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DEVELOPING SMART SERVICES BY INTERNET OF THINGS IN MANUFACTURING BUSINESS

Master’s Thesis 2016

Examiners: Jorma Papinniemi, Senior Lecturer

Lea Hannola, Associate Professor

ABSTRACT

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Manufacturing companies have passed from selling uniquely tangible products to adopting a service-oriented approach to generate steady and continuous revenue streams. Nowadays, equipment and machine manufacturers possess technologies to track and analyze product-related data for obtaining relevant information from customers' use towards the product after it is sold. The Internet of Things on Industrial environments will allow manufacturers to leverage lifecycle product traceability for innovating towards an information-driven services approach, commonly referred as "Smart Services", for achieving improvements in support, maintenance and usage processes.

The aim of this study is to conduct a literature review and empirical analysis to present a framework that describes a customer-oriented approach for developing information-driven services leveraged by the Internet of Things in manufacturing companies. The empirical study employed tools for the assessment of customer needs for analyzing the case company in terms of information requirements and digital needs. The literature review supported the empirical analysis with a deep research on product lifecycle traceability and digitalization of product-related services within manufacturing value chains. As well as the role of simulation-based technologies on supporting the "Smart Service" development process.

The results obtained from the case company analysis show that the customers mainly demand information that allow them to monitor machine conditions, machine behavior on different geographical conditions, machine-implement interactions, and resource and energy consumption. Put simply, information outputs that allow them to increase machine productivity for maximizing yields, save time and optimize resources in the most sustainable way. Based on customer needs assessment, this study presents a framework to describe the initial phases of a "Smart Service" development process, considering the requirements of Smart Engineering methodologies.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

API	Application Program Interface
BOL	Beginning of Life
BOM	Bill of Materials
CAD	Computer Aided Design
CL2M	Close-loop Lifecycle Management
CPS	Cyber-Physical Systems
DFX	Design for X-ability
EDM	Engineering Data Management
EOL	End of Life
ERP	Enterprise Resource Planning
FMEA	Failure Mode and Effect Analysis
ICT	Information and Communication Technologies
IoT	Internet of Things
IPSS	Industrial Product Service Systems
ISPS2	Industrial Software-Product-Service Systems
MOL	Middle of Life
MRO	Maintenance, Repair and Overhaul
NPI	New Product Introduction
PDM	Product Data Management
PEID	Product Embedded Information Devices
PLM	Product Lifecycle Management
PSS	Product Service System
QFD	Quality Function Deployment
RFID	Radio-Frequency Identification

1 INTRODUCTION

Due to the increasing competition in industrial markets nowadays, companies have increased their efforts to create and capture value throughout the value chain, which will be the main driver for obtaining an advantage that distinguishes them from competitors in the future. At the same time, customers demand products and services with the optimal use of resources, ensuring sustainable business through the whole product lifecycle. Centralized company-specific business models may not achieve such competitive advantage. Instead, manufacturing companies are leaning towards collaborations among different stakeholders; including customers, partners, and suppliers in order to obtain mutual economic benefits (Westerlund et al., 2014).

The value chain is a term used to describe the value added activities of a productive system. It starts with the creation of a product or service to its final consumption. Such activities involve those related directly to the product, i.e. sales, marketing, manufacturing, delivery and development activities. In addition, indirect activities contribute to the value chain, i.e. human resources, finance and accounting (Fearne et al., 2012). The perception of value chain used to be static and focused on a single company value creation. However, currently businesses and organizations are becoming part of more complex networks and ecosystems to create value together, gaining mutual economic benefits (Möller et al., 2005).

Information and communication technologies are primordial to collect valuable information from stakeholders' usage processes towards the product. Industrial machines equipped with sensors and computing intelligence will allow manufacturers to observe data regarding customers' behavior using their products throughout the whole lifecycle. Analyze the information from data and take decisions for product and service development. Moreover, for improving the existing solutions with better performance and quality (Pankakoski, 2015).

1.1 Background

The complexity of businesses in the current economic environment has transformed the way organizations deliver value to customers. Such complexity can be reached by shifting an approach from unified and centralized strategies, towards a networked shared value creation (Möller et al. 2005). Namely, organizations require continuous cooperation with stakeholders involved in several product processes from different value chains. Creating an ecosystem where participants' business activities are linked to a platform (Muegge, 2011). In addition, Muegge (2011) defines a platform as a group of entities with interconnected assets, which can utilize such assets to deliver interrelated products or services.

The complementary assets participating in a platform have the potential to improve efficiency by integrating product and service offerings. Aiming to provide economic and environmental benefits to industry and society (Mont et al. 2006). Those offerings can be delivered as Product-Service Systems (PSS), which are a combination of sustainable products and services able to accomplish together customers' needs and goals (Goedkoop et al. 1999; Tukker, 2004).

Initially, industrial and manufacturing organizations used to sell solely tangible products as their main value proposition. Further on, those companies opted to offer product-related service throughout the product lifecycle due to the increasing input costs and competition (Herterich et al. 2015). This practice is known under the term "servitization", a service-oriented practice continuously growing among manufacturers, which is changing their offer from selling solely tangible products to complementary services customized to the product (Baines et al. 2009). Hence, the combination of "servitization" and the traditional practice of selling tangible products is refered as Product-Service Systems (Aurich et al. 2006). Industrial Product-Service Systems (IPSS) refer to the industrial field of such product and service bundles (Mikusz, 2014).

Product Lifecycle Management (PLM) is an integrative information-driven concept that aims to manage the product related information efficiently during the whole product lifecycle (Kiritsis, 2011). The information presented in PLM is composed of people, processes, and technology involved in all phases of the product´s life. Starting from the product design and development, continuing with manufacturing, deployment, service, maintenance and finalizing with its final disposal, reuse or remanufacturing (Grieves, 2009).

The term "Internet of Things" (IoT) has been present on research and business in recent years. Several definitions and authors describe the technology concept. However, practical purposes IoT refer to a "global network infrastructure where physical and virtual objects are discovered and integrated seamlessly" (Kiritsis, 2011). These embedded technologies in the form of sensors, actuators, and radio-frequency identification tags (RFIDS), monitor and gather data related to the behavior, conditions, and environment of a single item or product (Pankakoski, 2015). This item information is later analyzed in order to transform it into valuable insights used to optimize product processes during the lifecycle, representing the creation of new customer's solutions within different value chains. The Industrial Internet of Things (IIoT) is the field of IoT related to respond to product information requirements, by facilitating information concerned the product interactions and behaviors during the whole product lifecycle in manufacturing environments (Bras, 2009). Utilizing IIoT with PLM, allows different stakeholders to acquire more flexibility by responding faster to changes in customer needs and product requirements (Gomez et al., 2009). Those needs can be identified and analyzed by diverse members of the value chain for further decision making in product-service development, process improvement and resource optimization.

1.2 Objectives and Scope

This thesis will focus on the opportunities that embedded technologies, recently known as Cyber-Physical Systems, will bring to manufacturing companies for generating innovative services to their customers. Specifically, through the case study conducted in a target company. This thesis study is part of a Lappeenranta University of Technology SIM Research Platform. Which aims takes community-based real-time simulation processes as the main drivers for the development of virtual prototyping environments in manufacturing businesses. The Platform emphasizes on the digitalization of R&D and manufacturing processes, by leveraging the advantages of the Internet of Things and Smart Services in the so called new Industrial Revolution. For this reason, this thesis will focus on the development of services based on Internet of Things ability to sense, store, process, analyze and communicate data along the product lifecycle.

The first phases of this study are related to the identification of customer information needs in the value chain, utilizing tools of customer needs assessment methodology. Once traced the customer needs within key links of the value chain, this study aims to interpret such requirements in detail for a deeper understanding. Finally, this thesis work presents a framework for "Smart Service" development process, based on analyzed literature and the empirical study.

Although the interest of the target company is to identify and assess customer needs of the whole value chain, this study is limited to focus on the information requirements between the target company and its direct clients. Due to research assigned time and information availability restrictions, this study does not analyze the whole company's needs in its value chain. Moreover, this work will focus on identifying information needs of certain phases of the lifecycle, especially those involved in the product delivery, support, use, and maintenance. The primary objective of this study is to identify customer information needs utilizing Customer Needs Assessment tools, which provide the basis for conducting product and service development. In this case, development of Digital (Smart) services with the so-called "Internet of Things" and other embedded information technologies.

New forms of doing business not only include the typical transactional model, where isolated companies sell tangible products to their customers. Innovative business models are shifting their traditional firm-oriented practices towards a cooperative-oriented business approach. With different value partners interacting each other to establish new product and service bundles. The recent trend in the competitive world nowadays is focusing on gaining a competitive advantage through the optimal value creation in all phases of products' lifecycle.

The main research question for this thesis is "*How to develop information-driven services for product lifecycle processes by the Internet of Things?*" In addition, this study considers the following four sub-questions to support the main question.

(1) *What is the role of PLM in contributing to the creation, management and control of product-related information?* The expected response to this question relies on determining the manner in which PLM systems and strategies facilitate the information management of products within organizations.

(2) *Why the Internet of Things and other embedded technologies can leverage product traceability during the lifecycle?* The second question aims to demonstrate whether the Internet of Things acts as a data carrier and analyzer for identifying product information, concerning its interactions and functionalities on every process of the lifecycle.

(3) *How customers' information needs assessment facilitate digital service development process?* In this research question, this study aims to validate whether Customer Needs Assessment methodology works as an identifier and evaluator of product information needs for digital service development.

(4) How the target company can apply the Internet of Things for developing value added services? This response aims to present a framework for the case company and other manufacturing businesses for moving from the identification of information needs to service propositions and business models.

1.3 Research Methods

This study is based on a literature study and empirical analysis concerning the role of digital service practices for manufacturing companies. To support the empirical part, the literature review considers several topics related to the most relevant research on technologies, tools, and strategies for the development of product-related services within the industry: such as product lifecycle management, novel services on manufacturing industry, service engineering, smart products, customer needs analysis, business models, Internet of Things, value chains and networks, among other important topics for the study. Concerning the empirical part, it employs the Customer Needs Assessment tools to conduct an analysis of the target company in terms of information requirements and digital needs. Further on, the study presents a framework for the development of customer-oriented digital services starting from customer needs.

This literature study begins with a theoretical review of broad literature from several sources, such as scientific papers in journals and conferences, specialized books, university courses, public videos, official websites, and magazines. The main search engine utilized in this process was the data management tool Nelli of Lappeenranta University of Technology. Which LUT is part of a networked portal where several Finnish universities, universities of applied sciences and libraries can obtain content from different databases, journals, books and other materials for academic purposes (Nelli-Portal, 2016). The present study consisted of a literature review with a focus on previous research related to Product Lifecycle Management (PLM), Customer Needs Assessment, Value Chain, Product Service Systems (PSS), Cyber-Physical Systems (CPS) and Internet of Things (IoT) principally.

The empirical part employed qualitative research methods for its accomplishment. More specifically, semi-structure interviews or also called half-structured interview (Hirsjärvi & Hurme, 2000), which considers both the interviewee’s experience in a particular issue and the general knowledge of the situation from the interviewer for obtaining an acceptable conducting and further analysis. Semi-structure interviews are enough structured to cover specific topics related to the object of study, while open enough to let interviewees to offer their opinion, information, and comments regarding their area of expertise (Galletta, 2013). In this sort of interviews, the interviewer begins asking open questions to obtain a general understanding of the topic. Next, the interviewee explains deeper concepts as the interview progresses. A significant benefit of the semi-structured interview is its looseness to allow respondents to express their experiences, while also explaining key processes and concepts. Interviews were conducted both personally and online-based to representatives of the Engineering, Administration and Information Technology departments. All of them being key areas in charge of digital service development.

The structure of this thesis study is the following: First, it explains a general background on how industrial companies have been doing business in the past few years, and the way these companies are changing paradigms towards a more service-oriented strategy. Second, the objectives and scope of the thesis are defined to delimitate content and research goals. Third, the research method and structure followed in this study are explained. Fourth, a brief introduction of the case company is described. Fifth, the theoretical background to support research questions is described through the content of chapters. Sixth, the practical part is developed with the customer needs assessment analysis. Finally, a general framework is presented for the development of digital services process, together with final conclusions and recommendations.

1.4 Case –Tractor Company

Valtra is a manufacturer of tractors and agricultural machinery and forms part of the AGCO Corporation. The company tractors are manufactured in Suolahti, Finland, and Mogi das Cruzes, Brazil (Valtra, 2016). Valtra is considered as one of the most innovative agriculture companies in the world, with several innovations in tractor power engines, transmissions, tractor bodyworks, electronic systems, and currently with innovations in knowledge and information oriented services through the use of the Internet of Things.

Concerning customization, Valtra has been one leading companies in the world to manufacture tractors by individual customer orders. Several options have been available for tractor configuration, such as tractors color, transmission type, and speed, hydraulics, and suspension. The Suolahti factory does not make a single tractor without an order from an importer, dealer or customer. Valtra offers a broad range of options and features, allowing customers to specify their tractors according to their specific needs (Valtra, 2016).

Nowadays the company is focusing on developing highly value-added product-service bundles leveraged by “smart” devices and the Internet of Things. Valtra’s vision for the development of such services is to create solutions with a high degree of customization, as they do with tractors. For this reason, Valtra was interested in participating with Lappeenranta University of Technology as a case company for conducting this Master’s thesis work.

2 MANAGING PRODUCT RELATED INFORMATION

Despite being verbal communication the primary factor for an efficient transfer of knowledge among people in organizations, with nearly 50 to 95% of the total exchanges of information (Kiritsis et al. 2008), information technologies are the drivers that have contributed to improvements towards communication, with storage and distribution of knowledge as the main advantages for business processes.

Several years back, information was stored and distributed in paper, with thousands of square meters of warehouse needed to keep files from every department. Employees were responsible for generating physical documents containing information concerned both product related and non-related processes; such as design, manufacturing instructions, materials purchase, financial statements, payroll among other activities (Stark, 2015). For this reason, engineers wondered themselves what could be the solution for a more efficient and practical management of knowledge. Thus, they came out with developments in information technologies and managerial tools, as critical enablers of knowledge exchange.

Due to the increment of product complexity and customer demands in the current market (Internal and external), companies nowadays face the challenge to perform product developments and support cycles in the shortest time with the lowest cost. Consequently, they need to employ the appropriate tools for the efficient exchange of knowledge among people and machines during the whole product lifecycle. Product Lifecycle Management (PLM) is a knowledge management strategic business approach for managing information related to product data, resources, and processes over the entire lifecycle in the most efficient way (Jun et al. 2007).

2.1 Background, definitions and purpose of Product Lifecycle Management

PLM is considered within the industry as a former concept of EDM (Engineering Data Management) and subsequently PDM (Product Data Management). Technology systems emerged in the late 1980s due to increasing need of manufacturing industries to track high volumes of CAD

(Computer Aided Design) files and manage parts and assemblies stored in BOMs (Bills of Materials) documents (Saaksvuori and Immonen, 2008). These particular methods helped those industries to standardize product items and processes, access to BOMs for design revisions and reduce risks incurred years back of using incorrect product versions. Nowadays, PLM is considered a knowledge-oriented strategy to obtain a competitive advantage, cope with a more demanding market, face global competition with shorter product lifecycles, shorter market launch time, and more complex, configurable and flexible products.

Several authors have described the PLM definition and its application in diverse fields of industry. Most of them agreeing on defining it as a useful tool for managing information and knowledge trough the product lifecycle. However, only some of them describe it as a whole company strategy for managing products, processes, people, and technology all the way across the lifecycle. Below are described various PLM definitions and objectives, mainly obtained from the most recognized authors in the field for the purpose of getting a solid theoretical base for the following chapters.

According to Stark (2015), PLM is the business activity of efficiently managing products through their lifecycle. From the idea concept until the product is disposed and retired. In addition, he defines PLM as a management system for handling all the goods and components offered by the company, along with entire product portfolio. For this author, the objective of PLM is to minimize product-related costs, maximize product value added, increment product revenue and maximize the shared value creation among stakeholders.

For (Kiritsis, 2011), PLM is a strategic approach with three essential dimensions. The first one related to managing accessibility and use of product definition information, the second aims to maintain the integrity of such information, and the last the chase to achieve and maintain business processes used to create, store, share and use information. This author establishes three primary PLM goals for organizations:

1) Face industrial challenges of today’s markets: Short product developments, product customization, and high complexity of goods.

2) Increase collaboration among stakeholders: Intra-enterprise and extended supply chain.

3) Adopt novel technologies: Digital manufacturing, remote customer service, decision support services.

Saaksvuori and Immonen (2008) have a more technical-centered definition of PLM. Describing it as an information processing system, developed for management of products and their lifecycle, including documents, items, Build of Materials, analysis results, engineering requirements, manufacturing procedures, among other product information. Besides the PLM objectives already mentioned by previous authors, Saaksvuori and Immonen (2008) address PLM benefits towards change management and collaboration, highlighting the efficiency occurred when groups across the value chain exchange knowledge, retrieve electronic information, reuse data and remotely communicate to each other.

As stated in the PLM definition of Belkadi, Bernard and Laroche (2015), it is a strategic business approach to facilitate the extraction and sharing of product and process knowledge. PLM objective for these authors is the caption improvement of product and process knowledge, for the efficient creation, organization, sharing and reuse of information through the lifecycle.

The most recent concepts and applications of PLM are related to sustainability and closed loop lifecycle. For Främling, Holmström, Loukkola, Nyman, and Kaustell (2013), the purpose of a sustainable PLM or closed-loop PLM is to reduce environmental impacts by collecting useful information from usage, maintenance, refurbishing and disposal phases of lifecycle. The objective of this approach is to use information in a multi-organizational manner for further design, manufactory, and product handling improvements, obtaining most efficient energy and resource consumption, translated into higher quality, decreased the need for spare parts, breakdowns, among other benefits. According to (Jun et al. 2007), closed-loop PLM allows stakeholders to visualize and control the whole product lifecycle by tracking and tracing product information and activities, especially those involved in delivery, use and disposal. In order to obtain valuable information for designers and engineers, the information has to flow further until product's final destiny, and go back to first design phases for product improvements.

This product lifecycle visualization can only be possible employing embedded information technologies, with the ability to collect real-time data from product conditions and the environment. During the following chapters and sections, this research will provide a deeper description concerning the application of the embedded technologies for tracking and tracing the entire product lifecycle. Consequently, describing the industry improvements utilizing data-driven tools and strategies.

2.2 Product lifecycle processes

Product processes are described as a set of value and non-value added tasks that people and machines have to accomplish towards the product in order to achieve a goal (Stark, 2015). They contain the information and knowledge on how a company design, manufacture, support, use and recycle its products. Therefore, the better quality of information and most value-added activities, a product process may have the greater possibilities to succeed.

According to Saaksvuori and Immonen (2008), the core processes of manufacturing businesses are product and order-delivery operations. The first category relates to product information and knowledge from product introductions and lifecycle processes. Product introduction processes, also known as NPI (New Product Introduction), are those involved in development activities and the introduction of new products to market. While lifecycle processes are the activities presented in the maintenance of a product already on the market. The second category related to the actual physical product and its lifecycle, is related to the products' supply chain. Starting from its procurement through its final order delivery, use and disposal. Both processes have a direct relationship with the product processes transfer information in order-delivery processes. As described in Figure 1, information is primordial to develop supply chain activities, such as procurement, sourcing, production, distribution, and sales.

Originally, PLM was used to support planning, design and engineering processes for manufacturers with complex systems, such as CAD/CAM, product data management (PDM) and Knowledge Management (Jun et al. 2007). Product information in manufacturing and post sales processes was incomplete and difficult to track, preventing feedbacks for design improvements. However, due to the emergence of new technologies, companies have no longer limited visibility in usage, maintenance, service, refurbish and disposal of products (Främling et al., 2013).

Finally, the PLM definition by Terzi, Bouras, Dutta, Garetti, and Kiritsis (2010), will be considered as the primary reference in this study. The authors describe it as the knowledge-based value chain approach for integrating people, resources, processes and information. They agree on describing PLM as a strategy for the knowledge creation and share in a collaborative environment, with different stakeholders over the product lifecycle. PLM is also known within the industry as a technology solution for streamlining information flows through the product lifecycle, seeking to provide the right information in time and form.

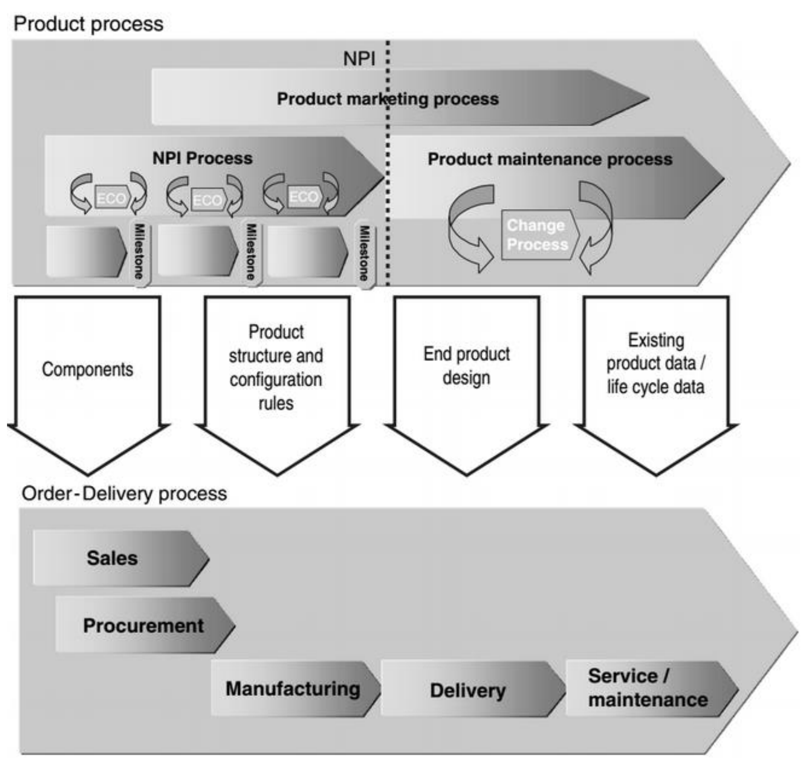

Figure 1. Product and order-delivery processes and their relation (Saaksvuori et al, 2008, p. 4)

For (Kiritsis, 2011), the product lifecycle process is categorized in the following three phases:
Beginning of Life (BOL): Includes conceptualization, definition, and realization.
Middle of Life (MOL): Includes usage, maintenance and service.
End of Life (EOL): Includes reuse, refurbish, disassembly, remanufacturing, recycle and disposal of the product.

Different authors describe the phases of lifecycle with their names and categories. However, this study will focus on Kiritsis, Jun, and Xirouchakis (2007) and Terzi, Panetto, Morel, and Garetti (2007), categories for practical purposes and familiarity due to previous experience studying PLM. During the following sections, a description of each lifecycle process is presented to understand the main activities, people, technologies, and information generated in every phase described in Figure 2.

