 (Telco)	Miika Okko, Remion Jukka Kivimäki, Remion
Plant simulation model SW	22nd November 2022 (Telco)	Markus Ranta, Ideal GRP Juha Lunkka, Ideal GRP Jaakko Hallavo, Ideal GRP
Machine as a Service	23rd November 2022 (In person)	Juho Silmukari, Konecranes Valtteri Peltoranta, Konecranes Heikki Mesiä, Konecranes Kimmo Rantala, Konecranes
Smart HMI for machine operations and training	23rd November 2022 (In person)	Juho Silmukari, Konecranes Valtteri Peltoranta, Konecranes Heikki Mesiä, Konecranes Kimmo Rantala, Konecranes
Optimized Production Line with multiple DTs	5th December 2022 (Telco)	Cem Yildiz, Ermetal

Additionally, to research methodology, Task6.3 have used ITEA Value Chain notation methodology for describing value chain and business ecosystem relationships and earning flows.

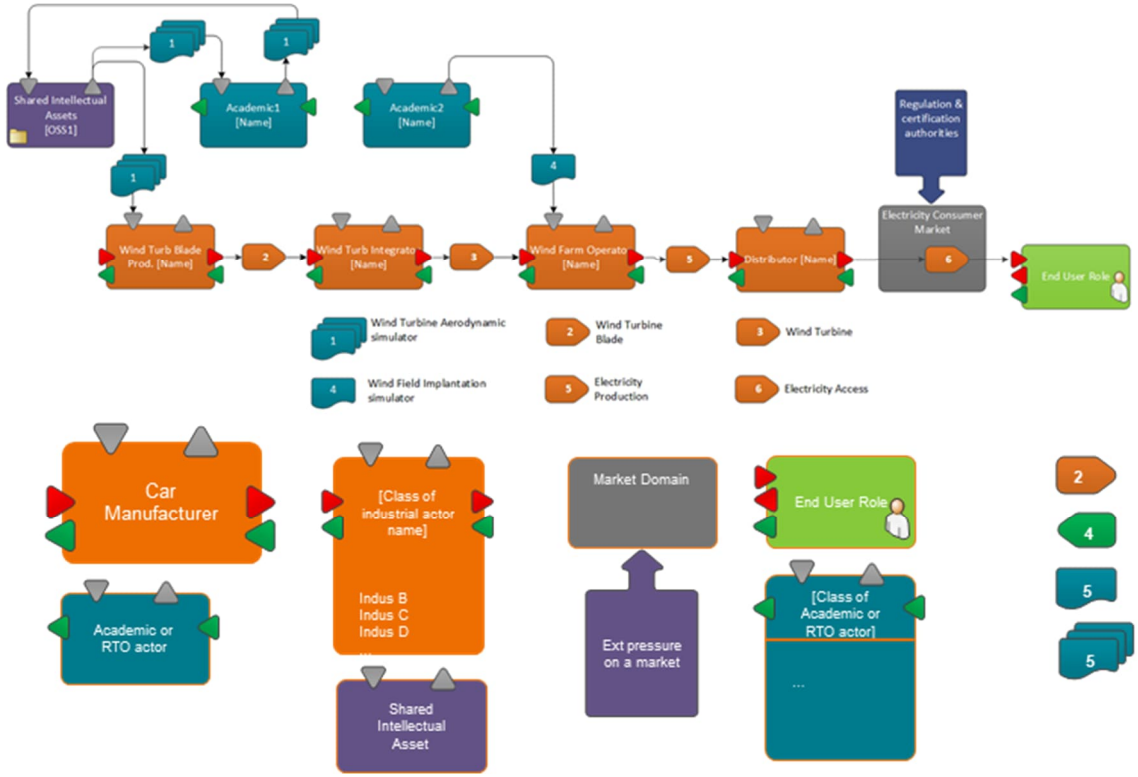

Figure 3 ITEA Value Chain notations methodology

Following chapters present the research findings.

3. Digital Twin

The term “digital twin” was seen as abstract and to have multiple definitions. The consortium members emphasised that term is indeed a buzzword now and their customers do recognize and talk about it based on different definitions. However, no customer is asking for *a digital twin,* or a service called *digital twin,* but rather some concrete digital service (which can be delivered via *digital twin*). This emphasises the need to focus on the value proposition of a digital twin: what are the pain points of customer that can be relieved with services using digital twin. The consortium members identified efficiency related value propositions to be something that resonated with the customers, however there are other dimensions to the potential value creation.

There is confusion on what characteristics a digital twin has (for example related to connectivity and interactivity). The consortium view towards the business case of a digital twin was leaning more on the idea that a digital twin is a machine specific thing. To create more value creation opportunities, the DTs need to be connected to one another in some way. Therefore, a factory owner (potential customer of a digital twin) is facing a situation where they need to manage multiple digital twins. The question also remains on what the role of a software platform related to a digital twin is, especially on connecting the different digital twins of machines, or fleets of machines. There are many different IoT-platforms available in the marketplace and many factories utilize multiple different platforms for data gathering and collection.