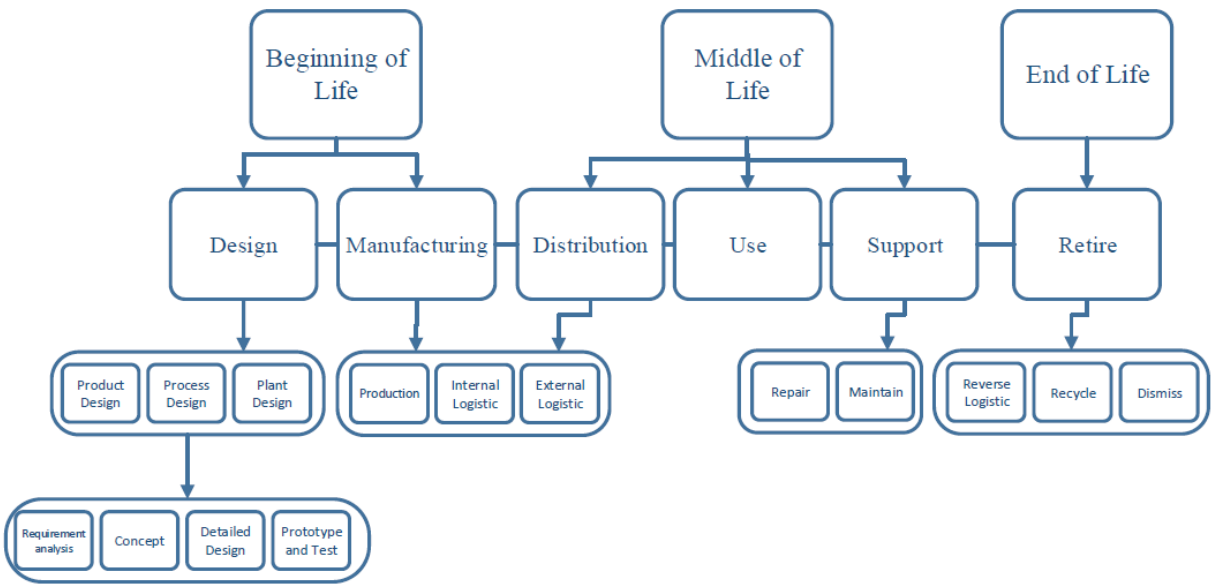

Figure 2. Product Lifecycle Phases (Terzi et al. 2010, p. 365)

2.2.1 Design and Manufacturing

Known as the Beginning of Life (BOL), this phase initiate when the product concept is generated, passes through prototypes and simulations, and finally ends in its physical realization (manufacturing). Some authors define this phase as the imagination, definition, and realization phase. However, this concept use to be ambiguous and does not provide a detailed description. As shown in Figure 2, the design phase is divided into three levels: product, process and plant design. Each of design class goes through various activities before its final introduction, such as requirements identification, reference concepts definitions, prototype development and finally testing the performance of the product (Terzi et al. 2010). Manufacturing and internal logistics take part of BOL phase, integrating processes such as production, warehousing, picking, packing, order preparation, and all the activities within the internal boundaries of a company.

The information managed during BOL phase is mainly for product development and engineering functions. Information systems, such as PDM software, are responsible for creating, storing and distribute data from several aspects of the product and its environment, such as CAD/CAM/CAE design drawings, assembly and workshop drawings, calculations, BOMs, workflows, among other essential information related to product items and their relationships (Saaksvuori et al. 2008). In addition, ERP (Enterprise Resource Planning) systems are employed to manage manufacture of goods with different suppliers and prepare deliveries. However, those systems are usually used in order-delivery processes.

2.2.2 Delivery, Use and Support

The product Middle of Life (MOL), refers to the use, maintenance and repair phases of the product lifecycle. It also includes the external delivery or logistics. During this period, the product passes from internal storage and distribution to the external transportation parts and after-sale assistance suppliers, for finally arriving in customer's hands (Ciceri, 2009). This phase does not necessarily finish when the client obtains the physical product. In some industries such as industrial equipment, agriculture vehicles, lifting machines and so on; usage, service, and maintenance activities continue on a daily basis. Consequently, product usage data could be considerable valuable for manufacturers, given that observing behavior of the machines and their environment can provide them information to track distribution routes, maintenance, and failures for service improvements and feedbacks in further improvements and designs.

In previous years, PLM systems were not used during the after sales activities of a company, or at least not used in an efficient way, losing most of the information between BOL and MOL. However, new systems and technologies have contributed on facilitating information flows between these two essential phases. For some manufacturing and engineering companies, selling tangible products without providing a support service is no longer a feasible business. Due to competitive markets, they need to create innovative product-related services. Therefore, developing new product-service offering is the main topic of this study.

PLM systems are necessary during this phase given their ability to manage product information for support practices, such as spare parts, product structures and versions, maintenance, customer service documentation, and so on (Saaksvuori et al. 2008). PLM systems also work as a communication platform for product information requests from different stakeholders in the value chain. Sales and marketing departments also receive the benefits of these systems. PLM systems support configuration systems, where users customize products according to their needs and wishes.

2.2.3 Retire

In the End of Life (EOL), products are recollected for further reuse, remanufacture, disassembly, reassembly, recycle or disposal. The end of life is the last part of the product lifecycle, when products are no longer useful for the consumer. Therefore, there may be presented various scenarios regarding the product, such as reuse of product with refurbishing, reuse of some components with refurbishing and disassembly, material reclamation with and without disassembly, and disposal with and without incineration (Kiritsis, 2011).

PLM systems provide information related to product materials, manufacturers, time of usage, recyclable components, among other valuable information for recyclers and re-users. Most modern PLM systems can track and monitor the actual use of elements, predicting the time they can be recollected for further reuse. This information can be convenient for product development purposes, given that designers can improve new products from developing new concepts and materials, such as recyclable or biodegradable materials.

2.3 Information flows among product lifecycle phases

Once described all phases of product lifecycle, it is important to mention the importance of data flows among different processes, resources and products presented on each step. Information created in one phase, flows directly to the following steps and vice versa, i.e. information generated during service and maintenance flows back to design stages, allowing designers to improve product development. The objective of a modern and efficient PLM system is to track, manage and control product information at any phase of lifecycle, anytime and anywhere (Kiristis, 2011). Information systems nowadays monitor and manage product information to allow stakeholders to create and use data during the whole product lifecycle (Terzi et al. 2007).

It is important to mention that information flows are created and distributed to different stakeholders in different value chains, thus the complexity of information increases while advancing from first stages of lifecycle until the end of product life (Xu et al. 2009). In addition, there is a considerable offer increment in the market, with competitors developing their information and communication technologies, making data management a challenging task for a more networked value chain. According to Ouertani, Baina, Gzara, and Morei (2011), the key to PLM systems success is the ability to identify the information available in the next phase and how can it be useful to perform business processes.

As mentioned previously, BOL data creation and distribution are well supported by numerous systems, such as CAD/CAM/CAE and other knowledge management systems. In addition, there have been improvements during MOL phases regarding use, service and maintenance information management due to utilization of PDM systems. However, there are still challenges in tracking information from MOL to EOL phases. Current systems still present difficulties to obtain accurate information regarding potentially recyclable materials and components.

According to Schneider and Marquardt (2002), information flows are defined as the information created or processed in a precise sequence. As shown in Figure 3, several technologies, products, people, and processes interact each other representing lifecycle information flows.

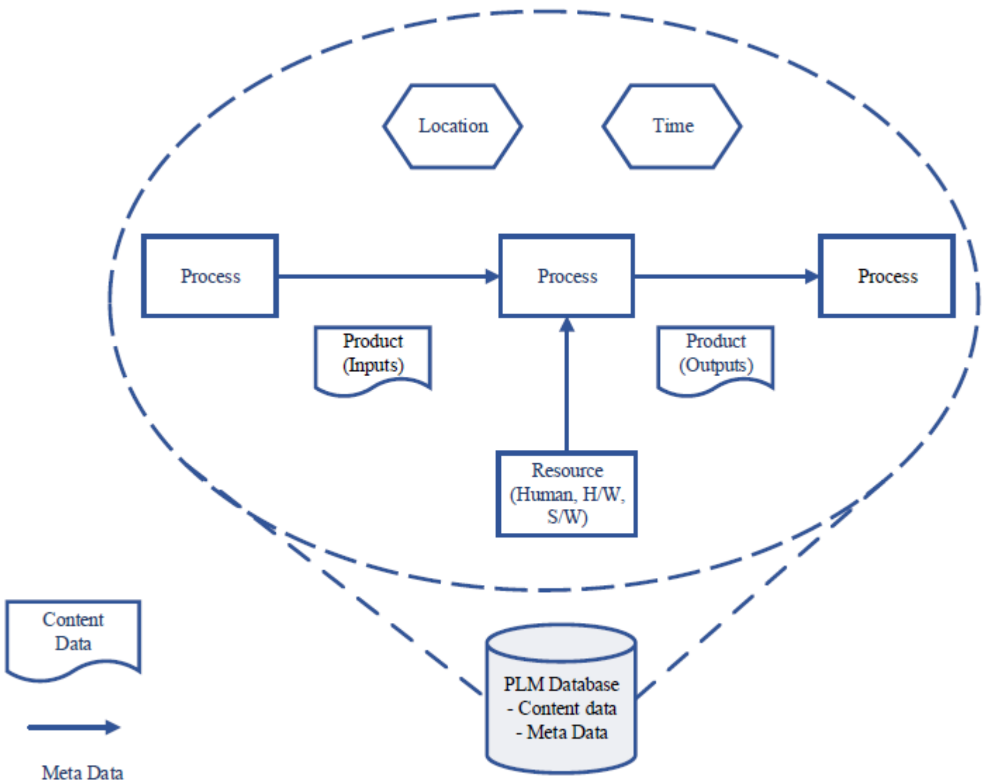

Figure 3. Product lifecycle information flow (Jun et al. 2012, p. 17)

In Figure 3, it is shown the content data and metadata as the primary drivers of product lifecycle information flows. Both kinds of data are dependent on each other with a direct relationship. Content data refers to the creation and manipulation of documents related to drawings, characteristics, BOMs, specifications, and other product information generated during the whole lifecycle. Content data creates the relationships among product, process, time and resource. These relationships are known as metadata. Finally, the consolidation of metadata and content data results in product lifecycle information (Jun et al. 2012).

Through the next lines, this study will describe a classification of information flows, their exchanges and feedbacks between phases. As well as the information generated by diverse stakeholders, and a brief introduction regarding new technologies used for data traceability.
According to Jun and Kiritsis (2012), information flows are classified into horizontal and vertical. Horizontal flows are divided into forward and backward flows, also known as feedbacks. Information flows are described as following:

Forward Information Flows

Flows sequentially followed to complete the entire product lifecycle. Outputs generated during initial operations directly stream to following phases. These sort of flows are necessary to elaborate the product, given that all the information related to product design, manufacturing and use is created during BOL and MOL.

BOL to MOL: The most common and historically used flows are presented between BOL and MOL phases. PDM systems are usually responsible for managing information in product design and manufacturing processes, since they are required to deliver quality products to customers (Kiritsis et al. 2008). During BOL phase, technical product manuals are created to support product usage and maintenance operations, as well as product information regarding spare part descriptions and installation processes (Terzi et al. 2010). Both internal and external service providers can access to this information and make decisions based on insights obtained. Thus, they can offer customized solutions to customers. BOL to MOL information flows are crucial for developing product-related services in manufacturing companies.

MOL to EOL: Due to current concerns regarding environmental responsiveness, companies are improving their systems for sustainability and resource optimization purposes. The information collected during use, service and maintenance, provide recyclers details regarding what components are about to terminate their lifetime. Usage status information, maintenance history, usage environment information and updated BOMs are the primary reports used for recyclers to predict future conditions and make decisions based on which components are ready to be recycled, reused, remanufactured or in worst cases disposed (Jun et al. 2007)

BOL to EOL: Besides obtaining the information related to component wear, value partners involved in recycling activities can also collect all technical details, price, manufacturers, materials and other information concerning products and their components. BOL phase not only provides technical information of materials and their characteristics, but it also shares knowledge related to disassembly, manufacturing and assembly processes, then interested partners can remanufacture products with recycled components. PLM systems can store and distribute information regarding characteristics and technical details of the new product build with new and recycled components. Current systems nowadays contain information related to environmental regulations and procedures needed to reutilize resources. Thus, recyclers can follow instructions on how materials should be treated to preserve the environment.

Backward information flows

Are represented by flows with an indirect relationship with the regular sequence of product elaboration. They are also known as feedback flows, given the information and data streams generated during MOL and EOL, backward to the initial phases. Information created through such feedbacks are used for several purposes. Mainly for design and producing improvements, by collecting feedbacks generated during product manufacturing, delivery, use, maintenance and recycle operations (Terzi et al. 2010). Feedback loops are making considerable attention among diverse actors of the industry. Value partners are interested on developing solutions to solve the problem of traceability of information generated from MOL and EOL, back to product development. One of the most important methods to make sustainable and competitive products is by improving operations through monitoring customer feedback, task currently difficult to perform efficiently.

MOL to BOL: Design and production developers receive product information from their starting distribution, usage, maintenance, service and support processes. Value partners can monitor the actual behavior of customers using their goods and verify improvement areas for better quality, resource consumption, price and efficiency of products and services. In addition, tracking customer behavior, can offer valuable sales and customer loyalty, since producers can customize solutions according to each client's needs and problems. Marketing departments may also design their campaigns based on customers' preferences towards products (Xu et al. 2009)
EOL to MOL: Flows between these two phases mainly contributes to making an optimal resource usage for sustainability purposes. Utilizing information related to the condition of products and components once they finish their lifetime may suggest betters forms of manipulating them. Jun and Kiritsis (2012), suggest theta these sort of flows contribute to improving reverse logistics activities, given that recyclers provide information to logistics engineers concerning reusable components. Therefore, engineers can make their resource planning contemplating both new and recycle parts.

EOL to BOL: While information from EOL to MOL is related to improving better product usage and handling. Interactions from EOL to BOL allow designers to improve resource consumption and utilize more recyclable and reusable components. Manufacturing engineers can also improve producing processes and develop new processes of product dismantle and remanufacture in the most efficient way.

Below are presented Table 1 and Table 2, describing the most used data in industry for both forward and backward information flows, their objectives, and categories.

Table 1. Forward information flows (Jun et al. 2012, p. 21)

Information flow	Objective	Category	Information
BOL to MOL	Improve design and manufacturing collaboration	BOM Information	Product ID, product structure, part ID, component ID product/part/component design specification.
	Improve Service collaboration	Information for maintenance/service	Spare part ID list, price of spare part, maintenance/service instructions.
		Production information	Assemble/disassemble instruction, production history data, production routing data, production plan, inventory status
BOL to EOL	Improving product reuse and eliminating environmental effects	Product information	Material information, BOM, part/component cost, disassemble instruction, assembly information for remanufacturing.
		Production information	Production date, low ID, production location, etc.
MOL to EOL	Improving product reuse	Maintenance history information	Number of breakdowns, parts/components, IDs in problem, installed date, maintenance engineers IDs, list of replaced parts, and aging statistics after substitution, maintenance cost.
		Product status information	Degree of quality of each component, performance definition.
		Usage environment information	Usage condition (e.g. average humidity, internal/external temperature), user mission profile, usage time.
		Updated BOM	Updated BOM by repairing or changing parts and components.

Vertical information flows refer to the utilization of information created in certain processes, resource or product, to analyze it and make decisions for further process optimization (Jun et al. 2012). Vertical information is utilized to support process and product improvements through several managerial tools and methodologies. The most common ones are Quality Function Deployment (QFD), Failure Mode and Effect Analysis (FMEA) and Design For X-ability (DFX) (Jun et al. 2007). However, this study will not cover detailed descriptions regarding procedures and impacts of such tools.

Table 2. Backward information flows (Jun et al. 2012, p. 21)

Information flow	Category	Objective	Information
MOL to BOL	Maintenance and failure information for design improvement	Incorporating voice of customer into design process	Ease of maintenance/service, reliability problems, maintenance date, frequency of maintenance, MTBF, MTTR, failure rate, critical component list, root causes.
	Technical customer support information		Customer complaints, customer profiles, response.
	Usage environment information		Usage condition (e.g. average humidity, internal/external temperature), user mission profile, usage time.
EOL to MOL	Recycling/reusing part or component information	Improving supply chain collaboration	Reuse part or component, remanufacturing information, quality of remanufacturing part or component.
EOL to BOL	EOL product status information	Incorporating voice of customer into design process	Product/part/component, remanufacturing information, quality of remanufacturing part or component.
	Dismantling information		Ease to disassemble, reuse or recycling value, disassembly cost, remanufacturing cost, disposal cost.
	Environmental effects information		Material recycle rate, environmental hazard information.

Information flows among product lifecycle represent a breakpoint in this study, being product and service development through information feedbacks the primary focus of research. One of the main goals is to observe and analyze feedback loops between BOL, MOL, and EOL, generating virtuous information cycles for continuous creation of competitive products and services. Additionally, those loops allow improvements in resource optimizations, cost reductions, better customer experiences, sustainable and environmentally responsible products, among others. The PLM branch in charge of managing information feedbacks through the entire product lifecycle, is referred as Closed Loop Lifecycle Management or Sustainable PLM (Främling et al. 2013).

2.4 Closed-loop PLM and lifecycle traceability

According to Kiritsis (2011), there is a generalized desire from value partners to develop solutions to deal with the problem presented when product information flow is interrupted when it is used, maintained, serviced or recycled. They do not obtain valuable customer feedback related to product usage for design and production improvements. In consequence, recent research has been focusing on finding alternatives to get seamless information flows and improve product traceability. Such seamlessness and traceability can be obtained by allowing data flow management to stream along the lifecycle for all the value partners.

Kiritsis (2011), define Close-loop PLM (CL2M) as the system that allows all the participants in a value chain to track, control and manage product information through all the phases of product lifecycle, anytime and anywhere. For Främling, Holmström, Loukkola, Nyman, and Kaustell (2013), CL2M is an extended PLM approach for improving product design, manufacturing, use, and disposal through information collected and used by technologies in a networked environment. Främling, Holmström, Loukkola, Nyman, and Kaustell (2013), also assures that CL2M enhances the quality of products and services, minimize breakdowns, decrease needs for spare parts. All with the objective to perform continuous operations of productive systems with the optimal use of energy and resources. According to Terzi, Bouras, Dutta, Garetti, and Kiritsis (2010), CL2M will facilitate accessibility of information at every stage of lifecycle, enabling value partners to optimize costs, environment, risk and efficiency among others. The authors point out that CL2M will allow companies to identify individual customer needs by tracking information related to product usage. Therefore, they can offer customized products and services according to their particular needs.

For closing information flows, it is necessary to have the appropriate technology able to monitor and track lifecycle information. Emerging technologies such as RFID, barcodes technologies, sensor networks, cyber-physical systems, product embedded information devices (PEID), or also known as smart or intelligent devices (Kiritsis, 2011), will change paradigms and business models by monitoring products and their environment. As shown in Figure 4, smart devices facilitate forward and feedback information flows, forming closed-loops through the whole product lifecycle.

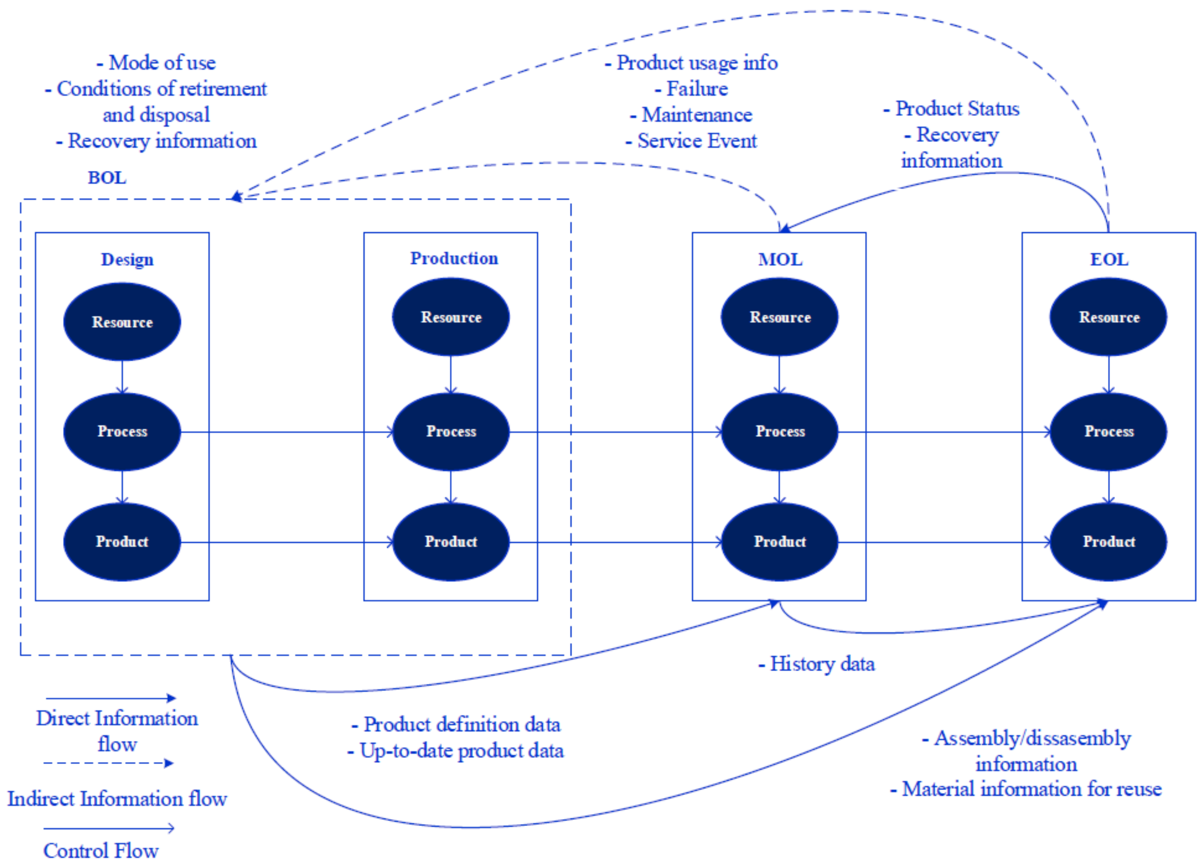

Figure 4. Information flows in PLM (Jun et al., 2007, p. 857)

According to Kiritsis, Nguyen and Stark (2008), the technology requirements needed to obtain successful closed-loops are: availability of efficient local and internet connections for information exchange and retrieval, uninterrupted information and data flows, and decision support software for data analysis and decision making. Such requirements are referred nowadays as the seamless electronic conversion from data to information, and finally to insight knowledge.

In the following chapters, this research will focus on the role of digital embedded technology as the primary tool to trace and track information regarding product and customer behavior through the whole lifecycle. The study will emphasize on the so-called Internet of Things, applied to manufacturing companies and the innovation opportunities that this technology brings to the industry. It is important to mention that manufacturing companies are no longer selling tangible products as their primary value proposition. The current competitive market has been the driver to develop product related services after the product sales. Such services require a continuous feedback from customers, more collaboration among value partners, technologies to track product-user interactions and an accurate understanding of information needs of all diverse players within several value chains.

3 INTERNET OF THINGS FOR LEVERAGING PRODUCT DATA AND INFORMATION

Value creation is a term that has been taking importance for organizations during recent years. Not only companies are concerned about the topic, governmental and non-governmental organizations are also interested in value creation for their citizens and beneficiaries. According to Westerlund, Leminen and Rajahonka (2014), the value is created when single activities, procedures, people, processes, organizations and networks of organizations interact each other by exchanging information, resources and means aiming monetized outcomes for different value partners. Having said that, the Internet of Things is an important tool to create value for various actors presented in several value chains. Digitalization will be the primary driver to innovate business models in networked value chains in this knowledge economy, since its primary purpose is to network people and things converging the real world with the virtual world through information and communication technologies (Kagermann, 2015).