The multiple definitions of digital twin can be illustrated by a three layers approach illustrated in Figure 4:

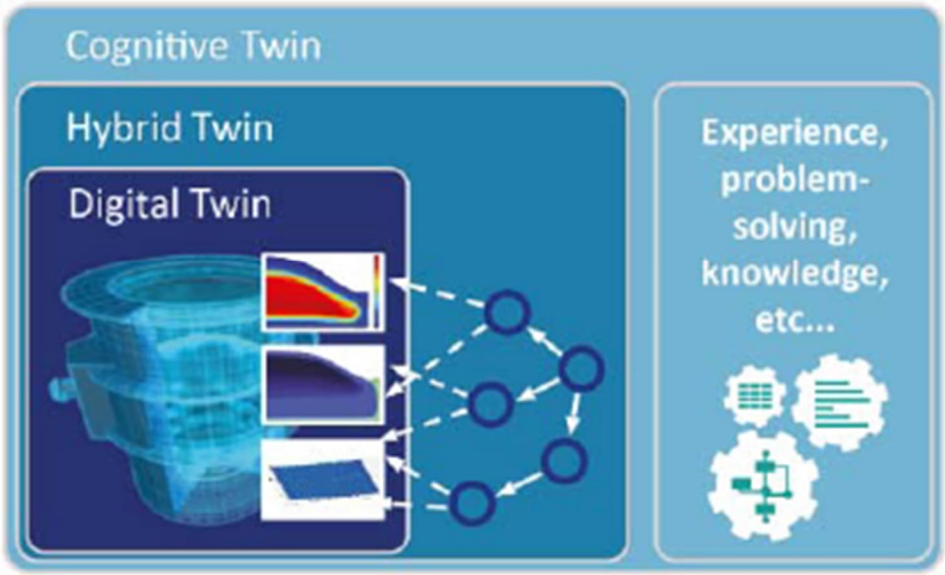

Figure 4 Layered Approach to Define Twins, Adapted from Abburu et al. (Abburu, ym., 2020).

Hybrid Digital Twin

Hybrid twin combines the individual digital twins into interconnected models and provides some basic capabilities like prediction on unusual behaviour (Zheng;Lu;& Kiritsis, 2021).

Cognitive Digital Twin (CDT)

Cognitive capabilities would mean that the DT includes cognition capabilities (meaning it can perform human-like intelligent activities to deal with unknown situations (Zheng;Lu;& Kiritsis, 2021).

The different definitions of DT are causing confusion in the marketplace, and situation will continue to be like that for some time. This will in-turn influence the business maturity of DTs and services based on DTs. Positive impacts to progress the business adoption of DTs were stated to be promotion of successful cases of DT adoptions within the industry value networks (the positive word of mouth) and that the cases have measurable impact on the customers business.

There were some cases amongst the Machinaide consortium members, where their customers had been asking for direct access to data related to some specific machinery and indeed some consortium members were selling machine specific data to their customers. Their customers would then combine the machine-specific data in their systems to gather insights and create services from themselves.

It was stated that in some industrial domains the business culture of old-fashioned and that buying digital services related to a machine is new. The status quo being that machine is bought in a one-time deal, adding additional digital services related to the physical product are considered foreign and as an expense. The consortium members speculated that this is a generational thing and will change when the younger generation, who is accustomed to digital services, assumes responsibilities on within the customer organizations. Included in this culture aspect of a DT are the different monetization possibilities enable by a DT, for example selling a machine as service with a monthly fee. Currently these kinds of options were not mainstream business at all.

4. Machinaide Service Business Models

Machinaide have had four demonstration cases:

- Crane domain (Team FIN)
- Production process optimization (Team TUR)
- Machine updates (Team NED)
- Material handling domain (Team KOR)

Within the demonstration cases, the WP6 have analyzed related business opportunities and industrial services which are being the basis for several business models and monetization scenarios. The Machinaide project with the consortium member identified 10 different potential business models using DTs. These models can be monetized in different ways, in the Machinaide project we have explored six different monetization options for business models based on DTs. The initial set of business models is presented in Table 3.

Table 3 Service Business Models

Business Models	Business theme	Initial Value Propositions
1. Optimized Press Line with multiple DTs	Production line	Optimization / OEE
2. Multiple DTs and Sensor data HMIs	Human-machines interfaces for accessing data	Easy to use interfaces
3. Overall Equipment Efficiency (OEE) with DT supported 3D printer production line	Machines	Maximizing OEE / minimized downtime
4. Smart connected factory	Data management	Connecting multiple machines into a single platform
5. Machine as a Service	Machines	Maximizing OEE / minimized downtime
6. Smart HMI for machine operations and training	Human-machines interfaces for accessing data	Faster and easier training of personnel for machine use via AVR
7. Industrial IoT Data platform	Data management	Connecting multiple machines into the single platform
8. Plant simulation model	Production planning	Simulation of production lines and predicting production flow
9. Material handling platform for AMR operations with modern HMIs	Production logistics	Optimization of material flow
10. Smart Factory Orchestrator or Manager	Platform provider for DTs and related services	Provides machinery, premises, and services for customers – “one stop shop” for production environment.