The term “Internet of Things” (IoT) was first defined by the former P&G technologist Kevin Ashton, when presenting a project for linking the RFID P&G’s technologies for its supply chain and the trending topic of Internet at that time (Ashton, 2009). The IoT came from author’s concern related to current information creation and capture. He affirmed that the human being firstly captured the most amount of data available on the internet, either typing characters, pressing a button, scanning a code or taking a picture. However, humans have limited time and accuracy to capture all the data concerning the environment and things interacting with it. Thus, embedded technologies such as RFID and network sensors in coordination with information and communication technologies, can be a useful resource to track and understand interactions among different processes, people and resources in the physical world (Ashton, 2009). The IoT has been applied in various industries and fields, from home appliances to manufacturing devices.

For Kagermann (2015), embedded systems equipped with sensors and actuators are capable of storing, recording and processing huge amounts of data from the physical surroundings, and perform actions based on the data analyzed. Embedded systems connected to each other and to the Internet, converging the real world of physical objects with the digital world of digital functionalities are recently known as Cyber-Physical Systems (CPS), (Geisberger, 2012). CPS are responsible for collecting data related to the environment and monitoring the current phenomena happening in real time for further decision making.

IoT in industrial environments is applied for product lifecycle monitoring nowadays, given that it facilitates the previous mentioned closed-loop PLM (CL2M). Sensors and other embedded technologies in the context of IoT can measure parameters such as temperature, humidity, pressure, acceleration, velocity, shock, among other measurements (Kiritsis, 2011). With such parameters monitored, value partners can observe and analyze data and information from customer interactions toward the product in different phases of lifecycle, allowing them to make decisions for quality improvements, better customer service, less maintenance, spare part replacement, optimal resource utilization, among other advantages for various value chains.

3.1 Internet of Things within industrial environments

For Jun, Kiritsis and Xirouchakis (2007), the functionality of "embedded" technologies consist in the fact that product lifecycle data and information can be traced, monitored and tracked in real time through the whole lifecycle by embedding an information device to a product. For MacDougall (2014), embedded systems are intelligent central control units able to operate as data processors "embedded" to a particular device in forms of sensors and actuators. When such systems are synchronized each other, they connect the physical world with the online world.
In a manufacturing environment, such products are presented in form of machinery and industrial capital goods composed of thousands of components, subassemblies, and electrical parts. While embedded information devices are presented in form of tags, sensors, and connectivity (Herterich et al. 2015).

It is important to differentiate the several concepts assigned for digitalization of industrial value chains in recent times. From a general to particular approach, it can be said that the Industry 4.0

or also known as the fourth industrial revolution, embrace the establishment of smart products/services, Cyber-Physical Systems and smart factories embedded in the Industrial Internet of Things through, also called Industrial Internet (Stock et al., 2016). Although previous concepts mentioned before may not sound familiar for a large part of the readers of this study, below are described in detail definitions and applications of digitalization presented in manufacturing and service organizations.

The Internet of Things is defined by Gomez, Huete, Hoyos, Perez and Grigori (2013), as the interconnection of embedded objects able to sense, communicate, identify and collect data by the employment of technologies such as sensors, actuators and radio frequency identification (RFID). For CERP-IoT (2009), IoT refers to a global network, where physical and virtual objects are integrated and discovered seamlessly, being able to provide and receive services, which are elements of business processes presented in a value chain. Those objects embedded in the Internet of Things are commonly known as “Smart” products, Product Embedded Information Devices or Cyber-Physical Systems. Devices able to gather vast amounts of data concerning their real and digital environment to support decisions based on those data.

To make the collection and analysis of massive amounts of data generated by “Smart” devices in the IoT, it is necessary to store all data (big data) in the so called “Cloud” computing. To obtain valuable knowledge and insights from all the data generated, firstly it has to be mined using “smart algorithms based on correlations and probability calculations” (Kagermann, 2015). Once data is mined, it is analyzed by systems, which identify patterns for finally represent them in form of information.

For Geisberger (2012), it is considered a “Smart” device, when it employ sensors, embedded systems, Cyber-Physical Systems, actuators, “cloud” computing, big data, data mining and analytics all together to create valuable knowledge for people. In a more appropriate definition according to this research purposes, Kiritsis (2011), define “Smart device” as a product system able to sense, store, process, analyze and communicate data along the product lifecycle. Assess changes in the environment while communicating with other “Smart” objects through the internet. For finally take decisions and perform actions by itself.

On the other hand, the term Cyber-Physical System (CPS), has been gaining attention from the academy and industry in recent years. While still being a synonym of “Smart” object in a certain degree, CPSs are referred as “opened, linked up systems that operate flexibly cooperatively and interactively” (Mikusz, 2014). Such devices connect the physical world with the virtual world of software and information technology in a seamlessly way for use of data, services and communication facilities. CPSs collect real-time information regarding the environment and system conditions to interact with users through networked services and systems, either locally connected or by the Internet (Internet of Things) (Acatech, 2011; Geisberger, 2012).

To better understand the concept of IoT for general audiences, Goldman Sachs (2014) define it as the connection of everyday products and industrial machines to the internet, allowing people manage and manipulate products and their information via software. They describe IoT as one of the primary drivers in this economy to obtain new product cycles, new opportunities for revenue streams, productivity and cost savings. Whether applied to industrial environments, wearables, connected cars, homes or cities, the IoT will bring efficiencies, creation of new services, health and safety benefits, sustainability of resources and environmental preservation to our societies. In Figure 5 it is represented a structure of the IoT system, showing the steps from which the data is collected, transferred and analyzed by CPSs to provide valuable knowledge to users.

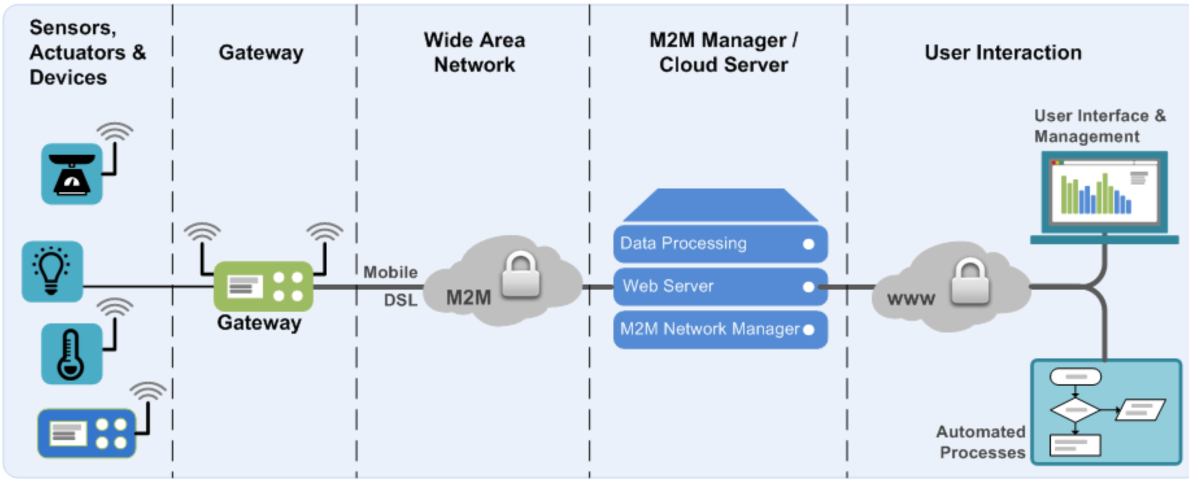

Figure 5. Structure of the Internet of Things system (Neratec, 2016)

This study takes this opportunity to conduct a research based on the possibilities that the Industrial IoT will bring to manufacturers concerning service development through the entire product lifecycle. More specifically, during the use, support, service and maintenance phases. IoT applied within industrial environments (Industrial Internet), can work as an information carrier throughout the entire product lifecycle. More concretely, by facilitating the information flows among different phases and entities described in previous chapter. When information requirements from customers are identified and assessed, developers from various value partners innovate with customized solutions according to patterns, behavior and environment perceived on the information exchanges and feedbacks along the value chain. Such information exchanges can only be possible through the employment of cutting edge information and communication systems, nowadays the use of Internet of Things through Cyber-Physical Systems.

Material handling has been a field where industrial equipment and machinery is used and maintained based on experience and inherited knowledge, making innovation introductions a challenging task due to rooted practices and paradigms. Experienced staff commonly trains workers, adopting the learned practices towards the equipment. However, nobody affirms the current operation is the most efficient and effective. Such equipment is not generally being monitored in real time regarding its status condition, thus operators employ corrective and preventive revisions regularly scheduled to avoid shutdowns or breakdowns. Looking at it from different points of view, preventive and remedial measures represent the unproductive time for equipment and unnecessary expenses. Firstly, because when a failure happens, productive activities are stopped for several minutes or even days, serving significant costs in spare parts and fixing fees. Secondly, when preventive maintenance is made, many times all the components are working correctly, consuming unnecessary time and expenses.

The Industrial Internet came to one of the most traditional industries nowadays to solve the problems in efficiency and productivity within manufacturing, energy, farming, logistics, among other several straggler sectors. Integrating "smart" devices in the cloud to a machine, will allow such machine to be aware of its status and surrounding environment, e.g. detecting wears on the brakes or if some component needs to be replaced (Pankakoski, 2015). "The machine also knows how much time it has left before maintenance is required" (Pankakoski, 2015). In addition, IoT benefits operators in the way it provides them feedback related to the optimal operation of the machine, working as a digital trainer and evaluator.

3.2 Industry 4.0: The fourth industrial revolution

Henning Kagermann firstly introduced the concept of Industry 4.0 as an initiative from the German government with its German National Academy of Science and Engineering (acatech) (Kagermann, 2015). The author defines Industry 4.0 as the following step of the third industrial revolution, characterized by automation of production processes by IT and electronics. As shown in Figure 6, the fourth industrial revolution focuses on digitalization of manufacturing and industrial services, utilizing Cyber-Physical Systems as the principal means to connect people, machines, and resources among each other, in order to perform the most optimal actions based on data analyzed (Kagermann, 2015). The Industry 4.0 will bring to economies new opportunities to develop new services and business models based on data and information. Being information itself the essential resource to propose value to different participants of a more networked value chain.

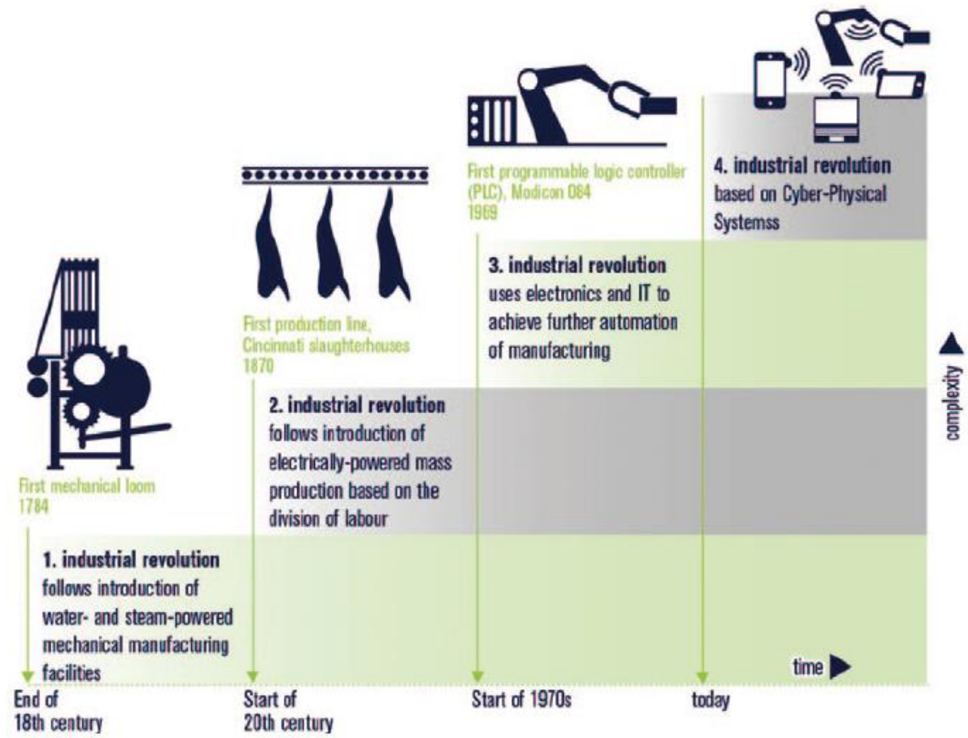

Figure 6. The four stages of Industrial Revolution (acatech, 2011, p. 13)

The fourth industrial revolution scales up the concept of "Smart" devices into the Internet of Things to a global scale of an interconnected network of several participants from different value chains. Industry 4.0 takes manufacturing as the central piece of a whole environment of "Smartization" of the entire product lifecycle, including its processes, services, people, technologies and machines involved. It consists of driving economic systems towards an Internet of Things, Data, and Services approach, where centralized productive systems (machinery) are no longer considered the main actors for processing products, but rather the product "smartized" communicates with machines to tell them what to do (MacDougall, 2014). MacDougall (2014), state that the new technological age of Industry 4.0 will change industries, productive value chains and business models trough interconnected embedded systems with product processes.

Acatech (2011), claims that the Industry 4.0 presents two technologies necessary to take place in economies: embedded systems and global networks. Such technologies combined create

Cyber-Physical Systems. Both technologies have been present in the economy for several years. However, they used to work separately from each other until recent times. Embedded systems started in closed-based technologies, i.e. airbags in cars connected with the local car's systems, were one of the first inventions related to such systems (acatech, 2011). Regarding networks, during the past, organizations used to develop their local networks for internal purposes, where different members were able to communicate each other without the presence of the Internet. Nowadays, both technologies have emerged with new developments improving capacities to allow people and "things" communicate each other to exchange information to support decisions and actions. Figure 7 illustrates the evolution of both technologies, from their beginning with product-based local embedded systems in few markets, passing through the use of first developments in Cyber-Physical Systems for internal purposes, until they reach their merge into the Internet of Things, Data and Services era (Industry 4.0). Era aiming to connect entire supply chains, transporting systems, healthcare and even entire cities and countries.

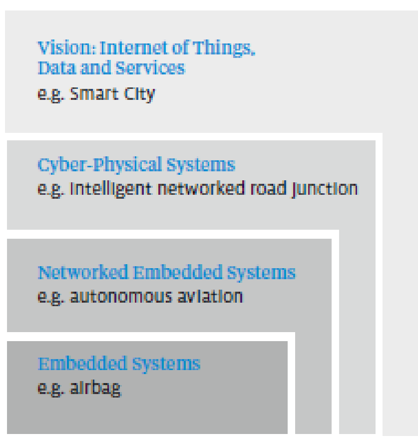

Figure 7. The evolution of embedded systems into the Internet of Things, Data and Services (acatech, 2011, p. 11)

As mentioned before, the central idea of Industry 4.0 is to place manufacturing as the primary node of creation and development of "smart" products and services. One of the Industry 4.0 main projects is concerned to integrate product lifecycle processes into technology and data processes. This project receives the name of "Smart Factory" (MacDougall, 2014). The "Smart Factory" has the characteristic of integrating Cyber-Physical Systems with resources, products, and processes within value chains. The objective of this project is to develop a service-oriented and sustainable environment of productive systems, in order to provide benefits in resource optimization, time efficiency, cost reductions and quality improvements (MaDougall, 2014).

"Smart Factories" within the Industry 4.0 will bring value chains significant advantages, since designers, engineers and managers will conceive the product as "smart". Starting from its conceptualization utilizing "smart" components and systems, being manufactured by "smart" machines and equipment, used by "smart" operators within "smart" environments, and finally being recycled or disposed through "smart" processes. In Figure 8, it is represented the framework of "Smart Factory" initiative, considering Cyber-Physical Systems connected to the "Cloud" as the primary drivers for the fourth industrial revolution success.

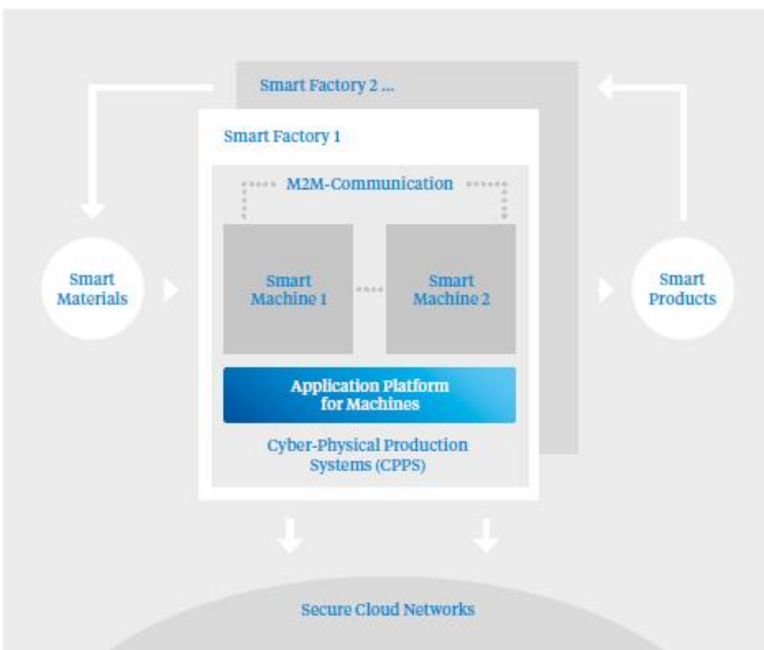

Figure 8. Industry 4.0 "Smart Factory" Pipeline (MacDougall, 2014, p. 11)

3.3 Smart Engineering in the Industry 4.0

According to Abramovici, Göbel, and Neges (2015), nowadays no appropriate methodologies for the engineering and development of smart products and services exist. The authors consider several engineering methodologies for developing separately products, systems and services employed within several organizations in their development processes. However, there is a lack of a combined tool for engineering product-services bundles together with ICT technologies (systems). It also exists a lack of engineering methods in MOL phases of product lifecycle. Thus, this thesis study encounters the identifiable need of a methodology framework able to cover the product use, maintenance and support stages in the lifecycle.

Despite the noticeable gap in availability of an appropriate tool, Abramovici, Göbel and Neges (2015) consider four characteristics or requirements that a novel engineering approach for developing smart products, services and systems (Smart Engineering) should take into account:

(1) Generic Process Models: The coming methodologies should be flexible to adapt to operational and strategy changes. They have to contain generic processes with a strong focus on the early development phases, especially on the requirements engineering and functional design.

(2) Multidisciplinary networks: Nowadays the collaboration among different areas of expertise, departments and even organizations is vital for the success of products and services introductions. The methodology should consider the networked value chain, involving several value partners in the lifecycle.

(3) User-oriented approach: The user experience is also important for the development of the methodology. Users have to be able to easily analyze, employ and share their outcomes with functional and intuitive systems.

(4) Product use data and information: One of the main characteristics of the Internet of Things and the "smartization", consists on obtaining valuable insights based on the data collected from embedded sensors. Further on, the generated knowledge can be used for the development of smart products and services.

The Industry 4.0 and the "smartization" of all the participants of the whole lifecycle will bring to manufacturing value chains with innovative tools and methodologies in their development processes. Since the market is going towards a "less product property" and "more product usage" behavior, manufacturers will have to adapt to the future trends and employ the cutting edge technologies, methodologies and strategies to offer value-added services. In the coming years, value partners will pay for the outcomes they obtain through the usage of certain product-service bundles, representing both opportunities and challenges for participants of the industry.

3.4 Internet of Things for product lifecycle value creation

According to Stock and Seliger (2016), the Internet of Things, Data and Services era (Industry 4.0) has three main dimensions to be considered: (1) Horizontal integration through the value creation network; (2) end-to-end engineering through the whole product lifecycle; and (3) vertical integration and networks among manufacturing systems.

Horizontal integration refers to value creation through digitalization of interconnected and synchronized value modules with different product lifecycles and value chains (acatech, 2011). End-to-end engineering through the whole lifecycle promotes digitalization with Cyber-Physical Systems of each product lifecycle phase within several value chains, from design to manufacturing, delivery, usage and final disposal of products (acatech, 2011). Finally, vertical integration among manufacturing systems describes the application of digitalization within value creation modules (productive areas) of a value chain, such as factories, manufacturing machines, and lines together with logistics, sales and marketing activities (acatech, 2011).

For Stock and Seliger (2016), the Internet of Things, Data, and Services (Industry 4.0) perspective is classified into two fields, macro and micro. The macro perspective covers the first and second dimensions, i.e. the combination of value chains and Cyber-Physical Systems previously mentioned. The macro field focuses on a product lifecycle point of view, where different value creation modules represented as “Smart Factories” exchange information, materials and even energy among each other to create value on the networked value chain with various product lifecycles, creating a “System-of-Systems” environment. In Figure 9, the Macro Perspective is represented graphically for a better understanding.

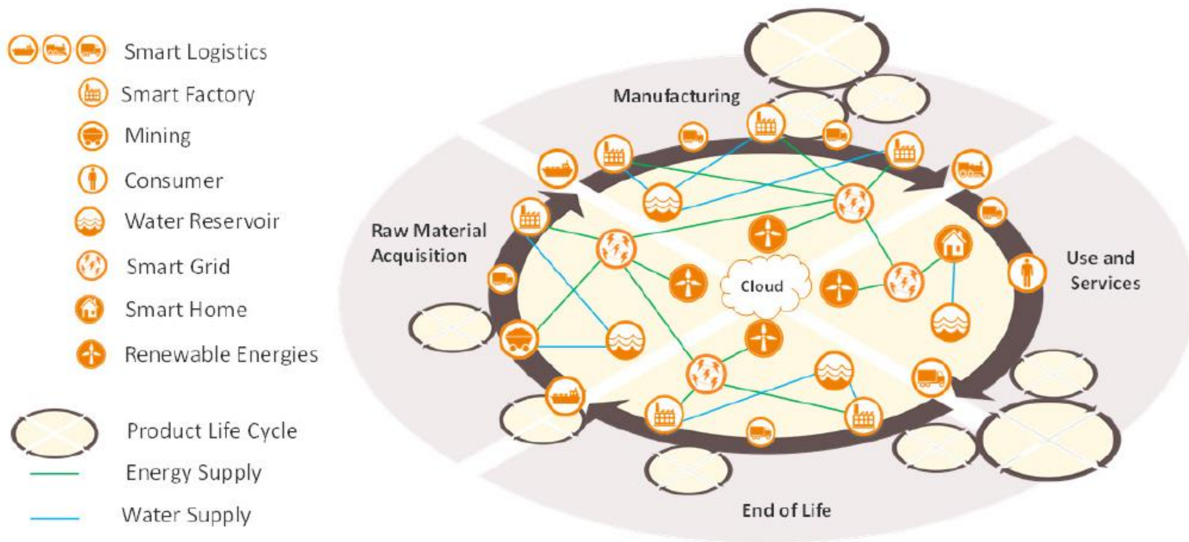

Figure 9. Macro perspective of the Industry 4.0 (Stock, et al., 2016, p. 537)

The term value creation module in a macro perspective refers to all processes, people, machines and products involved in the "Smart Factory", taking it as the central and highest level of aggregation. In terms for product lifecycle purposes, value creation modules are "cross-linked throughout the complete value chain of a product lifecycle as well as with value creation modules in value chains of adjoining product lifecycles" (Seliger, 2007). Value creation factors are defined by all the products, equipment, and people integrated into a value creation module, i.e. all people and things participating in the "Smart Factory". Meanwhile, value chain activities are those order-activity processes, such as sales, procurement, and marketing activities on constant interaction with value creation modules and their value creation factors. All these linkages form a connected embedded network of value modules from various value chains integrated into different product lifecycles.