The analysis of potential business models showcases that there are three streams of business opportunities to be explored:

- Machine providers: companies providing machines for manufacturing industries
- Software companies: companies providing digital services for manufacturing industries
- Smart Factory Orchestrator: a new opportunity to provide both physical and digital ecosystem for manufacturing industries

Following figure presents the idea of machine manufacturing value chain, where machine manufacturer offers machines and related maintenance services for the smart factory customers. SW providers are needed for offering DT related SW.

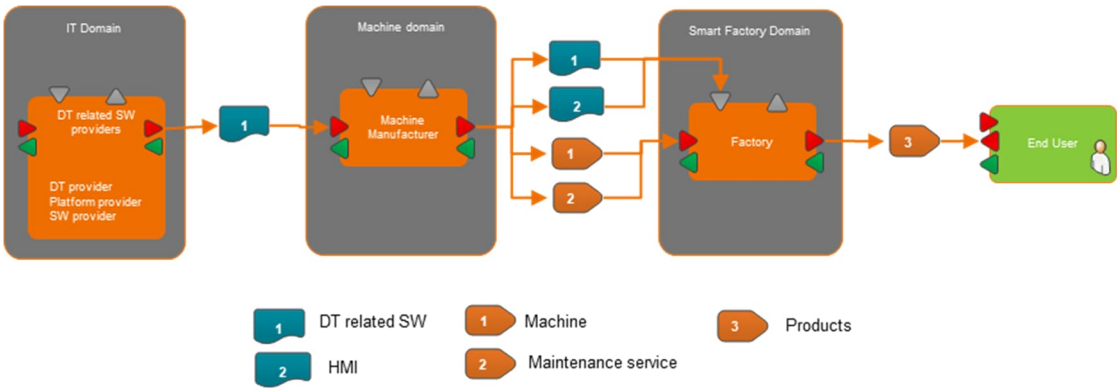

Figure 5 Machine manufacturing value chain (ITEA Value Chain notation methodology)

Next, we will explore these opportunities in more detail.

4.1. Machine providers

For machine providers, the business opportunities presented by different digital twins are based on providing value adding digital services related to the physical machine they are selling. The new, digital services require a functioning digital twin of the machine, so that digital services can built based on it. In addition to digital services, some of the Machinaide partners had already started to sell information based on data directly related to the physical devices of a customer. The potential of digital services for a machine is also dependent on the type of machine and its role in the manufacturing process: some machines form basic functions with very little potential for additional services, but others may be critical for the process (like 3D Printers). An interesting note was that the ownership of data was in many cases attributed to be the property of the machine purchaser.

However, capabilities required to build digital services are very different from traditional, machine building capabilities. Many of the Machinaide partners pointed out that in order from them to expand into providing digital services, a completely new business line would have to be created. Capabilities that would be required include software engineering, user interface design and data engineering. Also, the business logic of digital services is very different, usually based on monthly or yearly occurring feed. In contrast, machine selling is a one-time deal and is more currently more prominent way of doing business in manufacturing industry.

There would be an opportunity to combine these approaches and form a completely new business model for providing machinery-as-a-service (MaaS), also known as Equipment-as-a-service (Eaas). Instead for selling machines with one-time fees, companies could provide machinery-as-a-service and use the digital twin to monitor the machinery and optimize maintenance services so that the customer always has a working machine. Digital twin was recognized to be an essential asset for this kind of a business model, but the traditional business culture of manufacturing industry is slowing down the adoption of this kind of a business model.

The resources required to provide machinery-as-a-service, or any other way supported digital services would probably mean the financing for the machines acquisition would need 3rd party support because of the change in revenue stream logic.

4.2. Software companies

Machine provider companies do not necessarily have software intensive capabilities needed to provide advanced digital services. Creating these services for different machines presents an opportunity for software companies to integrate their services with different, physical machines. The services are dependent on the types of machines – some manufacturing equipment is more data intensive than others.

An opportunity was identified based on machine manufacturers opening their API's, so that new software services may use the data of the machine in their services. An example of this the KUKA robotics and their API environment.

Another opportunity was identified for providing digital services based on the circular economy and sustainable manufacturing: information about the machines and production activities would be needed to prove the sustainability of the manufacturing activities. These services could provide a digital passport like service for validating the entire machines lifecycle.

Some of the Machinaide partners were using prevailing industry platform to provide services with, currently the manufacturing industry platforms are dominated by larger players like Siemens. Some partners were offering a platform of their own to gather data from machines and provide digital twin-based service with their platforms. The customers (e.g., factories) are facing the pain of having many different platforms in the marketplace, so the market is very fragmented.

4.3. Smart Factory Orchestrator

A new opportunity for business was identified based on the combination of owning some machinery and a digital platform to govern them. This kind factory orchestrator role could provide the marketplace with manufacturing services based on the EaaS model for customers who only need to use expensive devices every now and then, for a limited time. These kinds of services do already exist for some specific machineries, like 3D Printers. However, to scale-up this approach, a smart factory orchestrator cloud offers a plethora of machines and services for customers in need of manufacturing services.

However, based on findings in academic literature, this kind business model would approach an *ecosystem level orchestrator* role. It has been identified that this kind of role would not only require digitalization of manufacturing processes, but it would also require an innovative business model. Digital business models consist of new ways of value creation, delivery, and capture. The term digital myopia has been introduced to describe the barrier of value creation of different manufacturers. The physical product design approach which they are accustomed to prevents them from seeing the digital value creation dimensions. (Sjödin;Parida;& Visnjic, 2022)

Other barriers include the traditional value chain inertia, moving from reactive mind-set to a more predictive mind-set, and the firm-centric value capture logic which prohibits incumbents from moving into a profit-sharing model related to working in a business ecosystem. (Sjödin;Parida;& Visnjic, 2022).

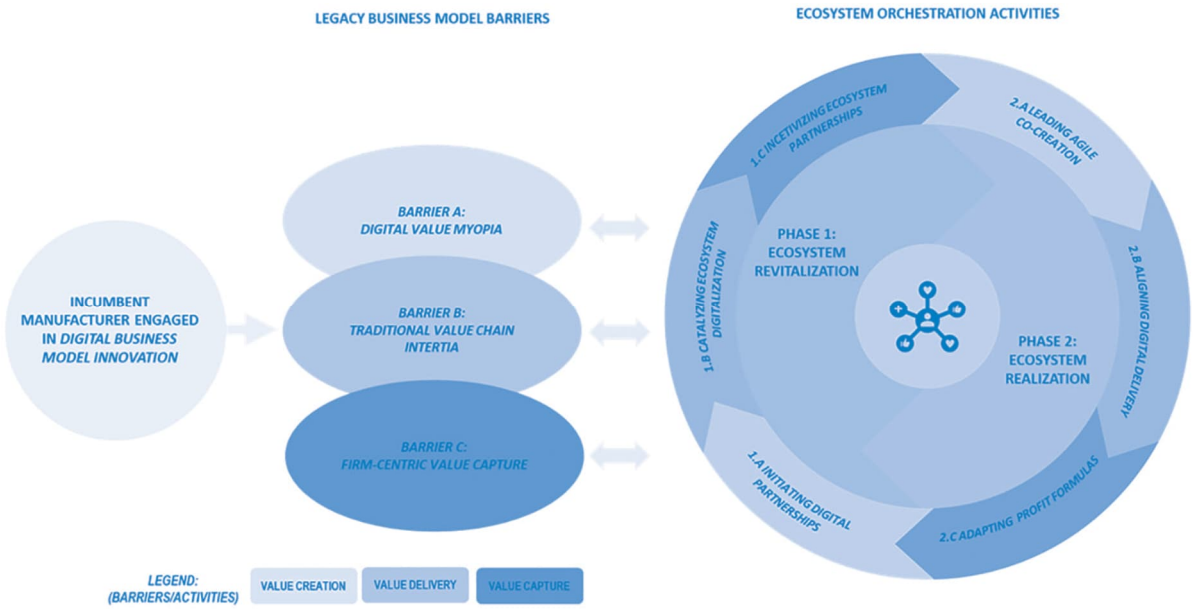

Figure 6 Barriers for ecosystem level orchestrator role.

Ecosystem Orchestration for Digital Business Model Innovation		
Key Question	***Orchestrating Ecosystem Revitalization***	***Orchestrating Ecosystem Realization***
What (Value Creation)	What partnerships are needed to catalyze our digital value creation?	What digital value propositions can we quickly develop and scale together?
How (Value Delivery)	How can we support the digital transformation of existing value delivery partners?	How can we align delivery processes to realize potential value creation?
Why (Value Capture)	Why should partners join forces with us in revitalizing the ecosystem?	Why will ecosystem partnerships remain profitable for all sides over time?

Figure 7 Value dimensions for ecosystem orchestrator

When looking at the Smart Factory Orchestrator as a value chain, the complexity arises when more machines are considered.