The micro perspective describes the internal environment of a particular value creation module. Put simply, value creation modules in micro perspective are represented by the manufacturing embedded equipment, such as production line, cell, module or any productive entity within the "Smart Factory". It is similar of doing a "Zoom-in" to every value creation module presented in the macro perspective, where the "Smart Factory" (Value creation module) is always exchanging data and information in real-time with its value creation factors (product lifecycle processes) and the external value chain activities (order-activity processes). In Figure 10, the mentioned "Zoom-in" of a value creation module is graphically represented, as well as its interaction between external value chain activities.

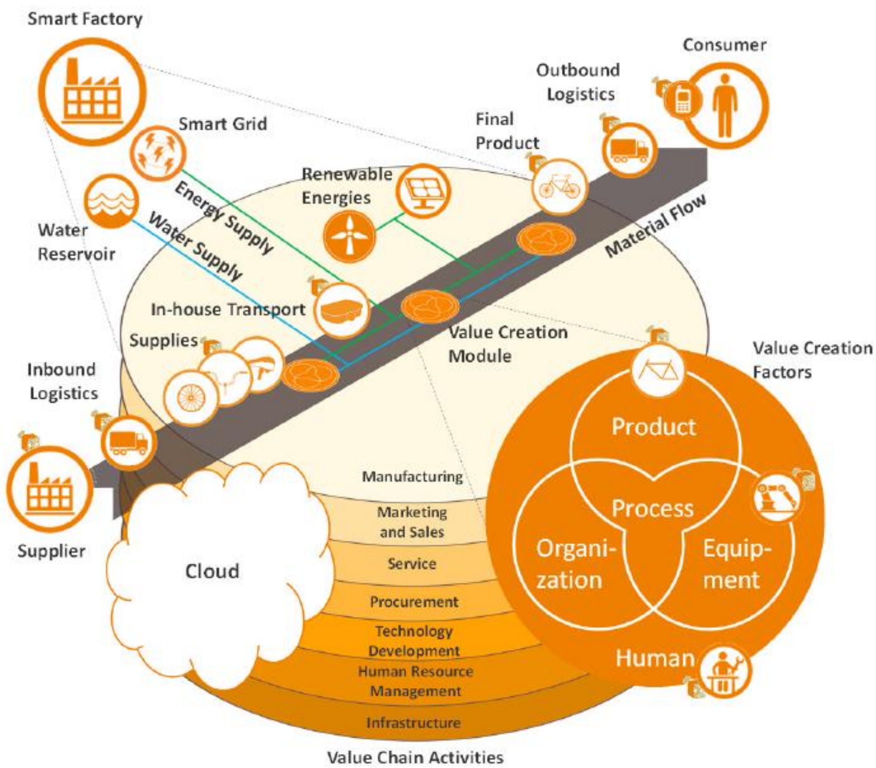

Figure 10. Micro perspective of the Industry 4.0 (Stock, et al., 2016, p. 538)

Through this chapter, the concept of Internet of Things was described from its general definition and application industries to the particular area of interest of this study: the industrial internet in the fourth industrial revolution of the Internet of Things, Data, and Services (Industry 4.0). Although this study will focus on product usage phases of the lifecycle (Middle of Life), and not in manufacturing phase itself, it is important to understand the initial point of reference from Industry 4.0 for value creation. Being value creation module of "Smart Factories" as the root for developing the whole "Smart" environment, including "Smart" products and services in different product lifecycle phases and value chains.

The arrival of the Internet of Things, Data, and Services (Industry 4.0) has brought multiple opportunities to develop competitive and sustainable products and services. In Table 3, it is presented a summary of future opportunities for sustainable value creation among value networks in the digital industrial environment (Macro perspective). While Table 4 summarizes the possibilities of improvement on each value creation factor of the value creation module (Micro perspective)

Table 3. Opportunities of Industrial Internet of Things in networked value chains (Stock, et al., 2016, p. 540)

Area	**Opportunities**
Business Models	-Outcome-based business models, i.e. offer functionality, results or accessibility instead of selling physical tangible products.
Networked value creation	-Closed-loops product lifecycles by offering customized services based on product usage and selling remanufactured and recycled products. -Cooperative value creation among value partners by exchanging resources, energy and data and information.

Although Table 4 shows the opportunities presented in value creation modules starting from the “Smart Factory” (manufacturing-based), it can be deducted from previous content, that idea of “Smart factory” can be scaled on an environment heavy equipment machines once they are produced. Whether they are tractors, vehicles, motorcycles, manufacturing equipment, cranes, or other industrial equipment, these machines can be interpreted as an individual mini “Smart Factories” or possibly called “Smart Industrial Equipment”. With capacities to manipulate, assemble, transport, move or lift materials and people with embedded Cyber-Physical Systems.
Henceforth, this study is going to approach the heavy equipment environment as the main object of research. Being manufactured industrial equipment and machines the central focus for the

value creation in networked value chains with the Internet of Things, Data, and Services (Industry 4.0).

Table 4. Opportunities of Industrial Internet of Things in value creation modules (Stock, et al., 2016, p. 540)

Area	**Opportunities**
Equipment	-Retrofitting: Upgrading existing equipment with Cyber-Physical Systems to adapt them to the Internet of Things era.
Human (user based)	-Operator training through virtual and augmented reality. -Gamification of activities through CPS and virtual reality to increase motivation. - Behavior and operation feedback systems for worker improvement through CPS.
Organization	-Sustainability of resource consumption using CPS for tracking consumption for their optimization.
Process	-Design of efficient product processes through CPS.
Product	Closed loop lifecycles enabling reuse and remanufacturing. -Additional services added to the product after it is sold.

Finally, it is important to illustrate the relationship between PLM information flows described in previous chapter and the Cyber-Physical Systems within the Internet of Things. Such relationship is essential for the development of data-driven services for manufactured equipment and products. Coming from the fact that the Internet of Things works as the main driver for facilitating information flows among product lifecycle phases, aiming the value creation within networked value chains. In Figure 11, it is shown a representation of PLM within Industry 4.0 from a macro and micro perspective. Adapting the “Smart Factory” value creation module from manufacturing point of view to a “Smart Equipment” approach for value creation in use and services phases of networked product lifecycles.

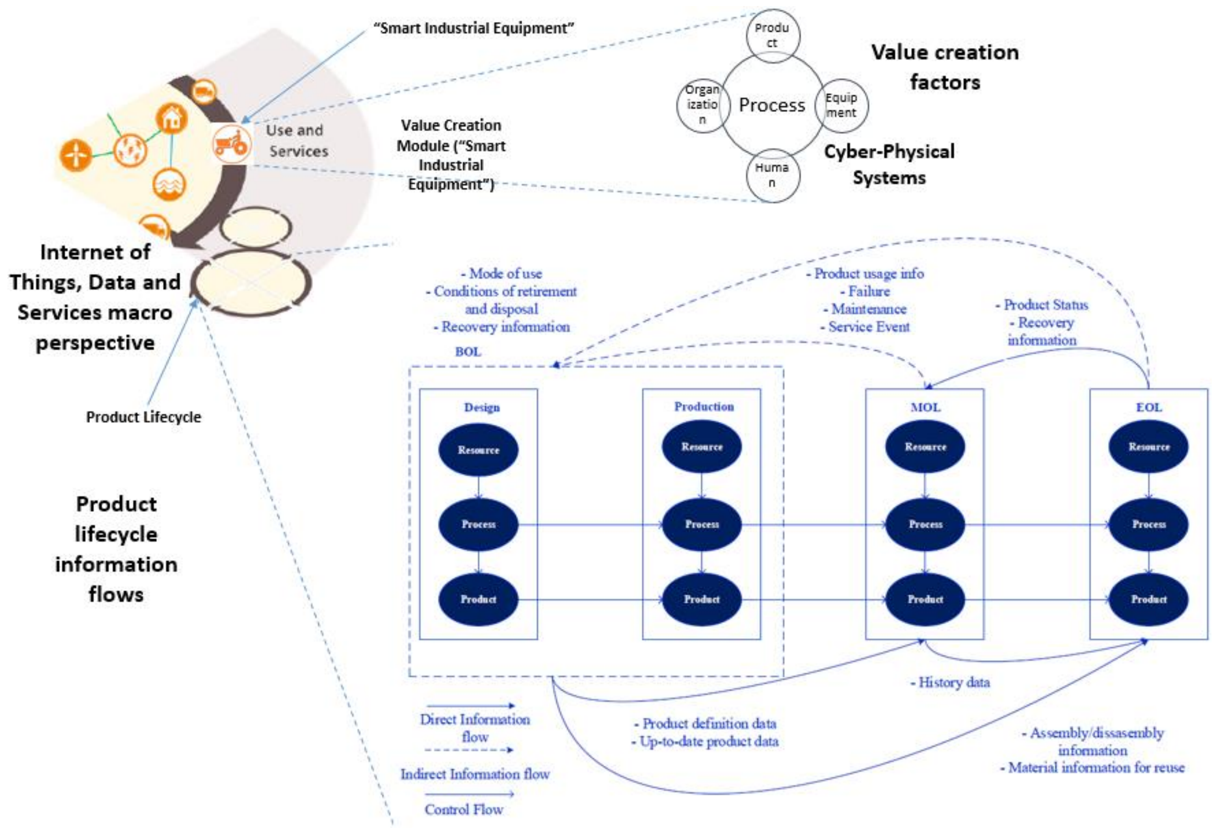

Figure 11. Integration of PLM within the Industry 4.0 macro environment for networked value creation. Adapted from (Stock, et al., 2016, p. 537) and (Jun et al., 2007, p. 857)

As mentioned above, some of the main opportunities within the Industry 4.0 are the development of services, functionalities, results or accessibility instead of tangible products, with data and information created by CPSs considered the primary drivers for such developments. Hence, following chapter will cover the tools that can be implemented in order to identify and assess customer needs in terms of data and information, considered the main asset of the Internet of Things. Once identified such needs, service developers can evaluate and select the "Smart Service" that could meet the customer requirements, topic covered in chapter 5.

4 INFORMATION NEEDS ASSESSMENT IN THE VALUE CHAIN

The Internet of Things, Data, and Services (Industry 4.0), considers essential to operate and create value in conjunction with different value partners. Otherwise, all the technologies developed in this digital era will be useless. Nowadays it is considered to obtain a networked competitive advantage, instead of the preceding company-based competitive advantages. Co-creation of sustainable and customized solutions is a synonym of effective integration of different stakeholders into the innovation process, also known as Open Innovation (Kagermann, 2015).

Value chains used to be company-centered as well, where suppliers and customers were considered as providers and receivers of value respectively, holders of own processes and information with protective practices and cooperation avoidance. Voice of customers have been critical for organizations since decades. However, due to the new technologies, they are capable to collect, analyze customer needs, process information and take decisions based on the insights obtained from such analysis. It is also possible to identify customer's customer needs and process information and so on, in such a way several value partners from different value chains are creating systemic platforms to co-create innovative products and services among industry, academia, government and civil society (Kagermann, 2015).

During the following chapter, this study will present certain tools and methods for assessing and understand real customers' needs and requirements introduced during product lifecycle phases within value chains. Putting emphasis in use, service and maintenance (MOL) needs for the development of data-driven services by CPSs in the Internet of Things. According to Kärkkäinen, Piippo, Salli, Tuominen and Heinonen (2004), Customer Needs Assessment is the combination of activities that defines "customer-oriented objectives for development activities and ensuring the accomplishment of these objectives". This study will consider the User Guide "From Customer Needs into Successful Product and Service Innovations" published by Kärkkäinen, Piippo, Salli, Tuominen and Heinonen (2004), in Lappeenranta University of Technology.

4.1 Tools and methods for Customer Needs Assessment

Customer Needs Assessment tools are useful to identify companies' problems and suggest the best suitable solution for striving product and service developments. The assessment process involves a series of steps to follow. It starts defining the current situation of the company, then passes through the collection of information regarding customer needs from different collaborators in company´s departments, and finalizes setting the objectives of product and service attributes required to meets customer needs. The implementation of the process typically concludes with the assistance provided to the company for achieving the goals defined. However, this study scope will not cover the final step of the process. Customer Needs Assessment is a process that has to be done continuously, given that that information can change through time and customer needs can change as well, assuring constant knowledge acquisition.

To begin the Customer Needs Assessment process, it is necessary to understand what the current situation of the company is. That means that analyzers should focus their efforts on identifying what are the real concerns and problems happening on the business and what are the primary goals concerning usability of information obtained. In Table 9, it is represented a list of several tools for Customer Needs Assessment, their goals, and inputs required to develop such tools.

As shown in Table 5, different tools can be applied to assess client needs depending on organization's goals, scopes of the analysis, availability of information, time and resources, among other factors to consider before starting to implement the tool. For purposes and scope of this study, as well as the goals defined by the interviewed collaborators of the case company, the tools analyzed within next section will be the One-On-One Interview, Trace Matrix and Need Interpretation Table. The justification of selecting Trace Matrix is given by the fact that case company interest is to identify the inputs and outputs from and to different value partners of their value chain. This tool identifies demands of various interest groups and transforms requirements into issues applicable to the company (Kärkkäinen et al. 2004). Need Interpretation Table is considered the following step after developing Trace Matrix. It focuses on needs and demands of a particular interest group and analyzes them in detail. The method utilized to collect information in this research was the semi-structured interview. Therefore, the One-On-One Interview was the other tool necessary to accomplish the analysis.

Table 5. Tools for Customer Needs Assessment, applications and goals (Kärkkäinen et al. 2004, p. 34)

Tool	Goal	Preliminary information	Resources	Need of time (duration)
Customer Screening	To ensure that customer needs assessment is focused for R&D and the whole company.	Company strategies, product development objectives and starting points.	1 person in charge. At least one representative/function.	**Preparation:** several hours. **2-3 sessions:** approx. 1 hour.
Creative group interview	To form a structured picture of customer needs and to create a direct discussion link with the customer.	Information on important customer (s).	1 instructor. 4-8 customer participants. A few participants of the company.	**Preparation:** several hours. **One session:** 2,5 – 3 hours. **Analysis:** 1-3 hours
One-on-one interview	To form a picture of customer operational environment and demands and to create a direct discussion link to the customer.	Information on customer (s).	Planner. Interviewers. 1-2 interviewers at a time.	**Preparation:** days during several weeks. **One interview:** 1-2 hours. **Analysis:** days
Trace Matrix	To illustrate the complex customer environment and to assist in detecting demands placed on the company	Information on customers and their requirements	2-8 participants, one of them acts as the leader.	**Preparation:** several hours. **Session:** hours.
Need interpretation table	To analyze the "Voice of customer" and to detect background needs and to compile a structured analysis of customer needs.	Information on the "Voice of customer" collected by/in the company, e.g. customer requirements, opinions and complains	1 or more persons. If possible, customer representatives.	**Preparation:** one hour-hours. **Meeting:** 1-2 hours.
Competitive position analysis	To analyze the competitive situation on the background of customer views and to find out the needs to be satisfied as first priority.	Recommendation: a structured picture of customer needs (e).	1 or more persons. Customers replying to the inquiry or interview.	**Compiling the form:** hours-days. **One inquiry:** less than one hour. **Analysis:** hours-days
QFD	To find out the most important product attributes to be developed.	Recommendation: a structured picture of customer needs, importance of various needs and on competitive situation.	1 person in charge. Project team.	**Sessions:** Hours during several weeks or months.
Pugh	To develop and select concepts based on important customer needs.	A structured picture of most important customer needs and product attributes	1 person in charge. Project team.	**Preparation:** one hour-hours. **1-3 sessions:** one hour-hours.
Problem source assessment	To detect product problem sources in advance	A clear picture of product concept.	1 instructor. 4-8 participants.	**Preparation:** one hour-hours. **One session:** 3 hours. **Analysis:** hours.
Future competitive analysis	To form a picture of the competitiveness of the new product. To assist in improving the customer needs assessment process.	Recommendation: a structured picture of customer needs. A good picture of most important product concepts.	1 instructor. 4-8 participants, part of them preferable customer representatives.	**Preparation:** on hour-hours. **One session:** one hour-hours.

4.2 One-On-One Interview, Trace Matrix, and Need Interpretation Table tools

Through the use of interviews, information can be gathered from the client. The one of a kind component of One-On-One Interview is that the operational environment of the interviewee is dissected in point of interest. The primary favorable position of One-On-One meetings in correlation with different method for gathering data is the individual contact, which makes the communication immediate and serious. On the off chance that essential, the information stream can be sent in both headings, and more consideration can be paid to the most critical issues. Foundation information on interviewee's exercises can be utilized to break down necessities that are normally hard to distinguish. Interviews give significant data on client requests and the focused circumstance. The focal part of the outcomes must be prepared before it can be dissected efficiently (Kärkkäinen et al. 2004).

With respect to Trace Matrix, a table describes different interested participants of the business chain. It also describes client needs, requests, patterns, advancement goals and issues influencing them. These issues are utilized to determine necessities on the result of the organization being referred to. This system is called "tracing". A noteworthy favorable position of "Trace Matrix" is that it can be utilized as a part of examining the organization's interested parties as an element. Moreover, tracing can be utilized to distinguish requests on the organization, which would be hard to discover otherwise. For instance, tracing can be utilized for examining the effects of patterns in future. The outcome is a table introducing the organization's most relevant interested parties and critical issues consolidated with different participants. The table additionally gives information on requirements considering organization's products (Kärkkäinen et al. 2004).

It is important to mention the relationship between both tools, given that they are dependent on each other. Being Trace Matrix a means to support the analysis and structure of customer needs information, it requires a tool to collect such information. Since Trace Matrix presents the “whole” picture of the needs structure, and Need Interpretation Table reaches particular needs, opinions, wishes of the customers, allowing analyzers to pay attention to actual demands. The information collection can be done through Creative Group Interview or One-On-One Interview. Thus, it can be deducted that Need Interpretation Table and Trace Matrix cannot be made without developing any interview. In this case study, the One-On-One Interview to collect the information from the case company. In Table 6, it is presented a description of each tool used in this study, their goals, applications, results expected, advantages, restriction, among other valuable information.

Table 6. One-On-One Interview and Trace Matrix tools for Customer Need Assessment. Adapted from (Kärkkäinen et al. 2004)

	One-On-One Interview	Trace Matrix	Need Interpretation Table
Usage in a customer needs assessment process	-Customer activities and customer demands on the product of the company are defined. -Can be used to collect information on competitors.	-Assessment of determinants combined with various interest groups of the company, which can affect customer needs and the demands placed on the product. -Analysis of the impact of existing or future trends on product demands making it this possible to detect demands of this kind as early as possible.	-The interpretation of diverse information obtained from the customer contributes to making an analysis of background customer needs. At the same time, a structured picture of customer needs can be formed.
Appropriate usage situations	-The company wishes to get acquainted with customer activities on a profound and wide basis. -The company can meet only one or two customer representatives at a time and it wishes to profit by these meetings as much as possible. -The quantity of objects to be analyzed is 5-30.	-The company has a lot of interest groups and wishes to illustrate their interdependencies and the dependencies considering the company. -Remote interest groups can have a remarkable impact on demands placed on the product.	-Analysis and structuring of demands expressed in meeting with the customer. -Situations, in which the company wishes to assess the needs behind the customer words or other customer needs information. -Situations, in which the company wishes to form comparison criteria for competing suppliers in cooperation with the customer and on the basis of customer needs.
Results	-A picture of customer activities and of its demands on the supplier can be made. -Information on competitors can be obtained	-A picture of interest groups -A picture of demands placed on the company and on the product to be developed and of their origins.	-A structured picture of customer needs and of comparison criteria of suppliers.
Main Advantages	-Personal contact and direct interaction with the customer. -Issues can be dealt with by taking customer standpoints into consideration and by using the customer´s language -Profound questions can be asked and a question framework can be compiled. -Gestures, tones of voice and other details can be analyzed. -Background information can be obtained and possible used to define totally new needs.	-A great amount of detailed information on various interest groups can be structured while keeping the entirely in control. -A chain of impacts can be formed, which can be used to detect demands originating even from remote interest groups. These demands include requirements to be fulfilled presently and in future. -Possibility of early assessment of demands originating from future trends. -An effective means of communication and commitment tool to be used in team work.	-Assists in understanding the customer and in looking for profound, even surprising needs. -Assists in discussions with the customer and in considering various factors from the customer's point of view. -Customer needs are documented.
Restrictions	-Preparing for the interviews, conducting the interviews and analysis after the interviews require a lot time. -It can be difficult to obtain an adequate sample size.	-A lot of time is required for filling in the table. -The tool requires "pottering" when implemented by using wall table technique.	-Topics for the column "Voice of customer" have to be collected directly from the customer, before the tool can be used to obtain reliable results. This tools can also be used for analyzing internal information in the company.

4.3 Linkage between Customer Needs Assessment and service development

Customer Needs Assessment and product-oriented services are closely connected with each other. Customer Needs Assessment is an essential and crucial part of successful service development. It provides the customer with information required for conducting product and service development activities. The information obtained can serve as a basis for selecting the most important service development objectives and for defining their scopes. Customer Needs Assessment is a well-grounded means of analyzing product development results in various phases and of predicting the success of services already developed. (Kärkkäinen et al. 2004)

Customer Needs Assessment tools are designed to improve the careful understanding of customers' business, operations and needs, as well as the understanding customer's customers and other value partners. In few words, for facilitating the service development by enabling a wider and more in-depth understanding of the value proposition from the customer standpoint. For purposes of this study, the objective is to understand the real value proposition that CPSs in the Internet of Things are providing to customers in terms of information, data and knowledge through the whole product lifecycle. More specifically, during product use, support, logistics and maintenance phases of lifecycle (MOL).

5 PRODUCT-SERVICE SYSTEMS IN MANUFACTURING

Due to increasing competition and demands from customers for customized solutions in shorter times with the highest quality, manufacturing companies have passed from selling uniquely tangible products, to adopting a service-oriented approach to generate steady and continuous revenue streams. Companies are cooperating with different members of the value chain to develop jointly product-related services through the whole product lifecycle (Herterich et al., 2015). Manufacturing companies are more concerned in offering customized services such as maintenance, repair, training, overhauling, and technical supporting. This continuous trend within producers of tangible products is commonly known as “Servitization in Manufacturing” (Lightfoot et al. 2013). In addition, this trend has occurred simultaneously with the increasing trend of digitalization and the Internet of Things, Data and Services era (Industry 4.0). Thus this chapter will cover the link between “Servitization” and “Internet of Things” for the development of product-related services “equipping products with intelligent digital systems” to increase productivity, (Lerch et al. 2015).

As previously mentioned, PLM information flows are being facilitated by Cyber-Physical Systems in the Internet of Things for value creation. Highlighting CPSs’ capacity to remotely generate, analyze and share information regarding product interactions with other “objects” and people within different value chains. Manufacturing companies will face multiple opportunities to develop new product digital services (data-oriented), according to the information insights obtained through the Internet of Things. Networked value chains will gain advantages difficult to imitate for competitors since customers will meet their expected functionality, results or outcomes in different phases of product lifecycle through customized digital services.

During the following lines, this study will describe the definitions of Product-Service Systems, currently used services in all phases of the product lifecycle, and future opportunities for service developments with a data-oriented approach. However, it must be remembered that this research takes Equipment and Industrial equipment as the central focus for such service developments in MOL phases of the product lifecycle.

5.1 Digital Product-Service Systems

The term Product-Service Systems (PSS) has been gaining attention from research and industry in recent years. It takes the "Servitization" approach of manufacturing companies of switching from a physical product-based business to a service-oriented strategy. The term PSS has been an object of study of several authors, interested in the opportunities this new trend represents for the development of new sustainable business models and value creation.

PSS are defined by a merchantable combination of products and services able to meet or surpass customers' needs in a sustainable way. (Goedkoop et al., 1999; Tukker, 2004). For Martinez, Bastl, Kingston and Evans (2010), adopting a service-oriented strategy is still being a challenge for manufacturing companies, due to customers' resistance of perceiving value from services once the product is delivered. The author claims that manufacturers' customers regularly oppose to pay reasonable prices for services, arguing that such services should be included in the purchase price. In addition, some customers refuse to share information regarding their processes, resources, and products, being information an essential requirement for adopting a value creation strategy in the current Industry 4.0. However, service business still represents more opportunities than challenges for manufacturers, given their capability to provide them more steady revenue streams by contracting services, support, maintenance or even performance or results.

Despite all the challenges mentioned above from the "Servitization" of manufacturing companies, value chains can adopt strategies and operations to create "perceivable" value for customers in an economic, social and environmental points of views. According to Reim, Parida and Örtqvist (2015) framework, PSS strategy can be implemented in two ways to create value: The first strategy consisting in implementing new business models for PSS. The second strategy related to implementing operational tactics of PSS carried out by different fields, such as marketing, product development, sustainability, legal, among others.

The first PSS strategy from Reim, Parida and Örtqvist (2015), establish different business model strategies to be chosen depending on each company or value chain goals and objectives. The second strategy focuses on the tactics derived from every business model adopted, i.e. operational actions which determine how much value is created and perceived by such business model. Before describing those business models and tactics, it is noteworthy to mention that business models “refers to the logic of the company, including how it operates and how it creates value for stakeholders” (Magretta, 2002). In Table 7, it is described a classification of different service-oriented business models strategies according to their way of creating value. While in Table 8, a general framework of business models with their set of tactics. For interest and scope of this research, uniquely “Product and Service Design” (Lifecycle services) tactic will be considered and described in this study.

Table 6. Value creation in different business models for Industrial PSS (Reim et al., 2015, p. 66)

	BUSINESS MODEL CLASSIFICATION (Industrial Services)		
	Product-Oriented	**Use-Oriented**	**Result-Oriented**
VALUE CREATION	Selling product-related services in addition to the tangible product (Product maintenance, support, recycling).	Selling accessibility and availability by renting the usage of tangible products and their intangible services. Periodically payments by contract.	Selling results, outcomes or performance. No physical product or services are sold. Offering results based on a measurable result.

Table 7. PSS Business model strategies and their tactics. (Reim et al., 2015, p. 67)

Strategy	**Business Model**	**Tactics**
Manufacturing Company aiming for an increased service offer	-Product Oriented -Use-Oriented -Result-Oriented	-Contracts -Marketing -Product and Service design -Sustainability -Networks

The PSS product and service design has the characteristic of considering the whole product lifecycle as the primary reference for new developments (Aurich et al., 2006). According to Reim, Parida and Örtqvist (2015), for designing and developing services, it is firstly necessary to understand and assess customer requirements. Every company usually has different product and service requirements depending on its goals, operations, and practices. Thus, value partners need to adapt and customize solutions according to specific requirements or needs. The authors also manifest that in order to success in meeting customer needs, it is necessary to “Align physical product characteristics with service offer characteristics and vice versa” (Aurich et al. 2006). In few words, being able to identify preferable product properties, such as product ability to be upgraded, maintained and reused (Sundin, et al., 2005).

5.2 Digital Services within Industrial environments

The Internet of Things, Data and Services era (Industry 4.0) has leveraged service-oriented business models for manufacturers. CPSs embedded with industrial equipment allow service providers to improve their value added offers by improving efficiency in support, maintenance and usage stages of the product lifecycle. Services processes such as condition monitoring, operations tracking, and predictive maintenance are only a few examples of how services could be provided to different customers in the value chain. Nowadays, manufacturers possess technologies to track information and data from customers’ use towards the product, either by identifying and predicting breakdowns and shutdowns in machinery, or by remotely fixing and manipulating machines to operate in the most efficient way through CPSs in the Internet of Things.

Industrial Product-Service Systems (IPSS) are referred as PSS applied to “industrial context to such product-service bundles” (Mikusz, 2014). Mikusz (2014), understands the idea of CPS as the primary driver to obtain Industrial Software-Product-Service Systems (ISPS2), term assigned to the development of information-driven services embedded with CPS in the Internet of Things, Data, and Services (Industry 4.0).

The next subtopics will present a literature review of the different approaches and business models of ISPS2s or “Smart Services” within different phases of product lifecycle in industrial value chains. Three categories of PSS approaches are presented taking as a reference the classification made by Parida, Rönnberg, Wincent, and Kohtamäki (2014). As mentioned in previous sections, this research will pay particular attention to describing services and their affordances of use, support, service and maintenance processes (MOL) within Industrial Equipment products.

5.2.1 Functional and Operational Services

Functional and operational services are based on the previously mentioned result-oriented business models. These services consist in offering to customers results, functionality or desired outcomes based on product performance. Services providers are responsible for operating their products in customers’ processes to achieve a quantifiable goal, i.e. the customer pays for the functional output that is going to receive from the product in a contract-based agreement (Parida et al., 2014). To illustrate with an example, the case of Rolls-Royce aircraft engines division focuses its approach towards outcome-based services, called Power by Hour program. Such program consists in offering airlines hours of engine operation, taking RR responsibility of providing maintenance and every kind of services needed to operate the specified hours contracted (Parida et al., 2014). Other examples of quantifiable outcomes which can be offered by service providers are energy savings, energy emissions, raw material savings, productive land area, among other measurable results.

Manufacturers can leverage CPSs within the Internet of Things to develop and extend their outcome-based service offerings through the whole product lifecycle. The opportunities in these sort of services are based on the fact that manufacturers have and spread expertise on how to use the product and technologies they produce. Therefore, they can warranty the most efficient operations to customers. Put simply, if they operate, manipulate and maintain the equipment for particular customer’s processes, the probability of achieving expected outcomes and results are much higher than allowing customers to operate their products. CPSs in these cases can track and monitor the current usage of equipment, predict future breakdowns and shutdowns and even operate machines remotely for the most optimal outcome. The main challenges are in defining prices and contracts for this sort of services, given that no tangible products or defined services are sold.

5.2.2 R&D-oriented Services

Research and Development services are commonly referred as knowledge-based services offered for product improvements, customized designs, prototyping and user training. The CPSs in the Internet of Things allow manufacturers of Industrial Equipment to test prototypes digitally in a simulated environment. Customers are invited to test digital prototypes on early development phases. Further on, developers collect valuable information feedbacks regarding customer experience, product usage, resource utilization, among other parameters which can be improvable for a successful product launch. R&D-oriented services have not being exploited by manufacturers nowadays. There is still skepticism on CPSs capabilities to obtain significant predictions on how the product is going to behave in real environments. In case prototyping simulation through CPSs result in an outstanding accuracy in predicting product usage, R&D-oriented services could allow value chains to optimize their productive systems, being such services an important channel for generating revenue streams.
Digital prototyping not only include the product itself, but it also includes prototyping the whole product lifecycle environment. CPSs collect data and information from different processes, such as logistics, manufacturing, usage and so on. Hence, developers can track and monitor information from the entire environment and make improvements based on product and user interactions.

According to Mevea (2016), R&D-oriented services through simulation driven by CPSs can be applied to improve product development, develop virtual prototyping and train operators using machinery and equipment. Virtual prototyping allows product and service developers to shorten development cycles, reduce costs, better decision making and improve the quality of goods. It also allows designers and several stakeholders to make changes in earlier development phases, without needing to produce or manufacture physical prototypes, test them, and finally, make the respective improvements. Manufacturers of equipment can offer simulation-driven services for any value partner interested in learning product usage; hence companies can reduce costs, risks and time involved in training activities. As shown in Figure 12, utilizing simulators in safe environments increases operators' skills in early development phases, increases their safety and save times and costs involved in training courses.

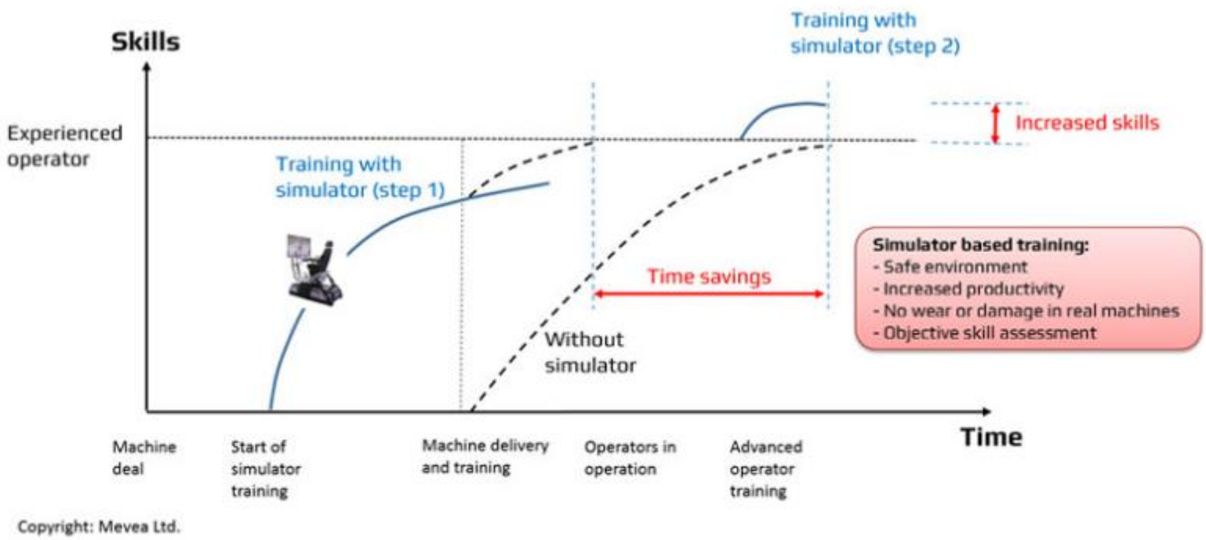

Figure 12. Simulation benefits in training machine operators (Mevea, 2016)

Data and information are considered nowadays the main assets a company can have and one of the most important drivers to obtain significant competitive advantages. However, massive amounts of information produced do not provide value to customers if such information is not converted into significant knowledge and insights. The real challenge for R&D service providers in selling data and information to third parties is to understand firstly what are the information needs and requirements of customers. Once analyzed and understood their processes and data, providers can customize their data-driven services, hence create value for their clients (Parida et al., 2014)

5.2.3 Maintenance and Product Support Services

Maintenance and support services are the primary focus of study in this research. Business models oriented to offer maintenance, repair and overhaul (MRO), remote monitoring, diagnostics and technical support services are strongly related to gains in financial performance (Parida et al., 2014). The main objective of these services is to minimize total cost of ownership, by offering to customers optimal time of efficient use in their machines.

Manufacturers are focusing nowadays on service-oriented strategies, creating innovative product and service bundles able to create value for customers. The coming era of "Smart" devices or CPS integrated into the Internet of Things, Data and Services has brought incremental benefits in effectiveness and efficiency in use and operations phases of product lifecycle (MOL). Concretely, CPSs data collection and analysis converted into value insights provide several advantages for improving usage and support processes. Such as allowing manufacturers to monitor customer behavior towards the product, tracking product and component condition to predict shutdowns and breakdowns, optimizing operations by identifying historical patterns, reducing operative costs by monitoring productivity of each entity, increasing operator expertise by remote training and even controlling and operating customer processes remotely. In Table 9, it is shown a list of use and support services leveraged by CPSs or "Smart" devices, specifying their description and main affordances achieved.

Besides use, maintenance and support processes in value chains, it is important to remember that logistics and delivery operations are also integrated into the middle of life phases of the product lifecycle (MOL). Logistics and mobility decision makers have been utilizing "smart" objects and CPSs from the beginning of inventions of RFID and other pioneer embedded technologies. Developments in tracking and monitoring services within logistics processes have been the drivers of the creation of "Smart Factory" and other "smart" environments within industrial activities, such as manufacturing, R&D, use, maintenance, recycle and the rest of processes of the product lifecycle.

Table 8. Use and support services leveraged by CPSs (Herterich et al., 2015, p. 325)

Service	Description and affordances
Engineering services	Engineer better equipment by leveraging operational performance data. Data from the industrial equipment of the current installed base can be used for engineering future version of the equipment
Optimization of equipment operations	Operation of the equipment can be optimized based on historic operational data. Breakdowns can be prevented. Based on historic usage patterns, operations can be optimized.
Remote control and management	Having the ability that CPSs can receive control information, dedicated functionality of the equipment can be controlled manually via remote service centers. A reset of CPSs can be conducted to eliminate faults remotely.
Predictive services	Continuous data collection based on CPSs might be used to trigger and predict service activities. For example, routine maintenance activities can take place based on usage or wear and tear of the equipment. Efficiency increases are not only possible by conducting the service activities efficiently but also by scheduling them in an efficient yet effective way.
Remote diagnosis and repair	In many cases, maintenance or even repair can be accomplished remotely. Comprehensive service centers are set up and experienced staff diagnose or solves problems remotely. Experienced service agents can be utilized more effectively, as travel is no longer necessary. Initial diagnosis is accomplished remotely.
Field services	Industrial CPSs can be used to optimize and enhance efficiency of existing service processes and particularly field service activities. Based on CPSs, field service activities can be performed faster and service quality could be increased. Field service technicians can be supported by remote experts to solve problems faster and more effectively.
Information and data-driven services	Data as well as insights obtained from CPSs can be used as an asset to realize unexpected information and data-driven service opportunities. For instance, in case that manufacturer is the owner of the data, data can be sold to other stakeholders via standardized interfaces. This data can be leveraged for the service business.

Current requirements in transportation are oriented to optimize resources and energy, reduce climate impacts and saving time, demand developments in mobility and logistics. Thus product and service providers should be focused to meet those requirements to stay in the more and more competitive markets. CPSs and "Smart Devices" in the Internet of Things represent an opportunity for those companies to cope with current challenges and demands, given their ability to improve "efficiency in the delivery of individual orders, supplier relationships and mobility service provision" (Kagermann, 2015).

Service in logistics processes facilitated by CPS or “Smart Objects” can be considered as “Smart logistics”, where supply chains are all connected each other monitoring supply needs in real time for immediate planning, purchase, and delivery when needed. Such services can be provided as data-oriented services, with “Smart Objects” tracking in real time loads transported in every transport means, to accelerate processes, reduce leisure times and lower costs. Other sort of services includes sharing use of transportation and logistics infrastructure, by offering to customers transshipment facilities, collection systems and delivery journeys (Kagermann 2015). The state-of-the-art technologies leveraged by “Smartization” of objects include the development of services utilizing “smart” cars and trucks, means of transportation able to connect to transport and traffic systems in the Internet of Things. Such trucks and cars will have the characteristic of being “autonomous”, which means they do not need a driver to transit trough cities and roads, optimizing in the most efficient way their use, reducing accident risks and cost in salaries.
In Table 10, it is represented a summary of IPSS integrated with CPSs in the Internet of Things previously mentioned through these sections. The table shows “Smart Services” obtained from the literature review, presenting the services that could be applied in all phases of the product lifecycle. In addition, this table represents the impacts of such services on several value partners of the various value chains.

Manufacturers face nowadays challenges to provide value to customers through “Servitization” and the Internet of Things economy. PSS providers should focus firstly on identifying and analyzing customers’ service needs and requirements. To meet those needs, service providers should concentrate their efforts in “aligning physical product characteristics with service offer features and vice versa” (Reim et al., 2015).

Table 9. IPSS leveraged by CPSs in the Internet of Things, Data and Services. Adapted from (Herterich et al., 2015, p. 325), (Parida et al., 2014, p. 47) and (Gelbmann et al. 2015, p. 53)

IPPS lifecycle phase	**Description**	**Digital-IoT Services**	**Impacts**	**Stakeholders**
Begining of life (BOL)	-Conceptualization -Definition -Realization of product	-Manufacturability Analysis -Prototype design and development -R&D Support -Problem Analysis -Feasibility studies -Engineering with operational performance data -Information and data driven services	-Shortening innovation cycles -Triggering of incremental innovation in the short run (upgrades) -Long-run improvements	-Manufacturer -Supplier -Co-innovation partner
Middle of life (MOL)	-Use -Service -Maintenance	-Operating sold products -Product Upgrade services -Optimization of equipment operations -Control and manage equipment remotely -Predict and trigger service activities -Remote diagnosis and replace field service activities -Information and data driven services	-Reduction of reaction and delivery time -Reduction in resource inputs -Higher service quality for customer -Optimization of performance (greater availability, higher output) -Optimization of efficiency (fewer required resources, less facility usage)	-Product operators -Service Organizations
End of life (EOL)	-Reuse of product or components -Refurbishing -Disposal	-Maintenance services by prolonging the lifespan of products (Repairing, Servicing Upgrading) -Recycling/reusing part or component information services -Close the product material cycle by taking products back -Secondary utilization of usable parts in new products -Environmental effects reports services	-Increase resource efficiency and productivity -Sustainability in resources and energy -Reduce waste	-Manufacturer

Given the fact that data and information are the main assets and resources of "Smart Services", this study will concentrate its efforts on identifying and analyzing information-related requirements through use, maintenance and support phases of product lifecycle (MOL). Manufacturers should determine what are the customers' information needs to create value with customized service deliveries. PLM information flows facilitated by CPSs in the Internet of Things will provide manufacturers several opportunities to create service innovations able to improve product processes, increase and create revenue streams and optimize resources in the most sustainable way.

5.3 Service and information requirements

With current competitive markets, companies must work in cooperative networked value chains to create value for different value partners, which nowadays use to have high demands of receiving customized solutions according to their needs. Thus, value partners should focus their efforts to understand customer product processes firstly, and then analyze their needs and requirements through the whole phases of product lifecycle. Service providers are maintaining close and long-term relationships with their clients to provide them the highest functionality according to their needs (Reim et al., 2015). Put simply, customers demand functional product-related services with high degree of customization, which gives them the flexibility to adapt to changes in markets and consumer behavior.

Functionality considers "how the product or service component should be designed to incorporate additional element in a way that offers high value to customers" (Reim et al., 2015). When customers demand functionality, they require the reliability of services, high flexibility, and easiness of maintenance activities, since they pursue the highest productive times of their machines and equipment. Functionality concerning information during MOL phases consists in providing to customers information converted into useful knowledge, which allows them to make decisions and take actions based on the highlights obtained from data and information collected from CPSs in the Internet of Things.

Customization refers on how the product and service are adapted to meet specific customer needs. Customization is an important approach for retaining customer loyalty, and therefore one of the most valuable competitive advantages for manufacturers. Several companies currently offer customized products to their clients, with complex configuration tools that allow them to select the product features according to their needs. However, customized product-oriented services haven't been developed to the same degree as product customization. It represents various opportunities to leverage the new era of CPSs and "Smart Devices" to focus efforts in development of customized data-driven services through the entire product lifecycle. Such services can significantly optimize customers' processes and resources, allowing them to deliver to their customers innovative products and services in the most efficient and sustainable way, with the highest quality and lowest cost.

As previously mentioned, to develop customized services, it is necessary to understand and assess customer requirements to meet such needs. Therefore, the Customer Needs Assessment will be the means to understand such needs for developing customized services. Through the next chapter, the most suitable Customer Needs Assessment tools will be selected for their application within the case company of analysis of this study. Finally, this research will proceed to present suggestions of data-driven service innovations for the case company. Recommendations based on both the literature review related to PLM, CPSs, Customer Needs Assessment, value chains and the Customer Needs Assessment analysis made with the information obtained from the interviews made to the case company.

The following framework (Figure 13), presents the procedure pursued for the identification of digital PSS based on customers' information needs. The framework considers the four characteristics described by Abramovici, Göbel, and Neges (2015), for the Smart Engineering methodology, especially for the development of smart services for use, service, maintenance and support phases of the product lifecycle. However, it should not be considered as a methodology itself, yet a foundation to begin a Smart Engineering process. The aim is to follow a particular series of steps starting from the description of the customer need and particular information requirement (Chapter 4). Proceeding by the selection of a suitable business model and factors based on the macro and micro perspectives of value creation module of "Smart Equipment" (Chapter 3). Continuing by enlisting the suggested "Smart" PSS (Chapter 5) for case company, according to the needs and business model selected. For finalizing with a description of each service, impacts and its implications within the value partners. A total of eleven needs for both MOL and BOL processes were identified for this study, six for Valtra and five for farmers.

The framework follows the assumption that a manufacturing company in question is developing "Smart Services" for the first time. Thus, the analyzer does not have a data supported insight of the real situation, rather the "Voice-of-customer" is converted into a business model and smart service selection. However, once the manufacturer decides to implement the connected CPSs and other embedded systems (Internet of Things) in its business processes, service developers will have important operation insights obtained through data-analytics software. Allowing them to make decisions based on both user behavior information and customer needs identification. As shown on Figure 13, the Smart Equipment will provide significant operational information at the same time the analyzer assesses customer needs. The continuous process feedback will create virtuous cycles for improving customers' operations through the Internet of Things and Customer Needs Assessment tools.

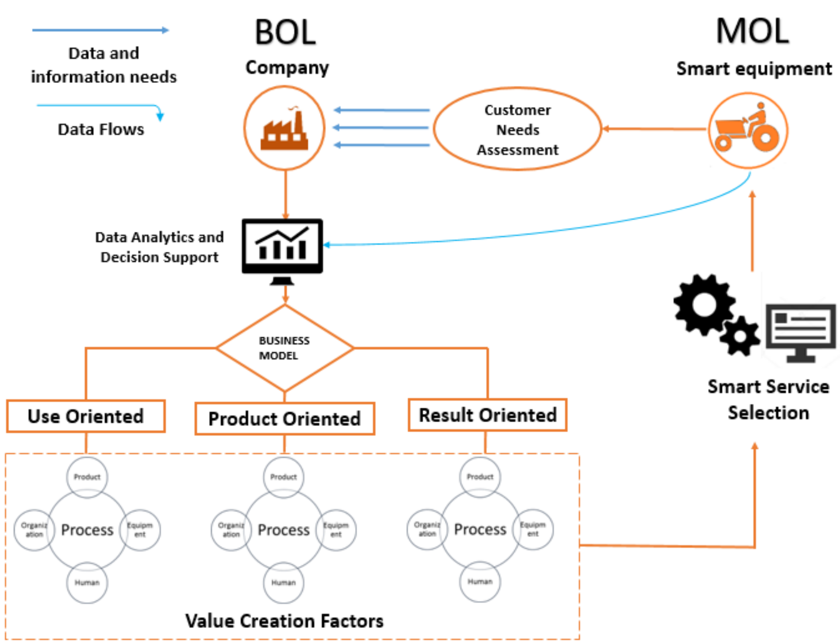

Figure 13. From customer needs to smart service development framework

5.4 Simulation aided service design

As previously mentioned on R&D-oriented services section, the digitalization of product and service development, as well as other important lifecycle processes have been gaining importance in manufacturing businesses. Several stakeholders of diverse value chains are becoming less skeptical and more familiar with the technologies that replicate real behavior of machines and equipment, such as automobiles, tractors, cranes, assemblers, and other machinery within a diverse number of industries. Such replication can be obtained through the use of simulation-based solutions, where different physical conditions, variables and scenarios can be virtually experienced before the real processes are conducted.