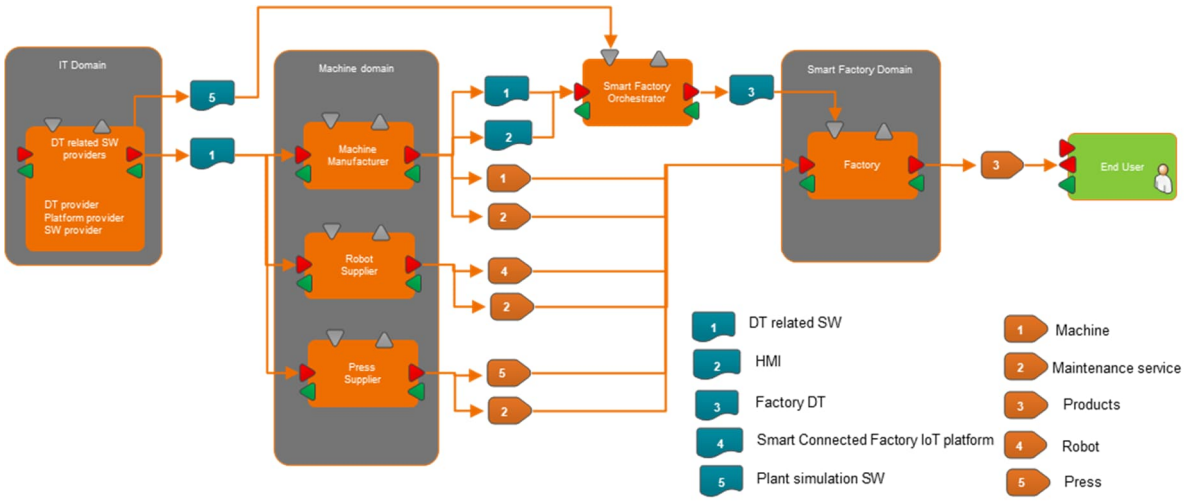

Figure 8 Smart Factory Orchestrator Value Chain

In the value chain example above (Figure 8), there are robot and industrial press suppliers, as we have had in Machinaide optimized production line case. If expanding concept towards the ecosystem view, where all Machinaide use cases are visible, the business environment becomes complex. The following Figure presents the ecosystem view. The addition to Figure 8 is the Material Handling Platform and Production process optimization case with automotive industry customers.

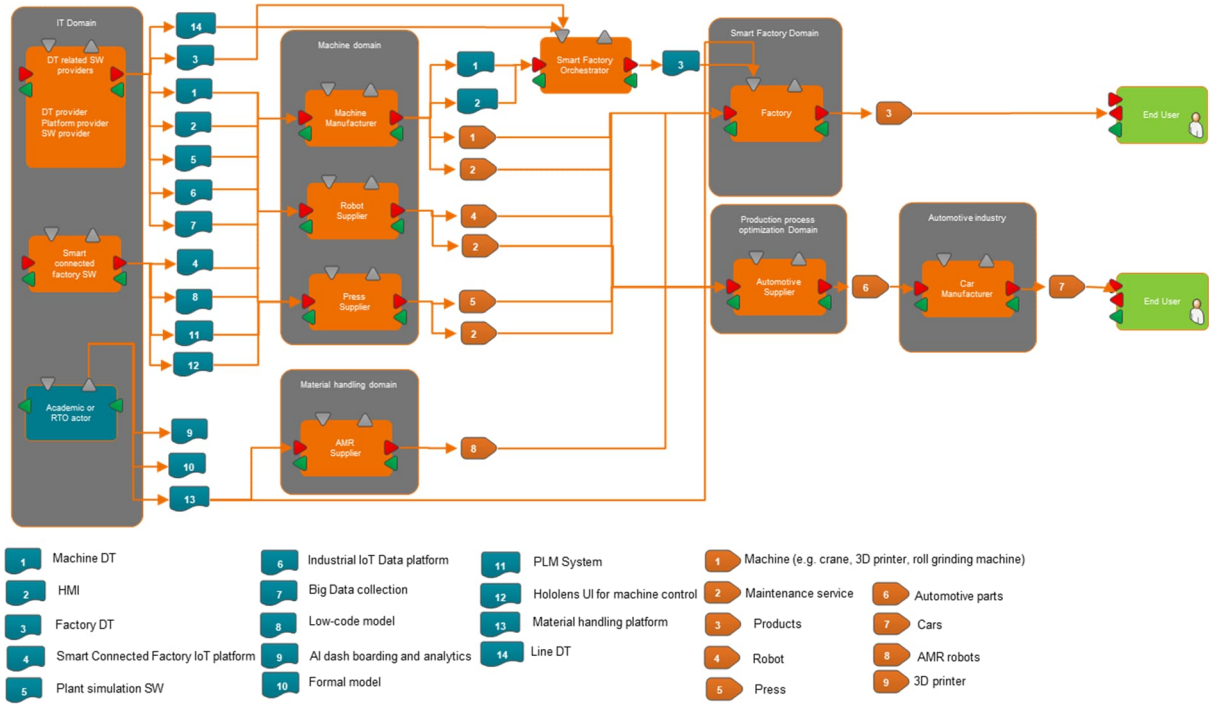

Figure 9 Machinaide offerings Ecosystem view.

Within the previous figures, the Smart factory can also purchase factory operations related software directly from the IT domain, but for simplifying the figures, those linkages are not included.

5. Monetization Scenarios

To support the explorative nature of new business model identification, we have adopted new monetization scenarios to support the business models. These monetization scenarios for the digital twin -based business models have been adopted from the different API pricing models (Glickenhouse & England, 2016). They have not been adapted into the manufacturing industry, but for digital twins and digital services they may be useful. The initial set of different monetization included the following options:

1. Pay-per-use of Machine (Micropayments per use)
    - Shared use in multi-user environment
    - Pay per use models: per tons, per hours, per amount of lifts
2. Total Care of Machine
    - Full service model supported by DTs
3. Minimized maintenance fee with optimized operations
    - Machine will be sold separately, service fee for maintenance operations
4. OEE ensuring / Process optimization benefit sharing
    - Revenue for SW provider from manufacturing operation / maintenance savings
5. DT Platform operations
    - SW fee for platform
6. Smart Factory Orchestrator

5.1. Mapping Monetization Scenarios with Business Models

Table 4 presented the mapping of business models with the new monetization scenarios, based on the feedback from the Machinaide consortium members opinions.

Table 4 Potential monetization scenarios for business models

Business Models	Business theme	Initial Value Propositions	Related Monetization Scenarios
1. Optimized Production Line with multiple DTs	Production line	Optimization / OEE	Total Care of Machine
2. Multiple DTs and Sensor data HMIs	Human-machines interfaces for accessing data	Easy to use interfaces	SW fee, for example monthly / yearly fee

3. Overall Equipment Efficiency (OEE) with DT supported machine	Machines	Maximizing OEE / minimized downtime	Pay-per-use of Machine, Total Care of Machine, Minimized maintenance fee with optimized operations
4. Smart connected factory	Data management	Connecting multiple machines into a single platform	SW fee for platform, for example monthly / yearly fee
5. Machine as a Service	Machines	Maximizing OEE / minimized downtime	Pay-per-use of Machine, Total Care of Machine, Minimized maintenance fee with optimized operations
6. Smart HMI for machine operations and training	Human-machines interfaces for accessing data	Faster and easier training of personnel for machine use via AVR	SW fee for platform, for example monthly / yearly fee
7. Industrial IoT Data platform	Data management	Connecting multiple machines into the single platform	SW fee for platform, for example monthly / yearly fee
8. Plant simulation model	Production planning	Simulation of production lines and predicting production flow	SW fee for platform, for example monthly / yearly fee
9. Material handling platform for AMR operations with modern HMIs	Production logistics	Optimization of material flow	SW fee for platform
10. Smart Factory Orchestrator or Manager	Platform provider for DTs and related services	Provides machinery, premises, and services for customers – “one stop shop” for production environment.	?

Following Figure 10 presents the earning logic of machine operations in smart factory domain. End user payments was not included in the studies, and it varies depending on which kind of end product is in case. Smart factories buying machines can use identified monetization scenarios (Pay-per-use of Machine, Total Care of Machine, Minimized maintenance fee with optimized operations). Machine manufacturers using software as a part of their machine operations can buy required software with identified software monetization scenarios (SW fee for platform, for example monthly / yearly fee).

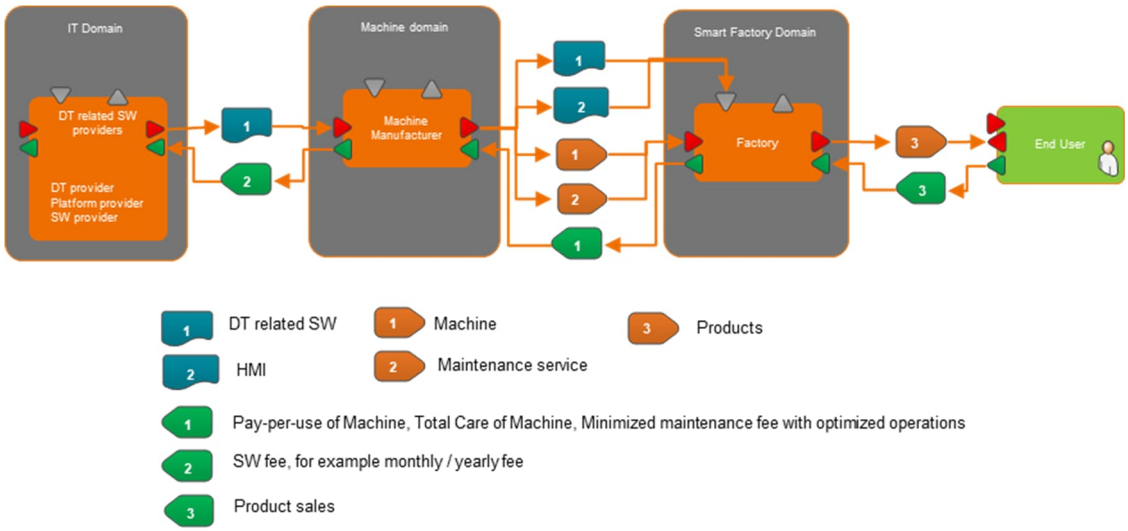

Figure 10 Monetization scenarios in smart factories value chain.

Figure 10 above is simplified, but there can be different monetization scenarios for each required software, it is not needed to operate with the same monetization scenario with all partners.

Next Figure 11 depicts the Smart Factory Orchestrator business case monetization scenarios, where orchestrator is middle player between machine manufacturers and Smart Factories. There, Orchestrator integrate machines to single view to factory, like offering turnkey solution from single source.