Simulations can leverage the knowledge and information generated by CPSs and other embedded technologies to create more accurate predictions from process variables. This integration could allow value partners to observe relevant information from diverse lifecycle processes to further contributing on the value co-creation of innovative PSSs. According to (Mevea, 2016), real-time simulation consists in a computer model which runs at the same rate at the real physical system. That means the model needs to obtain actual real-time data from the physical phenomena, which can be obtained through the use of CPSs and other embedded technologies. Contrary to conventional simulation, real-time simulation possesses the ability to analyze user and system behavior in milliseconds “online”, instead of the long hours taken by the traditional technologies “offline” (Mevea, 2016).

As shown in Figure 14, real-time simulation allows product and service development teams to “virtually” produce prototypes. Allowing them to obtain predictions concerning user experience feedbacks, user behavior, potential risks, among other valuable data that would be considerable expensive producing physical prototypes. However, it is important to mention that the more real data is collected through CPSs and integrated into simulators, the more accurate and reliable real-time simulation will be.

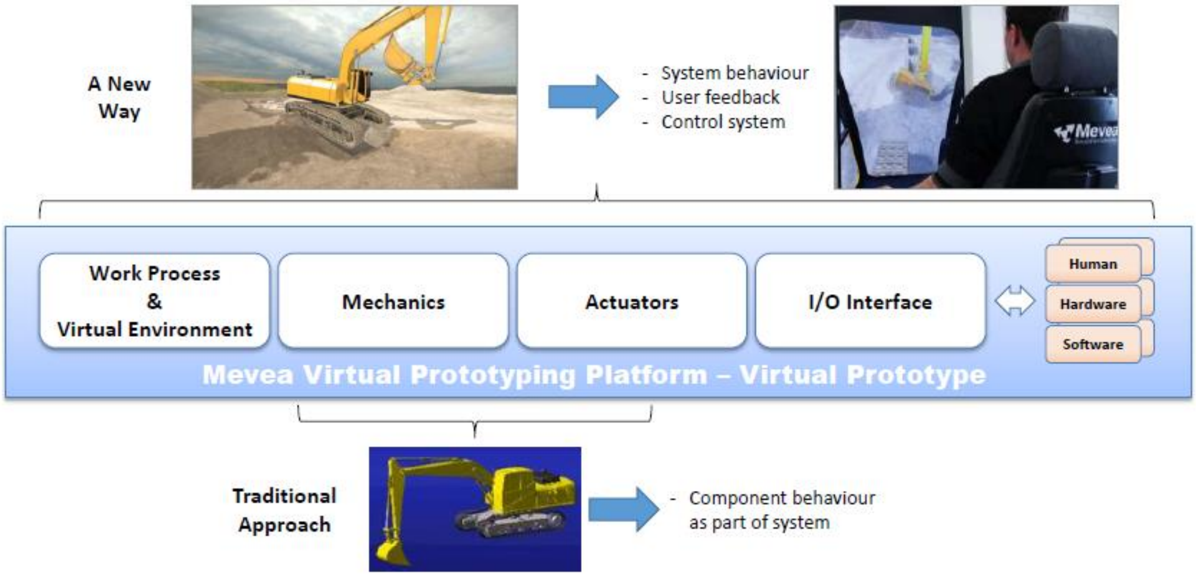

Figure 14. Real-time simulation vs traditional simulation (Mevea, 2016)

CPSs and other embedded technologies can carry feedback information and data streams to a simulator to "calibrate the model parameters to reduce discrepancies between its simulation results and observation" (Hu, 2015). This means that the collection and analysis of real data from the current environment is needed all the time in order to increase better analysis and prediction, due to the constant changes on the several variables presented in an operation process, both external and internal, such as geographic conditions, weather, humidity, operator handling, physiological situation of operator, machine behavior, among many others. For Hu (2015), without the assimilation and integration of real-life data into simulators, the difference between real life operation and simulation is likely to grow continuously.

The Internet of Things plays an essential role in the future development of simulation aided service design. The ability to monitor continuous and feedback data of products and their environment from all phases of product lifecycle (Closed-loops) will not only support decision making based on real events, but also make decisions based on predicted events set on predefined scenarios. Developers will be able to fix the variables they want to observe in order to analyze the system behavior and then proceed for the corresponding changes and improvements. In Figure 15, it is presented the relationship between the Internet of Things and real-time simulation, as well as the way simulators can be constantly improved by the continual integration of real-data.

The integration of IoT-generated data with real-time simulation represents new business opportunities to manufacturing companies for developing simulation-driven services. The constant simulator's learning on every time it receives data from the real workplace increases data reliability from simulated models. Product and service developers can leverage data-driven business models to the next level using real-time simulation, since they will be able to replicate possible events with predefined variables that would be risky and expensive to reproduce with physical prototypes. However, simulator companies will need to collaborate effectively with manufacturing companies to accurately replicate equipment features, design, work environment, systems, among other original characteristics. In addition, the use of simulations on product and service development leverages sustainability and responsible use of resources, since it reduces to zero the fuel consumption and gas emissions produced during prototype testing and trainings.

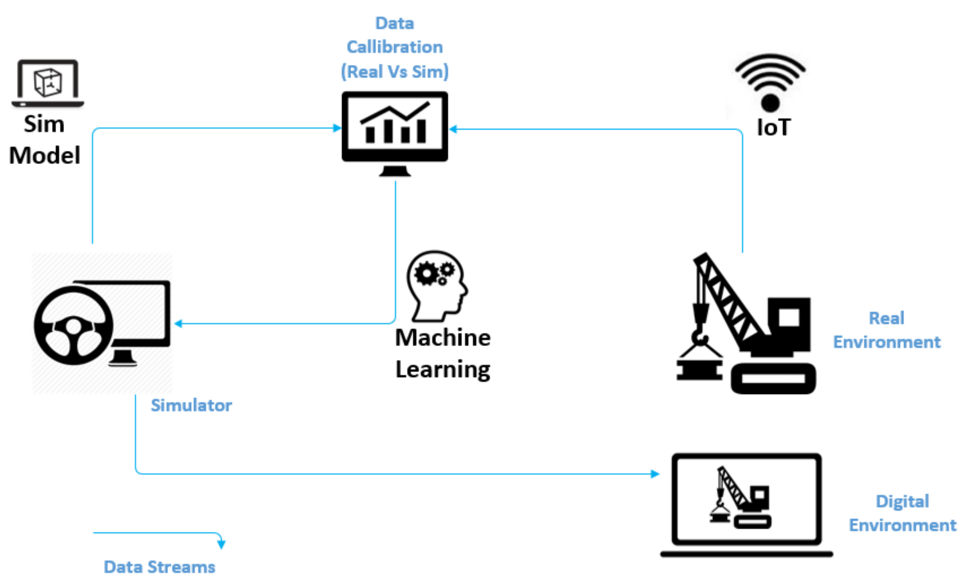

Figure 15. Simulation continuous improvement trough real-operation data

Simulation can take an essential role in the development of Smart Services. Through real-time simulators, customers can verify whether or not their needs are met by implementing smart devices and other embedded technologies in their process optimization. Put simply, customers could perform tests on digitalized-environments, where the smart services are already in "progress". Therefore, customers will be able to select features, components, information, functionalities and certainly expected outcomes that create value on Smart Services. Employing an effective Customer Needs Assessment analysis, followed by a simulation-based operation scenario creation, could provide manufactures certainty on what Smart Services and business models can work for meeting customer needs. Figure 16 presents the integration of real-time simulation within the described "Smart Service" development framework (Figure 13). Representing real-time simulation as a complementary tool for meeting customer needs, shortening development costs and market introduction times.

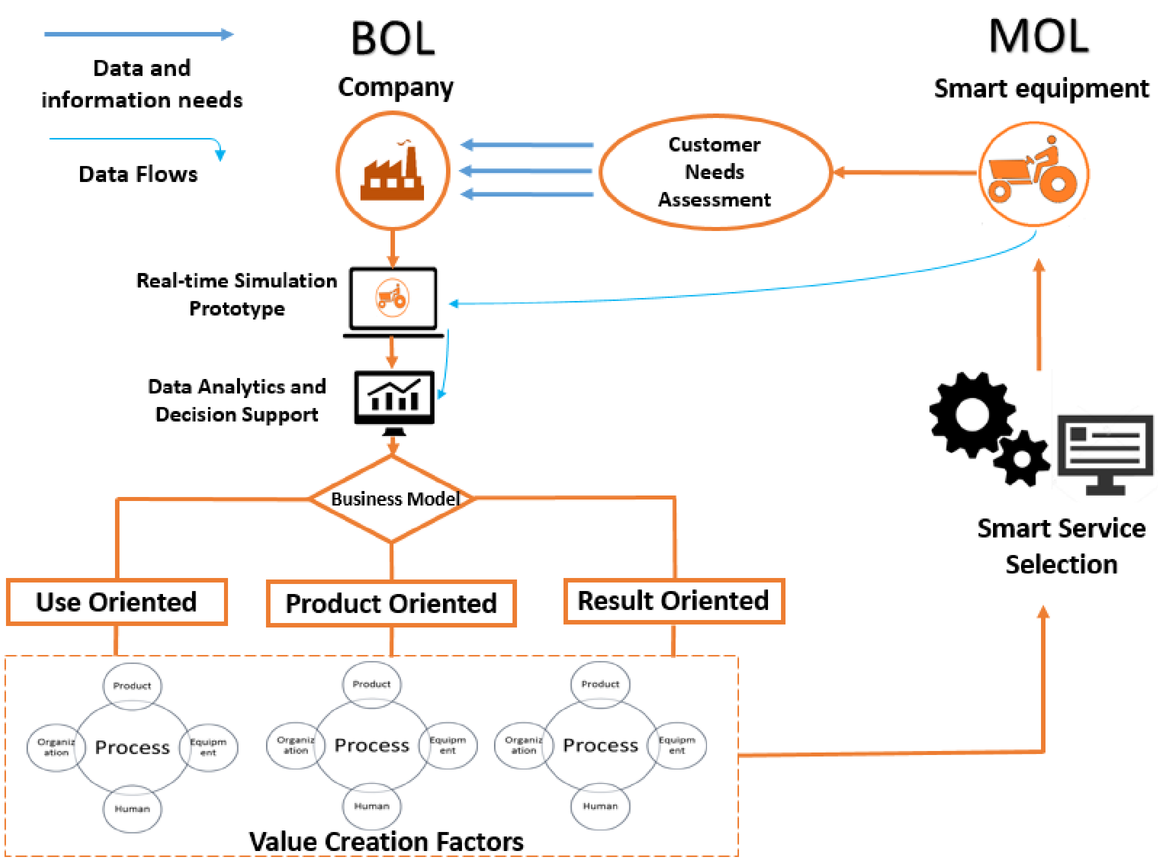

Figure 16. Real-time simulation integrated into the Smart Service development process

The continuous improvement of simulation-driven equipment not only is applied for product and service development and process improvement purposes. The constant data feedback from the real operation can establish optimal operation parameters and potential hazardous situations for operators. This means that staff on simulator trainings can receive improvement recommendations based on their training performance, obtain evaluations from the system, identify opportunity areas, as well as acquitting guidance on what to do in case a hazardous event could happen in the workplace. Simulation can increase considerably productive time of machines, since real machines will not be used for training purposes anymore.

6 CASE STUDY: TRACTOR COMPANY

The following case study was conducted from the cooperation of Lappeenranta University of Technology and the Finnish tractor company Valtra. The study involved the participation of personnel from the company during the interviews and meetings. All the information collected from the interviews in reference to company's processes, strategies, customers and technologies was provided for the proper realization of this study. In addition, one of the interviewees responded as a company's customer, since he considers himself as an actual farmer and a Valtra equipment user. A literature review concerning the food and farming industry was also conducted in order to complement the study. The sources from which the literature was obtained cover scientific papers, books, websites, videos and magazines.

This study aims to analyze the actual information needs presented in the industry for leveraging the Internet of Things, Data, and Services. In this case, the company analyzed was Valtra, a tractor company involved in the agricultural and food value chains. Valtra provides value to customers through tailor-made services and solutions. Being one of the leading companies worldwide to offer highly customized tractors and tractor-related services to farmers and other stakeholders involved in the farming industry. The case company is interested in finding out what are the main opportunities the Internet of Things can provide them in order to increase the value they deliver to their customers.

Nowadays, development teams are interested on identifying the needs and requirements when customers are using their tractors. Put simply; the special concern is how Valtra can track and trace data concerning product interactions with its users and environment, for then transform this data into valuable information and insights. Achieved this goal, it is simpler for the company to offer better products and services according to customer needs and goals. Nowadays, this information is collected through surveys and interviews to customers when maintenance and services are provided. In fact, those are valuable tools to gather information regarding customer needs. However, even if customers have a thorough understanding and expertise in their field, sometimes they do not perceive how their product is being used and how it interacts with the farming environment. The Internet of Things, Data, and Services will bring new opportunities to farmers and other stakeholders in the value chain to be more productive, reduce costs and risks, comply with governmental regulations, among other goals.

The farming industry is not an exemption of the “smartization” era nowadays. Being called as “Precision” or “Smart” Farming, the agriculture industry is experimenting a new phase towards CPSs. “Smart Devices” are tracking and monitoring the current crop environment and all the productive units interacting with it. This new trend for agri-food businesses represents a bunch of opportunities for optimizing crop yield and producing sustainable products and services within various value chains involved.

The aim of “Smart Farming” is to integrate several farming management systems into a “System-of-Systems” approach for connecting all the participants of the agricultural process, as shown in Figure 17. Such as irrigation systems, weather data systems, seed systems and surely the farm equipment system as well (Porter et al., 2015). The information analyzed from the “smart” environment will bring to farmers valuable insights concerning productivity of crops, pest detection, weather and land conditions, equipment productivity and operations, yield optimization, governmental requirements, among several advantages. During the next years, the industry will see a peak in providers of “smart” solutions in the market; thus Valtra can benefit from its know-how and expertise in the field for developing ‘smart” products and services customized to farmers’ needs.

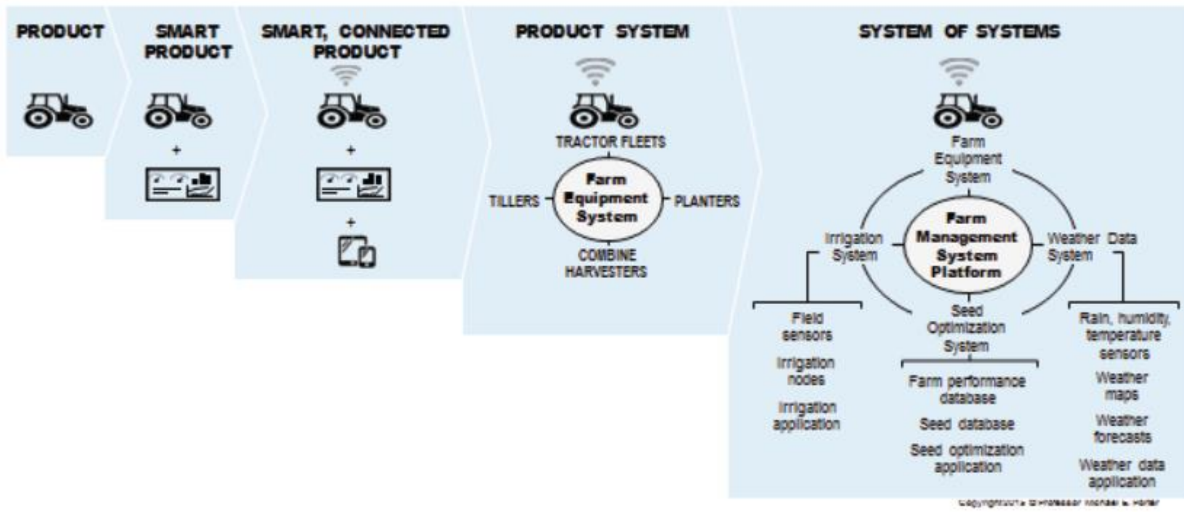

Figure 17. From "Smart tractor" to a System-of Systems. (Porter et al. 2015, p. 5)

Valtra already offers to its costumers Smart Services through the technologies developed by the AGCO group. AGCO Fuse™ Technologies (Valtra 2016), offer high-tech solutions to make tractors smart, connected products. According to Valtra (2016), the catalog of current Smart Services are classified in three main areas: (1) Autonomous steering system uses GPS and other geolocation data that allows the tractor to follow a predefined route while farmer focus on the implement. (2) Implement control systems transmits information to the tractor and viceversa, allowing farmers to observe through a virtual terminal what is happening on implement's operation. (3) Telemetry systems using GPS technology for tracking tractor location, area worked, productivity among other indicators.
It is important to mention that the current AGCO technologies employ geolocation-based services, some of them not connected to the internet (Internet of Things). Thus, the opportunities for developing Smart Services such as remote monitoring, remote diagnosis, predictive maintenance, operation recommendations, real-time simulations, among other services are identifiable. This study will present a framework for developing Smart Services from the customer-user point of view through the employment of Customer Needs Assessment tools.

The objective of this research is to identify and analyze the value partners' needs concerning the information provided by CPSs and suggest possible ISPS2 that Valtra can implement with their customers to increase value creation in MOL phases. The following subchapters will present a general description of Valtra's value chain, the methodologies employed to collect and assess information needs, and the recommendations proposed concerning the service-oriented business models that Valtra can use with "Smart Devices" and CPSs in the Internet of Things.

6.1 Introduction to Tractor Company's value chain

Given the Valtra's mission of "Supporting professional farmers and feed the world", one of the main concerns of the company is to increase product traceability along all the links of the value chain. In this case, the product in question is food produced in the farming industry, representing directly and indirectly all the food that people consume every day for survival. Put simply, Valtra's interest is to identify the requirements of every stakeholder within the value chain. The aim is to pick value starting from the last food consumer, going backward through markets, government, food industry, farmers, until reaching company's processes. Figure 18 shows a representation of the food value chain described by representatives of Valtra. It also shows the value feedbacks aimed from the final consumer all the way to the first farming suppliers.

According to Giovannetti and Marvasi (2016), the agri-food value chain is one of the most complex value chains in the industry. That means that it is composed of complex and long chains of producers, retailers, and distributors which make the product (food) reaches the final consumer. It is important to mention that non-productive participants are also involved, such as governmental and regulatory organizations, as well as financial and banking institutions. In addition, due to increasing globalized markets, the agri-food chain has more international participants, making it a complex network of global value partners coordinated each other to feed populations.

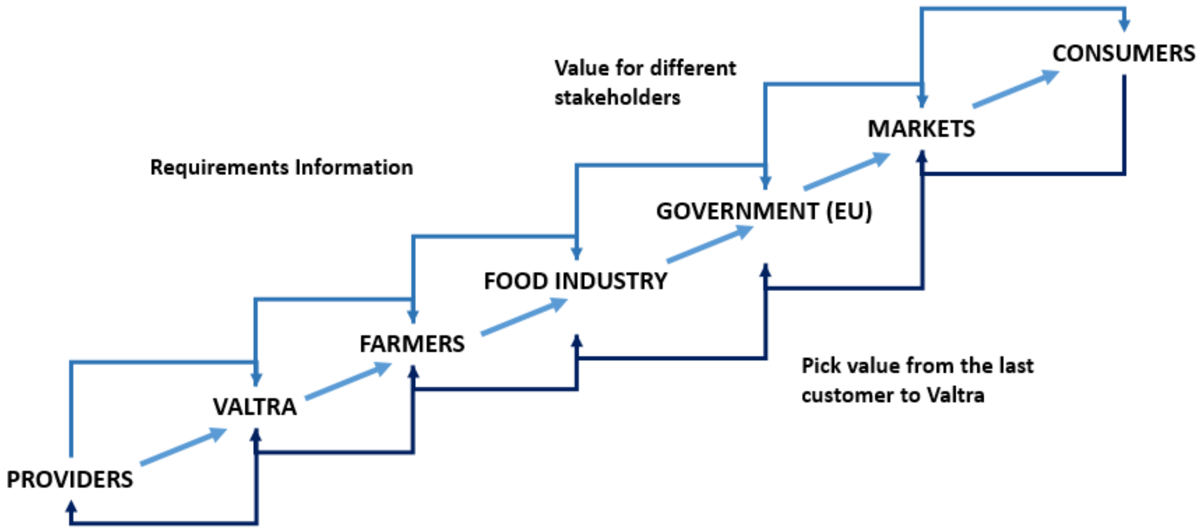

Figure 18. Agri-food value chain and value capturing in Valtra. (Piippo, 2016)

The agri-food value chain described by Giovannetti and Marvasi (2016) matches in many ways the value chain proposed by Valtra. The authors present the value chain starting from the inputs suppliers, such as seeds and chemicals; following by machinery and farming, which are the areas of interest of this study; to finalize with processing, distribution and other services related to the food industry. They also claim that the vast majority of the value added is produced on the first links of the agri-food value chain, from which Valtra forms part. Corroborating the particular interest of the case company of participating actively in identifying relevant information from different stakeholders regarding customer needs and requirements. Because once identified the value drivers for various participants, Valtra will not only have the means to improve their products and services but will be able to provide valuable information to the rest of the members of the value chain, creating more opportunities for partnering and create networked value.

The following section will present the development of a methodology to identify and assess customer information needs and requirements within the agri-food value chain. That is to say, to determine what are the main data and information demands to accomplish customer goals using insights obtained from data analyzed, specifically through the Internet of Things, Data and Services. Due to the scope of this research, the analysis will cover uniquely the information needs in the Farmers link of the agri-food value chain. Moreover, the research emphasizes in information requirements of delivery, service, support, repair and maintain of the product lifecycle (MOL) from farmer's point of view.

6.2 Customer Needs Assessment process

The methodology for carrying out the customer needs analysis was through the use of Customer Needs Assessment tools developed by (Kärkkäinen et al. 2004). As described in Section 5.2, the tools employed for the case company were One-On-One Interview, Trace Matrix and Need Interpretation Table. The election of such tools is due to their suitability for this research purposes. Moreover, are the ones that do not require large teams and a broad understanding of company's processes. On the contrary, they allow analysts to obtain valuable results with a limited amount of information gathered from the company of study.

6.2.1 One-On-One Interview

The method to collect information from the case company was the One-On-One interview. Two interviews were made to key personnel of Valtra. The first interview conducted to Petteri Piippo, IT manager from Engineering department. The second interview was made to Juha Tuikkanen, Project Manager for both Engineering and IT departments. During the first interview Petteri Piippo, the person in charge of PLM systems and strategies, described the company's value chain, customer segments, services, delivery, product usage, among other process information necessary to have a general understanding of the current situation. This preliminary step represents the beginning of the customer needs assessment process. Petteri also described their strategies towards IoT services in agricultural value chain, as well as the current technologies employed to deliver remote monitoring, predictive maintenance, and other potential areas of application of the Internet of Things, Data and Services.

As described by the interviewees, Valtra is interested on developing customized IoT services to their customers, as they do with their tractor customization. The company wants to obtain the most value from customers using its tractors. Thus, they are aware that the Internet of Things will bring opportunities for tracking and monitoring the product and its environment through the whole lifecycle. Marketing department is in charge of collecting information from customer feedbacks, for later identifying needs and further solutions to meet such requirements. The department is considered the main driver for communicating effectively the value propositions of the company's products and services, including the so called "Smart Services".

Juha Tuikkanen is currently participating in the development of "Smart Services" within the company. He is working together with farmers to develop services according to their needs. Juha described and presented the services that are currently in initial phases, as well as the platform they are utilizing to monitor tractor usage in certain areas of the continent. In addition, it turns out that Juha is also a farmer and he has utilized Valtra tractors in his farm. For this reason, he was asked to respond to another interview, now taking both roles as company employee and a tractor customer. This opportunity allows us to identify customer activities and demands, in this case, the information customer needs from farmer point of view. The main goal of a One-On-One Interview.

The second interview covered the opportunity areas that farmers perceive with the Internet of Things. Juha Tuikkanen responded the questions from the farmer's point of view at the beginning of the interview. After some questions, the interview focused towards an internal approach. Terminated both interviews with Vatra's employees, the main highlights identified for the development of this study are:

1) Collect information from customer product usage, conditions, maintenance, safety, productivity and service. Obtain real-time feedback information to increase productivity, reduce costs and improve product development. Nowadays, most of the times the dealers collect the information through interviews, surveys, and talks with the customers, and then stored and analyzed in their Early Warning System (EWS) system.
2) Tracking information from the tractor implements to create a whole farm equipment system connected to the tractor as well (seeding, harvesting, planting devices). Currently, they have

monitors that display basic information of implement operation and component condition. The system works in a local system, but not connected to the Internet.

3) Tracking work plans, progresses, amount of chemicals used, amount of fertilizer. Currently, paperwork is made by operators, causing time expenses and inaccuracy of information. In addition, the documentation is also a requirement from the EU.
4) Everyday check-in maintenance – Smart tracking could monitor which tractors are not receiving appropriate maintenance and check-ins
5) Given the fact that a large part of farmers is not ready for the technologies presented in the Internet of Things, Data, and Services era. It is challenging to train customers in using such technologies and showing them the value obtained from the data and information generated. Using simulation tools to train and raise awareness of the benefits of IoT services.
6) Interconnectivity with other farm management systems. Connecting the tractor with other IoT solutions such as irrigation, seed optimization and weather systems can leverage the optimization of operations, representing opportunities for partnerships and networked value creation.

Through the following two sections, this study will utilize the information gathered through interviews to develop the Customer Needs Assessment in the case company. The following tools will determine the information requirements which CPSs in the Internet of Things can meet for different product lifecycle phases. Once assessing such needs, it can be possible to determine the objectives for new service development and business models, as well as defining their scope.

6.2.2 Trace Matrix

As described before, the Trace Matrix tool assess needs from various groups of interest and their interactions. In this case, the Agri-food value chain described in Figure 19. However, due to scope concerns, this study will not include the assessment of all the interest groups presented in the value chain. Instead, the study shows the information demands originated from farmers to Valtra and also the critical information that the company can collect from farmers for product and service improvements and developments. Put simply, both parties are benefited from the data interactions and feedbacks between each other.

For Trace Matrix elaboration, it is necessary to collect customer information from One-On-One interviews. In addition, Table 1 and Table 2 of the theoretical background related to forward and backward information flows of the product lifecycle, will be taken as a reference to complement the case study. The structure of the Trace Matrix consists in placing requirements set by the interest group on another interest group (outputs) registering them in a horizontal line, on which the interest group making the requirement is recorded. While input requirements are registered in the vertical column, which is the object of the requirement. Figure 19 describes the mentioned inputs and outputs in a graphical representation.

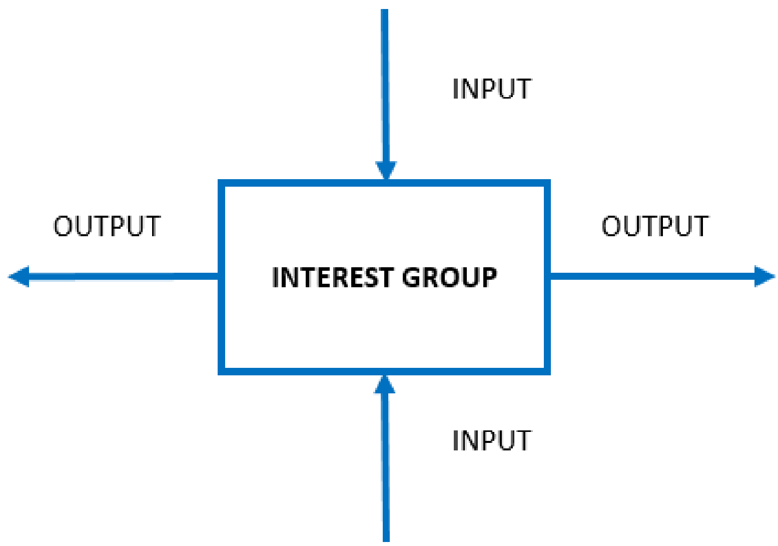

Figure 19. The meaning of horizontal lines and columns. (Kärkkäinen et al. 2004, p. 57)

The Trace Matrix developed in this study identified several aspects to be considered in the recommendations for service development phases. From the farmers' point of view, it is important to connect their tractors and implements to their environment (crops) through the Internet, from the fact that they are interested in performing optimal operations and save the most amount of resources (seeds, fertilizers, chemicals) possible. They have a particular interest in having valuable information regarding the processes made by different implements, as well as their conditions. Farmers also put particular emphasis on obtaining the everyday working plan based on data analyzed from previous work shifts. Finally, farmers desire to keep their equipment working the most number of hours, avoiding repairing times when breakdowns occur, thus receiving failure predictions for components will add considerable value to their operations.

Concerning Valtra, the valuable information that the company can collect is related to measurements of product usage and support phases. The information that can contribute to product and service improvements is linked to minimize failure rates by monitoring component conditions. If a component fails, the most valuable information to obtain is the root cause, in this way the company can focus its efforts on individual issues. Valtra could also be interested in collecting usage time and conditions, such as average temperature, humidity, and pressure of operation. In Figure 20, it is presented the Trace Matrix for the case company.

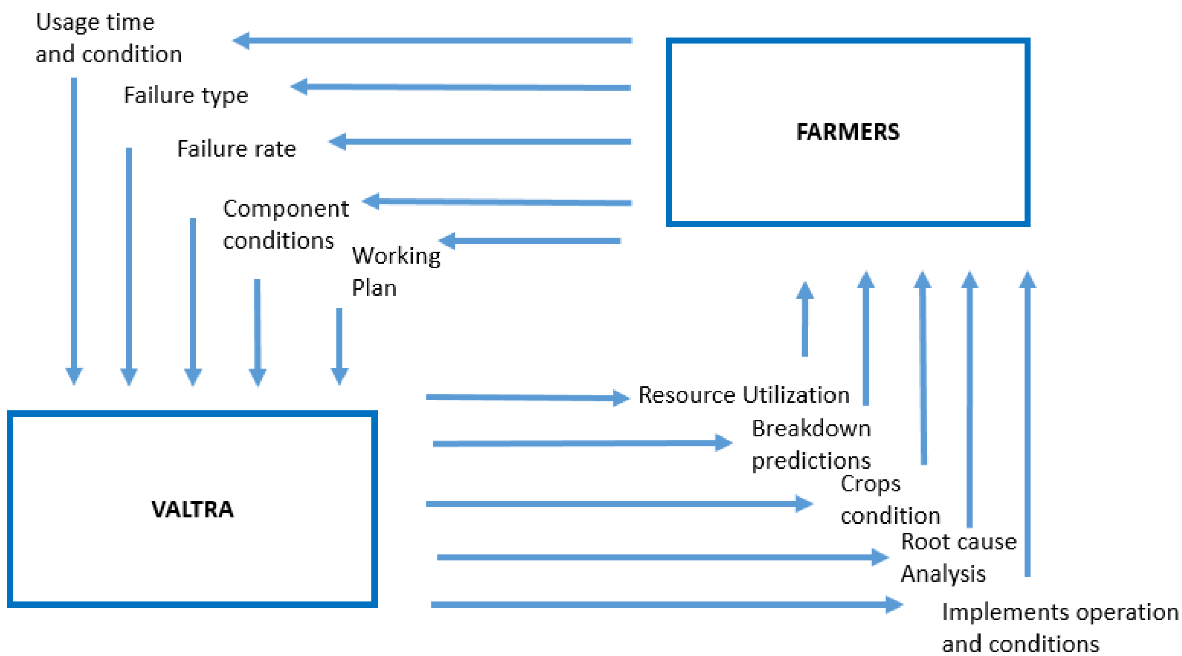

Figure 20. Trace Matrix for Valtra and Farmers information needs

As observed in Figure 20, most of the information required from customers is related to the optimization of operations and resources. Meaning that farmers are demanding valuable information that allows them to produce the maximum outcome (yield per acre) with the lowest income (fuel, chemicals, seeds, paperwork, time). Nowadays farming operators spend time on non-value-added and bureaucratic activities, such as the paperwork needed for governmental requirements and internal control processes. Farmers are searching for solutions which allow them to focus on their core operations and being more productive. This productivity can nowadays be reached through the actions performed based on information analyzed with the "smart" devices in the Internet of Things.

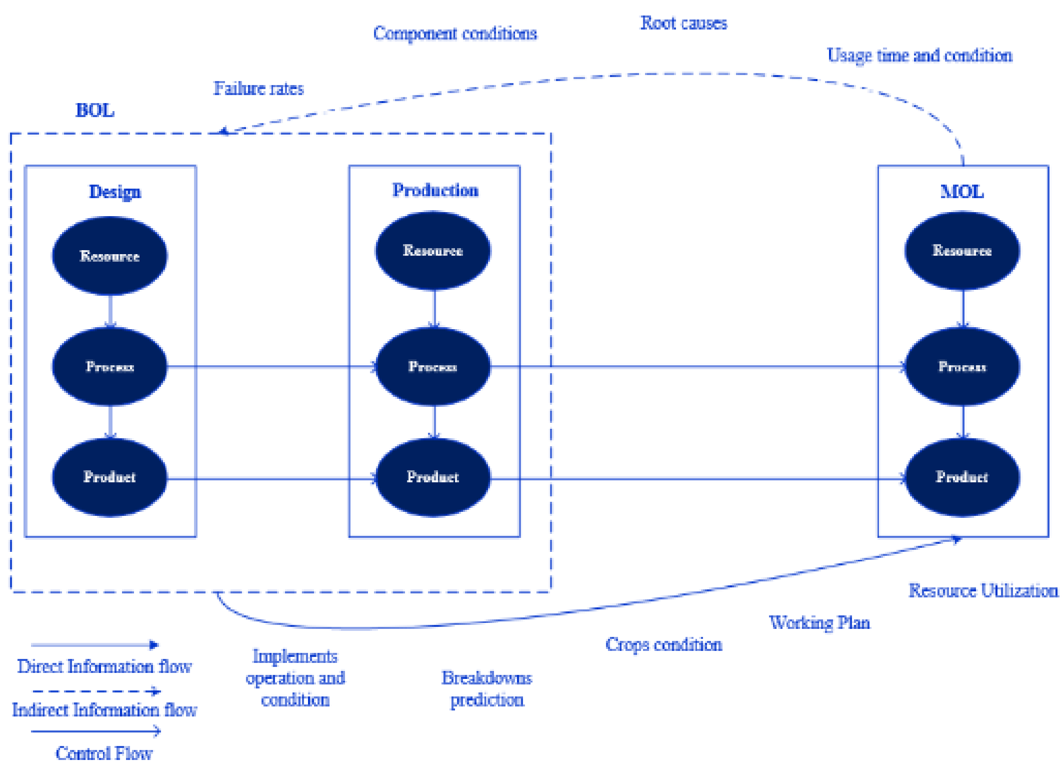

Figure 21. Trace matrix represented in a closed-loop lifecycle

According to Chapter 2, we can affirm that the information flows generated from farmers' MOL phases using the tractors, will provide valuable insights to BOL processes in Valtra for product and service development. While the information created by the company's technologies from BOL phases, will create value for farmers' MOL processes during the farming activities. Having as a result the described closed loop product lifecycles, in this case between BOL and MOL phases. The following tool used for this study will describe and analyze in detail the customer needs and requirements from both Valtra and farmers point of view. Once the Customer Needs Assessment process is done, the following phases will cover the recommendations of potential solutions for “Smart Services” leveraged by the Internet of Things. Figure 21 shows how the trace matrix can be represented in a closed-loop lifecycle diagram, showing the forward and backward (feedbacks) information flows between different phases of product lifecycle.

6.2.3 Need Interpretation Table

The main advantage of the Need Interpretation Table is its capability of identifying and analyzing the “voice” of customer. In several occasions, customers don’t know what they exactly need. Therefore, this tool covers the whole demands, beliefs, wishes, attitudes, strategies, values, behaviors, among other factors which influence their requirements. It also analyzes the causes of why certain customers are demanding particular products, services or information. Moreover, it expresses to suppliers the customer needs that normally are too obvious for both parts, but are not analyzed and communicated on an effective way to suppliers. Finally, through the correct use of the tool, analyzers can identify new needs and requirements previously collected from the One-On-One Interview. In this case, new needs regarding information from use, maintenance and support processes performed with farming equipment and systems.

The procedure followed to complete the analysis was the following. First, the “voice” of customer is recorded exactly as the customer expressed the issue, or at least very similar from the issue collected in the interview. Second, the issues expressed were interpreted for need identification by positioning from the customer point of view. Third, the needs identified were hierarchized and classified according to their category and level of importance. Hierarchy levels for this analysis are represented by hyphens assigned for the headline levels and asterisks for the intermediate and lower levels. Fourth, the identification of needs detailed parameters, which make customers selecting determined suppliers. It means starting from general perspective of the levels and hierarchy of needs, to the particular perspective for describing the details in which suppliers can have an influence. Normally, “Why?” and “How?” questions are made to get deeply into fine points, having a better understanding of the current situation. Fifth, potential solutions, product attributes or other conclusions are proposed for meeting customer needs. They should be written in the last column of the table, named commonly “Comments” column. Finally, the results are documented and presented to the interested parts. In Table 11, it is represented the Need Interpretation table, its parts and the main point to solve in every column.

Table 10. Need Interpretation Table. (Kärkkäinen et al. 2004, p. 63)

Voice of customer	**Customer need**	**Comparison criteria for suppliers**	**Comments**
What has the customer said?	What deeper need exists behind the words?	What are the detailed needs or factors derived from needs like, which the customers uses for comparing suppliers?	What product attributes or concrete solutions can be used to fulfill these needs?

The information collected through the two One-On-One interviews made in the case company was used for elaborating the Need Interpretation Table in this study. The procedure done for this analysis was guided by the steps described previously. It is important to clarify that both Valtra and farmers play the role of customer-supplier regarding backward and forward information flows. As described on Trace Matrix, Valtra supplies information to farmers and vice versa. Therefore, a Need Interpretation Table will be applied for each participant of the value chain. On one hand, there are the farmers, direct customers who require services and information that allow them to maximize productivity, save time and optimize resources in the most sustainable way. On the other hand, there is Valtra, which demands from farmers’ feedback regarding the product behavior and interactions with users, as well as the product interaction with its environment, in this case, farms.

The process followed to create the table for both farmers and Valtra was the following. First, the “voice” of customer was recorded according to the main insights obtained from the interviews. Second, the “voice” of farmers was interpreted to describe punctual information needs in their farming processes. Third, all the needs were classified into categories according to different processes and priority. Lowest levels of hierarchy define the specific need of the customer. Fourth, measurable parameters are defined from a qualitative perspective, i.e. defining the “hows”, utilizing words such as high, low, cheap, maximize, minimize, personalized, customized, large, etc. Fifth, lowest levels parameters are considered the attributes influenced by suppliers. For this research, it was considered the particular information needs. Finally, potential solutions, service attributes and comments are described for meeting particular customer needs. Should be noted that a broader description of potential solutions will be described within the next section. However, the conclusions obtained from the Customer Needs Assessment will provide the grounds for proposing service solutions leveraged by CPSs in the Internet of Things. Table 12 and Table 13 present the Need Interpretation Table analysis for Valtra and farmers respectively.

Several interesting insights were obtained through the Customer Need Assessment analysis for both farmers and company. More information needs were identified when creating the Need Interpretation Table, complementing the ones described in the Trace Matrix. As already mentioned, outputs resulted from one of the parts represents the inputs for the other. Put simply, Valtra needs the information generated from farmers’ operations for product and service developments, while farmers need information generated from Valtra’s technologies to increase productivity and reduce costs. This virtuous circle can be interpreted as a closed-loop cycle, where processes in the MOL provide feedback to BOL phases and vice versa.

Table 11. Need Interpretation Table for Valtra

Voice of customer	**Customer need**	**Comparison criteria for suppliers (Data and information needs)**	**Comments**
Provide to customers an outstanding after sales service.	1 High-quality support. * Fast and accurate diagnostic. *Whole system availability for tractor operation. *Responsive repairs and maintenance. 2 Customized service. *Personalized solutions.	**Operation monitoring data. **Real-time demand tracking. ** Failures and component conditions. ** Database from customer records.	Remote monitoring of farmers' operations. Predict events for triggering on-time support. Customized recommendations according to customers' historical events.
Agile and flexible response to customers' requests	3 Higher customer satisfaction. *Lower product-service development times and costs. *Higher flexibility to market changes.	** Data from customer processes and user behavior.	Test new products and services in early development stages.
Customers are not ready for the technology of remote monitoring	4 Consumer awareness *Higher perceived value.	**Customers' KPIs tracking.	KPIs and outcome improvements
EU is increasing emission control regulations.	5 Meeting ecological requirements. *Optimize oil consumption. *Reduce gas emissions.	**Track gas emission from tractors **Track tractor handling practices.	Optimal handling guidance for oil optimization. Maintenance and check-in practices to reduce gas emissions.
Conditions of the tractor usage may vary depending on geographical zone	6 Reliability of data * Accuracy of data collected from tractor usage in different locations	**Track product and environment measurements in different geographic zones (Humidity, weather, component wear)	Customized operating optimization according to geographical zone.

Table 12. Need Interpretation Table for farmers

Voice of customer	**Customer need**	**Comparison criteria for suppliers**	**Comments**
Farmers need to know what is happening in the tractor implements	1 Implement Integration. *Improve customer experience from tractors. *Obtain information from different farming processes.	** Track implement operation and interaction with environment.	Remote monitoring of implement operations. Synchronization with farming environment.
Paperwork for making work plans and resource consumption reports takes too much time.	2 Higher productive time *Efficient work plan elaboration 3 Resource reporting *EU requirements *Resource consumption control 4 Resource optimization *Reduce inputs *Reduce operative costs	*Register work shift progress. **Collect resource consumption records. **Identify areas which require resource application. **Track real-time resource consumption.	Automatic work plan generator. Resource consumption reports. Resource consumption optimizer.
It may happen that operators are not doing the daily check-ins in an appropriate way or even avoiding check-in.	5 Reliable operation *Adequate check-ins and maintenance *Verify completed check-ins	**Monitoring fluid levels **Track check-in procedures	Alert system to tractor owners. Check-in remote trainer for operators.
Nordic countries do not have much time for agriculture.	6 Alternative uses *Seasonal operability *Environment conditions	**Weather forecasts **Tracking crop conditions *Seed data base	Optimization system according to environmental conditions for precise agriculture.

It would be interesting to observe the customer's customers needs in order to provide them solutions according to their goals. Even though Valtra's and farmers' needs do not coincide, both of them are benefited from each other information interaction. Valtra by increasing sales to farmers, and farmers by optimizing production and reducing costs.

6.3 From customer needs to service development

In previous sections, three Customer Need Assessment tools were applied to identify and analyze information needs between Valtra and farmers. Moreover, the relation between customer needs and service development was described as well. Therefore, this section will focus on describing the "Smart" services that Valtra can employ based on the needs identified on the Customer Needs Assessment analysis. Then, selecting the business models and Smart Services suitable to meet those customer needs. All referred on the theoretical background. As mentioned on chapter 3, for designing and developing services, it is firstly necessary to understand and assess customer requirements (Reim et al., 2015). Therefore, once employed the tools for obtaining information-based needs, the following step is to identify the most suitable "smart" solutions that Valtra can leverage to create value to customers.

As previously mentioned, there are circumstances where manufacturing companies can have Smart Solutions already on the market. However, there is always the concern of improving process continuously, thus obtaining analyzed data in form of information and insight can contribute to the development of new and better services. This is the case of the following study company, a technology-driven tractor manufacturer with already developed Smart Technologies and Simulation tools in its portfolio. The company is interested on leveraging the Internet of Things for increasing food traceability in the whole chain and improve customer service through the new technologies.

This study will employ the described Smart Service development framework for the case company, more specifically, the framework employed for companies which develop Smart Services for the first time. Although the study company is already using analyzed data for service improvement, the scope of this study will only cover the customers' information needs obtained from the Customer Needs Assessment tools. Further research could focus on combining both information obtained from real-process and simulations, and Customer Needs Assessment tools (Figure 13). In Figure 22, it is represented an example of the process followed for selecting a Smart Service based on the described Smart Service development framework.

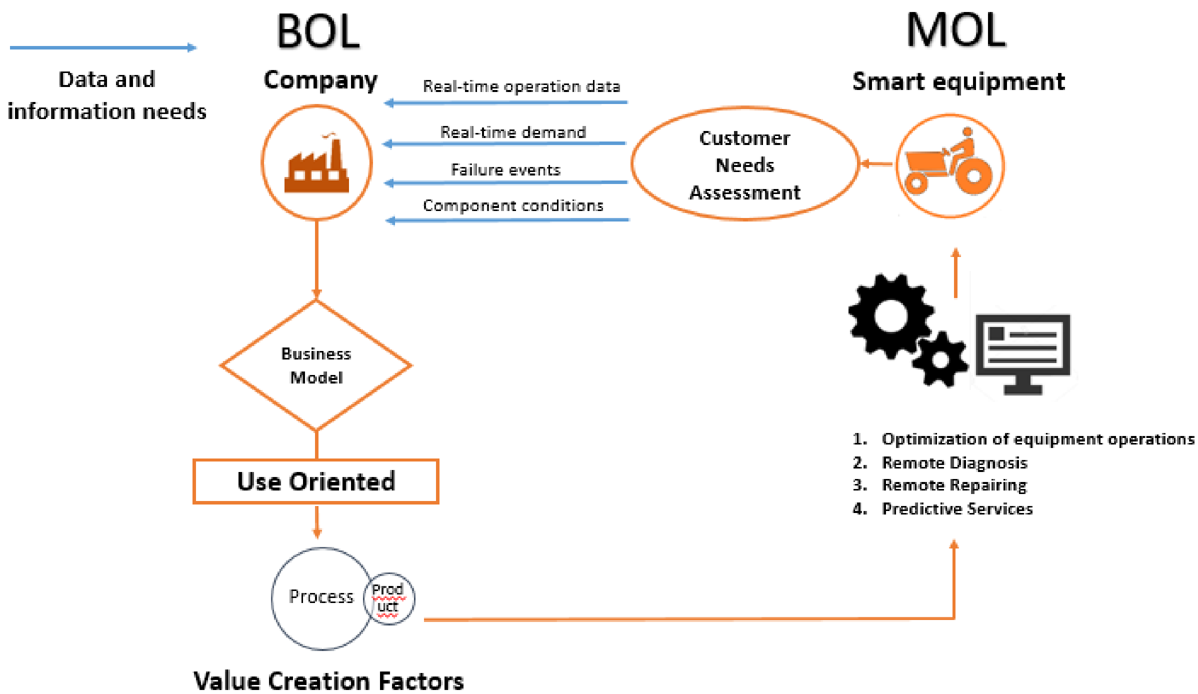

Figure 22. Smart Service development framework applied on company case

Although the "Voice-of-customer" is essential for developing Smart Services, it is important to mention that many times customers do not even know what their needs are and what they are expecting from certain solutions. For this reason, the analyzed-data from customer processes by Smart Devices could allow manufacturers to really understand what is happening on the work-place and then have a more solid base for developing further Smart Services. Moreover, the integration of Simulation-based technologies on early development process could allow manufacturers to replicate real-life operations without the cost of producing prototypes and the time invested to carry out the process.