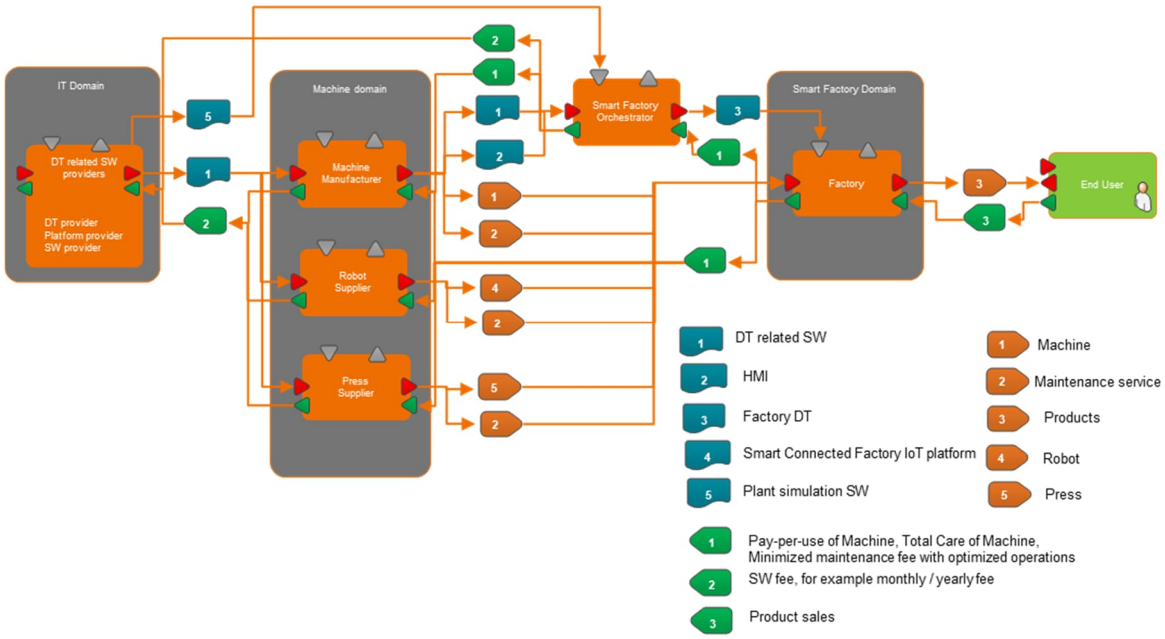

Figure 11 Monetization scenarios in Smart Factory Orchestrator case

Smart Factory Orchestrator model is ideal for the smart factories when everything can be purchased from one single provider. However, there are not so many examples in practice about this kind of operations.

The entire Smart Factory domain ecosystem is very complex, if taking in account all main partners of the business environment. Following Figure 12 summarizes the main findings of Machinaide WP6 studies. Business environment is complex, despite it is still simplified version of the real life.

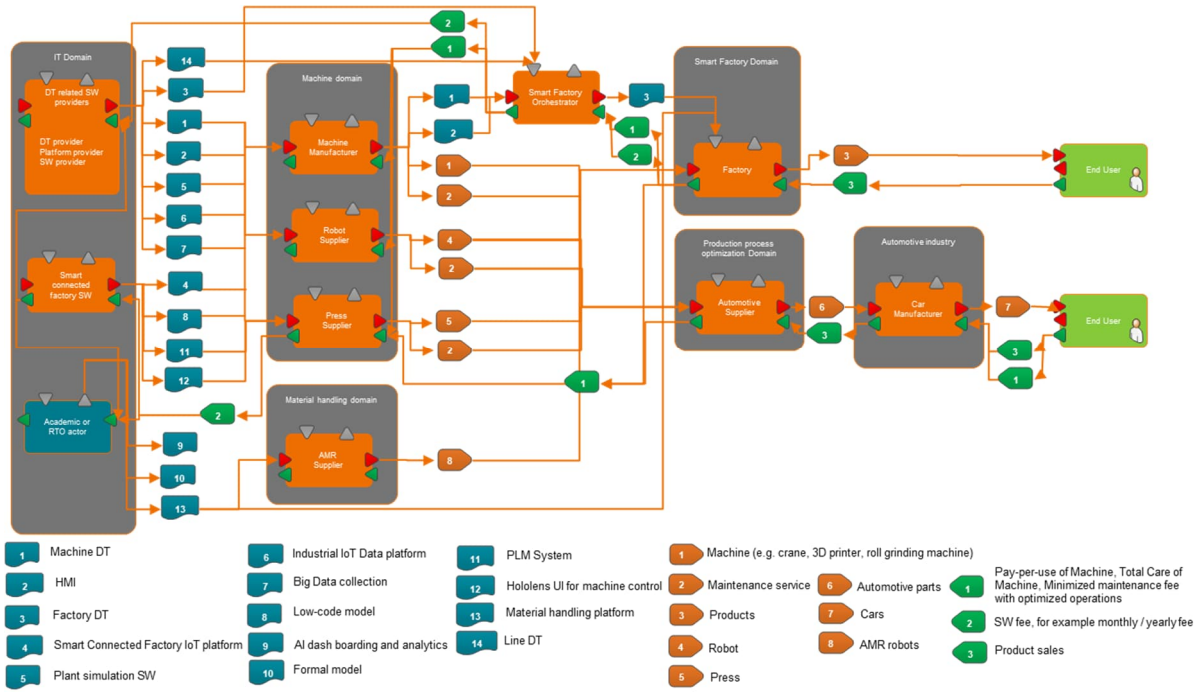

Figure 12 Smart Factory ecosystem machine, service and software business opportunities

All Machinaide use case environments are visible in the ecosystem, and all identified monetization scenarios. In practice, there is surely many options how to purchase software and machines.

6. Conclusion

It was notable that many of the business opportunities – both present and future opportunities was based on increasing the internal efficiency. While these are a large business opportunity, there could be more to be achieved in the digital service domain. In Figure 13 we have illustrated the different value creation layers when combining the physical assets of machines with the digital twin enabled opportunities.

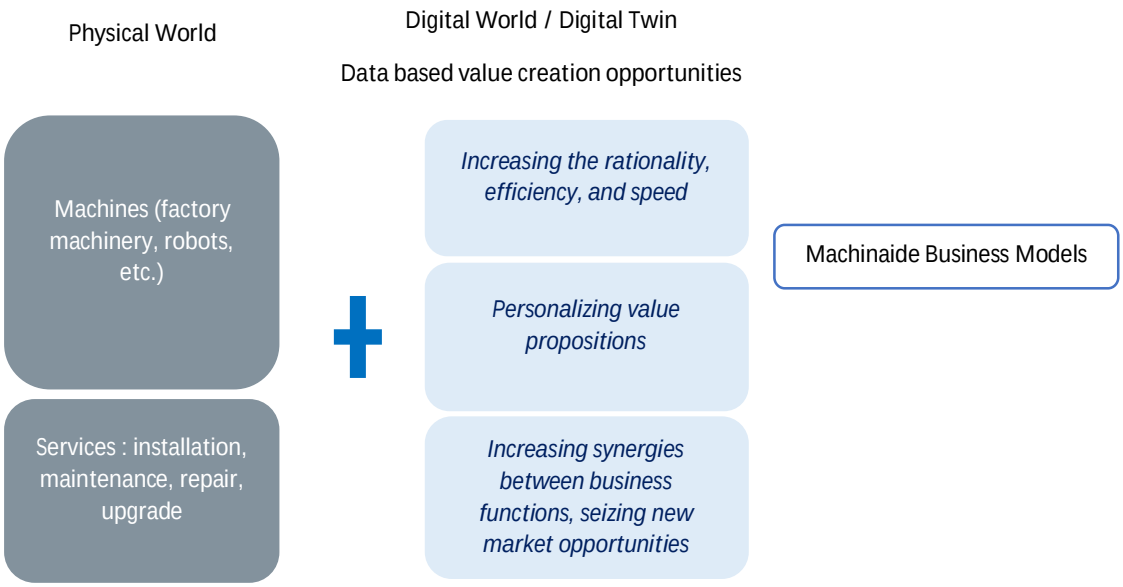

Figure 13. Value Creation Opportunities

Many of the current services are focused on increasing the efficiency, but there are also other opportunities in the personalizing value proposition (like creating customized UIs for machines) and creating a completely new business based of digital twin and data.

7. Future Research Avenues

Themes of Machine as a Service (MaaS), sustainability and metaverse were brought up in discussions by the Machinaide consortium members, these topics could present the next opportunities for different types of digital twins (hybrid twin, cognitive twin).

Machine as a Service (MaaS)

It has been estimated, that by 2030, companies will sell most of their equipment as part of bundled solutions including software and services, reducing hardware's share of total profits (Roth;Strempel;Straehle;& Liu, 2022) . This kind of development means realization of Data-as-a-Service and Everything-as-a-Service models. Machinaide studies indicated that in practice, manufacturing industry is still far from the machine-as-a-service type offerings. Why, might many ask? The customer base is not ready for changing from investments to service fees. It is about a transition from Capital expenditures (CapEx), that are a company's major, long-term expenses towards operating expenses (OpEx), which are a company's day-to-day expenses. Customers are still preferring investments rather than as-a-service model. However, in the future monetization of machine might be done in many ways in as-a-service model. Total care concept, where customer still invest to machine, but it is maintained fully by manufacturer is becoming more famous operation model. Study indicated that machine-as-a-service is possible today, but not yet widely implemented.

Sustainability

Sustainability was identified to a major driver for digital twins and the whole digitalization of the manufacturing industry at the moment. However, there were very few sustainability-based services currently presented in the Machinaide consortium. Sustainable Industrial Service offerings means the

support for customer's production sustainability goals, utilizing the novel data-enabled service business models, minimizing Operational Carbon Footprint. Maintenance programmes and the processes for delivering the services are optimized in terms of their impacts on overall sustainability goals, resulting in value-driven maintenance optimization. This includes services without visiting/ remote maintenance (life after Covid). Task also addresses the fact that a number of services are produced in company networks and aims at ecosystem level coordination in services where resource utilization is optimized at ecosystem level.

Industrial Metaverse

Industrial metaverse was also a hot topic for future research and development. Combining new digital technologies with the digital representation of the manufacturing environment would offer new possibilities for example in the training of personnel via different AVR equipment.

Development of business models in the digital twin context is a critical factor. Some large players have already tested out new kinds of business and monetization scenarios in the marketplace, for example Siemens and Nestle have used a profit-sharing based business models when digitalizing a factory in Finland. In this model, the gained revenues from efficiency are shared equally with 50-50 based model.

8. References

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