7 DISCUSSION AND RECOMMENDATIONS

Taking as a reference the presented framework of this study, during the next lines, it is presented a list of recommendations for the target company on how it can leverage the Internet of Things for developing digital services from customer needs. The process followed starts from the identification of an actual need from the customer, previously seen on the Need Interpretation Table. After the voice of customer is understood, the analysis begins with the representation of the customer requirements in terms of information needs. Once identified such needs, the analyst evaluates and selects the most suitable business model and value creation factors. The selection depends on whether the customer issue relies on the product, process, human, organization, or equipment. It is important to mention that the selected business model matches with the customer goals and strategies. Finally, the selection of the Smart Service is conducted. In this study case, the selection of the Smart Services (Table 10). The customer can decide the services to select depending on the impacts, implications, goals, stakeholders involved and strategies.

Although this study identified eleven needs from both the target company and its customers. It will be considered the most relevant and specific needs for potential services. The rest of the needs and suggested services can be reviewed through the Appendix 2. The following tables describe and explain the Smart Services selected from certain information needs, as well as the value creation factors involved and the business model to adopt. Finally, a list of impacts and implications of selecting such Smart Services are presented in order to facilitate the identification of the benefits and risks incurred on implementing such services.

Information needs and Smart Services from Valtra's point of view

The first recommendations are based on the needs identified from the interviews made to the company's representatives. Their main concerns rely on the customer satisfaction in terms of quality of information they receive from Smart Services, as well as the top-level support they want to provide to their customers in order to maximize tractor operations. In addition, the company is also concern on reducing equipment gas emission and energy consumption. Taking these needs into consideration, the following suggested Smart Services will focus on providing solutions that allow the company to offer more reliable data regarding tractor environments and reducing oil consumption and gas emissions.

One of the main concerns from most of the organizations nowadays is related to sustainability and ecological issues. For Valtra this topic is not the exception, since they produce equipment which produce CO^2 and other gas emissions. EU and other organisms are turning strict on these matters, imposing more regulations to several industries. In addition, there is the concern of optimizing fuel consumption in the entire equipment and automobile industry.

The Smart Services which can contribute to meet these needs are those able to ensure the optimal performance of the tractor through the proper check-ins and maintenance. As shown Table 14, tracking component conditions and historic data will facilitate the identification of the tractors that are not receiving proper maintenance. Therefore, Valtra might have the possibility to send alerts and recommendations to the customers that are not providing proper maintenance and routine checks to their equipment. The second service aims to reduce fuel consumption, thus a Smart Service able to track driving practices and send recommendations to user based on those practice could add value to customers.

Even though the benefits of monitoring maintenance practices and tractor handling practices for further gas emission and oil consumption are enormous, it is required an important investment on retrofitting the tractors which do not count with the proper sensors and systems. Farmer who own older tractors may consider this investment, given that older equipment usually emits more gas emission, consume more oil and require more detailed maintenance and checks.

Table 13. Smart Services for reducing gas emissions and fuel consumption

Customer need: Meeting EU emission control requirements and reduce gas emissions	
Information needs:	• Track gas emissions data from tractors • Track tractor handling behavior data • Track maintenance and check-in data
Potential "Smart Services"	• Optimization of maintenance and check-in operations: Recommendation system based on historical data and component conditions. • Optimization of tractor handling practices: Customized driving guidance to reduce fuel consumption.
Business Model:	Product-oriented
Value creation factors:	Equipment
Impacts	• Reduce gas emissions • Meet EU regulations for gas emissions • Reduce oil consumption
Implications	• Investments on retrofitting (upgrading old equipment with sensors and new systems) • Technology infrastructure costs

One of the main challenges for the target company is to monitor tractor usage in several geographical conditions. Weather, humidity, land condition, height, among other factors can affect and distort the data received from tractor usage. For this reason, a combination of Smart Services can be the solution for this issue. As shown in Table 15, combining tractor smart system together with other agricultural smart services, such as irrigation, weather and seed optimization systems could improve considerably the quality of data received from tractor on different geographical conditions. When all Smart Systems work all together, the tractor will be able to analyze the data of its environment and make better decisions based on the physical conditions on the crops.

Table 14. Smart Services for increasing data reliability on different geographical conditions

Customer need: Increase accuracy of data when conditions of tractor usage vary depending geographical locations.	
Information needs:	• Track environment condition data (Humidity, temperature, soil chemicals) • Track interactions between tractor and farm elements
Potential "Smart Services"	• Weather system service: Weather predictions and weather maps • Seed optimization system: Optimize seeding according to physical conditions • Irrigation systems: Trigger irrigation when crops need it • Remote control and management: Functionality of equipment can be controlled manually via remote service centers. • Customized recommendations: Suggestions for farmers based on geographical conditions • Real-time simulations: Simulate physical conditions and diverse geographical conditions for improving customer product usage.
Business Model:	Use-oriented
Value creation factors:	Product and process
Impacts	• System-of-Systems "smart" integration with other farming systems and technologies • Resource optimization • High level of farming automation • Less physical work required • Higher flexibility and response • Crop yield optimization
Implications	• High technology investments • Challenges on interface integration with other systems • Complex communication infrastructure • Investment on remote service staff and equipment

Combining different farming systems into one System-of-Systems require the collaboration with suppliers of such services. The collaboration goes beyond sharing data from each system, it requires a high-level of coordination and system interoperability, to create a one-single Farm Management System Platform as presented on Figure 18. In the coming years, the creation of partnerships among different farm management systems will be more common within the industry. Therefore, it would represent an important strategy for the company to create platforms for the value co-creation with different players. In this way, Valtra and its partners could gain a competitive advantage able to retain customer loyalty.

Simulation plays an important role on cases where the main concern is the uncertainty of variables dependent on both external and internal factors. Diversity of geographical and weather conditions is one of the main challenges for the case company in monitoring product behavior. For this reason, simulating different physical conditions and environments where the tractor can operate, could represent and opportunity to develop customized solutions for diverse workplace locations where Valtra has customers. Using simulators in different geographical locations can also improve operators' skills and qualifications. They can receive trainings in simulated environments, setting uncommon and hazardous situations that could be expensive and risky to perform in real life.

Information needs and Smart Services from Farmer's point of view

The second group of need and Smart Service recommendations were based on the opinions of a current farmer, which has been using the company's tractor for several years. The main concerns of the famer were related to reduce farming supplies and making easier the paperwork he needs to do to report resource consumption for EU requirements and owners control. In addition, farmers wish to receive valuable information of the tractor using different implements in real time. In few words, farmer's goal is to increase productivity and crop yield when using the equipment. Taking such needs into consideration, the recommended Smart Services from farmers' point of view.

One of the main concerns from the farmers' point of view is to perform and optimal work with every implement they use in their tractors. Using embedded technologies to the implements and connect them to the tractor and the whole environment could improve farmers' operations and crop yields. As shown in Table 16, several Smart Services can be implemented, such as remote monitoring of components for triggering maintenances, optimization of operations based on historic product usage data, remote diagnosis in case of breakdowns, even remote operation through a highly automated solution, among other services that can leverage operation outcomes.

Table 15. Smart Services for optimizing tractor-implement operations

Customer need: Farmers need implement integration with tractors	
Information needs:	• Track implement operation data • Track remote failure events • Track component condition
Potential "Smart Services"	• Product System: Highly integrated tractor with implements for optimal operations. • Optimization of equipment operations: Implement operation optimized based on historic operation data. • Remote diagnosis: Diagnosis accomplished remotely through remote service centers. • Remote repairing: Non-complex repairs made by remote service centers. • Predictive services: Trigger service activities based on current component condition. Anticipated spare part orders by forecasting real-time demands. • Real-time simulations: Simulate different tractor-implement operations for prototyping and testing purposes.
Business Model:	Product-oriented
Value creation factors:	Product and process
Impacts	• Highly integrated systems • Interoperability and synchronization between tractor and implements • Higher functionality and added value • Flexibility and response • Prevention of breakdown
Implications	• Technology investments • Development costs • Lack of system integration (APIs) • Customer adoption

As presented on previous Smart Service recommendations, the offer of these solutions can represent considerable investments from the company on development and marketing. However, if it is condidered the manufacturing trend shown in this study, Valtra can leverage its customer channels and expertise to switch from selling tangible products, into a service-oriented company.

Real-time simulation solutions can improve the user experience when using tractor together with its implement in question. Integrating tractor-implement operations into a simulated environment, could allow the company to observe and analyze data from interactions between the several implements that exist for different work purposes and the tractors. It will represent considerable savings on costs of prototyping, times on receiving customer feedback, as well as increasing certainty that the products and services offered are meeting customers' needs.

Agriculture operations are well known for having high cost of supplies. Farmers utilize certain number of chemicals and fertilizers to maintain the optimal condition of their crops. However, most of the times the resources are utilized in a preventive or reactive manner. Thus, farmers need to have accurate reports on how many resources they are utilizing every day. They also need to present reports on resource consumption to the corresponding authorities, in this case EU authorities. For this reason, Smart Services able to monitor real-time resource consumption, send reports to the correspondent authorities and even implementing automatic solutions for application of fertilizers, chemicals and pesticides could represent an added value service for the customers.

The Internet of Things, Data and Services represents several opportunities for manufacturing industries. In the particular case of the case company, they are participants of both manufacturing and agricultural industries, making it more interesting to develop customized Smart and Digital Services according to customer needs. It is important to mention that cooperation between value partners is essential for the development of Smart and Digital Services. Different members of the value chain have to agree on sharing data and information regarding their processes and resources. Otherwise, the development process for digital services would be useless.

Table 16. Smart Services for reducing farming inputs and generating reports

Customer need: Increase efficiency and reliability of resource consumption reports	
Information needs:	• Track real-time resource consumption (Fertilizer, chemicals, pesticides, etc) • Data from crop conditions • Record of historical consumptions
Potential "Smart Services"	• Resource consumption reports: Reporting system for EU paper requirements and internal control. • Resource consumption optimizer: Suggest optimal amount of resources to apply depending on current crop conditions. • Remote resource application: Automatic fertilizer, chemicals, water and pesticides with actuators.
Business Model:	Use-oriented
Value creation factors:	Process
Impacts	• Up to date resource consumption reports • Reliability of report information • Meet EU regulations • Resource optimization (Lower inputs) • Reduce manual labor work
Implications	• Interoperability with crop and other environment related systems • Technology and development investments

8 CONCLUSION

The fourth industrial revolution will bring new ways of doing business for manufacturing industry, with several business models, technologies, cooperations, services and so on. For this reason, the presented study had the purpose to conduct a literature-based research and empirical analysis to prove that Smart and Digital Services by the Internet of Things can improve product processes through the whole lifecycle, more specifically on the use, service and maintenance phases. Such improvements are represented in form of resource optimization, maximize efficiency of operations, reducing material and human risks, improve staff skills and qualification, and increase value-added tasks, among other benefits that increase value creation. At the end of the day, businesses are always looking for increasing profitability and higher economic outcomes, thus companies will need to cooperate each other to develop innovative business models based on Smart and Digital Services in the Internet of Things, if they want to compete in the current market.

Responding to the main research question on how to develop information-driven services for product lifecycle processes by the Internet of Things, it can be concluded that the framework developed for Smart Services from the identification of information needs, presents the initial basis for a more complex development methodology, where specific technologies and processes would be defined in the development process. Responding to the four sub-questions:
(1) PLM strategies and systems are responsible to create, manage and control product-related information through the whole lifecycle. Organizations utilize PLM to facilitate the information sharing and interactions between stakeholders. For this reason, we can say that PLM indeed contributes to the creation, management, and control of product-related information.
(2) The Internet of Things and other embedded technologies not only represent a cutting-edge innovation nowadays. It represents a whole industrial revolution where humans, machines, systems, processes, products among other "things" interact each other through connected networks, aiming the most efficient environment. The Internet of Things through sensors and other embedded technologies are able to trace and track product interactions and behavior through the lifecycle, analyze such information and report insights based on data analyzed.

(3) The Customer Needs Assessment tools provide the means for the proper identification of customer needs within several organizations. These tools possess the flexibility to adapt to different company sizes, resources available, people involved, time available and so on. One-On-One Interviews, Trace Matrix and Need Interpretation Table were effective tools for identifying customer information needs.
(4) The framework presented for developing Smart and Digital Services from customer needs responds to the final questions. As mentioned before, this study illustrates an initial process for Smart Engineering methodology following the four characteristics needed for developing effective methodologies. Although this study mentioned the current and most common Smart Services applied in the industry nowadays, there is always the possibility to innovate with a completely new service based on the benefits that the Internet of Things provide to organizations.

Although the presented framework illustrates an initial phase of a Smart Engineering process through the Customer Needs Assessment analysis and selection of business model, value creation and Smart Service suitable to the analyzed needs. Further research could focus on modeling the entire Smart Engineering methodology and process for the development of Smart and Digital services. Regarding the main concern of the case company, further research can focus on utilizing Smart Technologies and solutions to improve food traceability through the whole agri-food chain, aiming the production of valuable information to customers in all the links of the value chain, from the consumer to the tractor company (Closed-loop lifecycles).

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APPENDIX 1. CASE COMPANY INTERVIEW QUESTIONS

Interviews questions to Valtra's key personnel

I. Description of operational environment – Product-related services

1 What is the mission of Valtra?

2 How have you succeeded in your service activities?

3 What are your main customer segments?

4 How is your current after sales service process?

II. Data and information monitoring

5 What are the main parameters measured and tracked by Valtra's technologies?

6 What are the main opportunity areas of improvement of current technologies tracking and monitoring data and information?

III. The Internet of Things, Data and Services and "Smart Farming"

7 What is your opinion regarding the Internet of Things and "Smart Farming"?

8 What are the current IoT services that you offer or are currently developing?

9 In which customer processes do you see more possibilities to improve by IoT Services?

10 What are the main opportunities and challenges you identify in the Internet of Things, "Smart Services" and "Smart Farming"?

APPENDIX 2. INFORMATION NEEDS AND SMART SERVICES

Customer need: Meeting EU emission control requirements and reduce gas emissions	
Information needs:	• Track gas emissions data from tractors • Track tractor handling behavior data • Track maintenance and check-in data
Potential "Smart Services"	• Optimization of maintenance and check-in operations: Recommendation system based on historical data and component conditions. • Optimization of tractor handling practices: Customized driving guidance to reduce fuel consumption.
Business Model:	Product-oriented
Value creation factors:	Equipment
Impacts	• Reduce gas emissions • Meet EU regulations for gas emissions • Reduce oil consumption
Implications	• Investments on retrofitting (upgrading old equipment with sensors and new systems) • Technology infrastructure costs

Customer need: Increase accuracy of data when conditions of tractor usage vary depending geographical locations.	
Information needs:	• Track environment condition data (Humidity, temperature, soil chemicals) • Track interactions between tractor and farm elements
Potential "Smart Services"	• Weather system service: Weather predictions and weather maps • Seed optimization system: Optimize seeding according to physical conditions • Irrigation systems: Trigger irrigation when crops need it • Remote control and management: Functionality of equipment can be controlled manually via remote service centers. • Customized recommendations: Suggestions for farmers based on geographical conditions • Real-time simulations: Simulate physical conditions and diverse geographical conditions for improving customer product usage.
Business Model:	Use-oriented
Value creation factors:	Product and process

Impacts	• System-of-Systems "smart" integration with other farming systems and technologies • Resource optimization • High level of farming automation • Less physical work required • Higher flexibility and response • Crop yield optimization
Implications	• High technology investments • Challenges on interface integration with other systems • Complex communication infrastructure • Investment on remote service staff and equipment

Customer need: Customized services and recommendations	
Information needs:	• Monitor customer historical events
Potential "Smart Services"	• Personalized support service: Provide remote technical support according to customer's records, needs and goals. • Data analytics and recommendation system: Customized recommendations for better equipment practices based on previous product usage.
Business Model:	Product-oriented
Value creation factors:	Product and process
Impacts	• Leveraging productivity • Improve operational practices • Personalized marketing and sales based on data analytics • Meet and surpass customer specific needs
Implications	• Complex data analysis • Deep understanding of customers' processes • Value might not be perceived (service perceived as included on tractor's price) • Technology infrastructure investments

Customer need: Increase consumer awareness and perceived value on smart products in the Internet of Things	
Information needs:	• Identify and monitor farmers' KPIs and outcome goals

Potential "Smart Services"	• Functional and operational services: Offer to customers results or desired outcomes based on measurable benefits.
Business Model:	Result-Oriented
Value creation factors:	Organization
Impacts	• Improvements farmers' KPIs • Increase in customer's productivity and revenue • Increase perceived value • Payments by measurable results • Higher conversion rate on Valtra's sales
Implications	• Valtra is responsible for providing the technology and equipment needed • Farmers do not make initial investments • Complexity in contract agreements

Customer need: Provide high-quality support in after sales service	
Information needs:	• Monitor operation data • Real-time demand • Track remote failure events • Track component condition
Potential "Smart Services"	• Optimization of equipment operations: Tractor operation optimized based on historic operation data. • Remote diagnosis: Diagnosis accomplished remotely through remote service centers. • Remote repairing: Non-complex repairs made by remote service centers. • Predictive services: Trigger service activities based on current component condition. Anticipated spare part orders by forecasting real-time demands.
Business Model:	Use-Oriented
Value creation factors:	Process and product
Impacts	• Prevention of breakdowns • Operation optimization • Faster responsive support • Savings in diagnosis travels • Reduction of delivery times • Immediate repairs or faster technician dispatch depending on problems

Implications	• Cooperation between farmers and Valtra for data and information sharing • Technology infrastructure costs and limitations • Resistance to change • Investment on remote service staff and equipment

Customer need: Higher customer satisfaction and flexible response to customer requests	
Information needs:	• Monitor feedback data from product processes and user behavior
Potential "Smart Services"	• Simulation driven services: Create digital operational environments to test machinery in a virtual simulator. • Digital prototyping: Add specific features and functionalities to products in a digital platform for premature tests. • Operator training: Simulators and "smart" glasses for worker trainings through virtual reality and augmented reality solutions respectively. • Gamified solutions: Augmented reality games during farming processes to increase operator motivation. • Behavior and operation feedbacks for operator improvement: Recommendation and training system to guide workers towards better operation practices.
Business Model:	Use-Oriented
Value creation factors:	Human, product and process
Impacts	• Decrease product and service development costs • Allow customers to test products in early development stages • Reduce risks and accidents in workers and equipment • Increase worker skills and qualifications • Increase operator motivation • Train new staff on equipment operation
Implications	• Challenges to increase new technology awareness • Skepticism from farmers on technology benefits • Resistance from workers • High investments in equipment and software development • Increase sales force and marketing budgets

Customer need: Making the work plan elaboration more efficient

Information needs:	• Track and record work progress • Database from activities “to do” and resources
Potential “Smart Services”	• Automatic work plan generator: Generate work plans according to current progress and resources available. • Real-time project manager: Track the current progress, forecast potential delivery times based on historic data.
Business Model:	Use-oriented
Value creation factors:	Process
Impacts	• Save paperwork time to operators • Increase time for productive activities • Increase reliability of work plans • More accurate understanding on tasks “to be done” • Reports from work progresses and resources
Implications	• Investments on technology and development • Learning curves and training • Interoperability with current systems

Customer need: Adequate everyday check-ins and maintenances	
Information needs:	• Monitor fluid levels • Track check-in procedures and component condition
Potential “Smart Services”	• Alert system: Alert farmers and farm owners when tractor levels are not currently at the optimal level. • Remote recommendations: Suggest check-in better practices according to tractor usage.
Business Model:	Product-oriented
Value creation factors:	Equipment
Impacts	• Increase tractor lifetime • Better check-in and maintenance practices • Increase operability time • Immediate response to tractor’s levels anomalies
Implications	• Investments on retrofitting (upgrading old equipment with sensors and new systems)

Customer need: Alternative tractor uses according to weather conditions

Information needs:	• Weather forecasts • Track crop conditions • Seed and soil database
Potential "Smart Services"	• Optimization system: Suggest optimal farming activity according to weather and crop conditions.
Business Model:	Product-oriented
Value creation factors:	Product
Impacts	• Higher tractor usability for different seasons • Increase production throughout the whole year • Better land use • Reduce downtimes
Implications	• Integration with other farming management systems • Development costs and times • Challenges on customizing solutions (Different scenarios)

Customer need: Increase efficiency and reliability of resource consumption reports	
Information needs:	• Track real-time resource consumption (Fertilizer, chemicals, pesticides, etc) • Data from crop conditions • Record of historical consumptions
Potential "Smart Services"	• Resource consumption reports: Reporting system for EU paper requirements and internal control. • Resource consumption optimizer: Suggest optimal amount of resources to apply depending on current crop conditions. • Remote resource application: Automatic fertilizer, chemicals, water and pesticides with actuators.
Business Model:	Use-oriented
Value creation factors:	Process
Impacts	• Up to date resource consumption reports • Reliability of report information • Meet EU regulations • Resource optimization (Lower inputs) • Reduce manual labor work
Implications	• Interoperability with crop and other environment related systems • Technology and development investments

Customer need: Farmers need implement integration with tractors	
Information needs:	• Track implement operation data • Track remote failure events • Track component condition

Potential "Smart Services"	• Product System: Highly integrated tractor with implements for optimal operations. • Optimization of equipment operations: Implement operation optimized based on historic operation data. • Remote diagnosis: Diagnosis accomplished remotely through remote service centers. • Remote repairing: Non-complex repairs made by remote service centers. • Predictive services: Trigger service activities based on current component condition. Anticipated spare part orders by forecasting real-time demands. • Real-time simulations: Simulate different tractor-implement operations for prototyping and testing purposes.
Business Model:	Product-oriented
Value creation factors:	Product and process
Impacts	• Highly integrated systems • Interoperability and synchronization between tractor and implements • Higher functionality and added value • Flexibility and response • Prevention of breakdown
Implications	• Technology investments • Development costs • Lack of system integration (APIs) • Customer adoption