Value Co-Creation for Cyber-Physical Systems in Mining and Construction Industry

Full papers

Tuure Tuunanen
University of Jyväskylä
tuure@tuunanen.fi

Johanna Hänninen
University of Jyväskylä
johanna.hanninen@me.com

Tero Vartiainen
University of Vaasa
tvartiai@uva.fi

Abstract

This paper focuses on value co-creation in the context of cyber-physical systems (CPSs). We investigate how value is co-created in the mining and construction industry, where the intelligent equipment are examples of CPSs. We take an interpretive research approach and study a global corporation, which manufactures tools and equipment for the mining and construction industry. The data collection was done using the laddering technique (n=20) and for the analysis a thematic clustering approach was adopted. Our findings show how value is co-created in the use of intelligent equipment. More specifically, the findings indicate that the use and service experience related to intelligent equipment is important value driver in this context. Also the sharing and receiving information related to intelligent equipment use and operating environment are important. As a conclusion, the utilitarian values and goal-oriented perspective toward values were considered to be more relevant than the hedonic values.

Keywords: Value co-creation, cyber-physical systems, service experience, mining and construction

Introduction

The physical environment is increasingly becoming saturated with different entities capable of interaction with other entities and with people (Conti et al., 2012). The term cyber-physical systems (CPSs) describes the new generation of systems, which integrate the computational and physical capabilities and expand the capabilities of physical world entities through computation, communication and control (Baheti & Gill, 2011). Embedding computational systems into physical equipment provides additional intelligence for the equipment and transforms it into intelligent equipment (Broy, Cengarle & Geisberger, 2012). In this paper, our focus is on intelligent equipment, which we consider to be an example of CPSs. We define intelligent equipment in the mining industry as systems that gather data remotely, process the data and enable telemetry for control and monitoring purposes. Tightly integrated and coordinated processes between the cyber and the physical world provide integrated networking, information processing, sensing and actuation capabilities for intelligent equipment, which are important as there often are humans in the loop (Sztipanovits & Ying, 2013). According to Hovárth (2014), CPSs are reaching the point where they cease to be just technical systems, as they are constructed by various components, such as humans, equipment and other items and interact strongly with the human domain and the embedded environment.

A parallel to evolution with the CPSs is the shift of the marketing and business perspective from goods-dominant (G-D) logic to service-dominant (S-D) logic by Vargo & Lusch (2004), which emphasizes the role of service as the facilitator of value co-creation. S-D logic offers a complete and structured framework for exploring service-related phenomena (Vargo & Lusch, 2008). For the traditionally product-oriented manufacturers, adopting the service-centered perspective on business is challenging, as it changes the traditional view of the value chain and the linear value flow from raw material provider to manufacturer to supplier to customer (Basole & Rouse, 2008). Moreover, S-D logic views value as created through the network of resource integration and as including various different actors (Vargo et al., 2010a).

This study explores how value is co-created in the CPS environment, especially with intelligent equipment, where the value co-creation includes different horizontal and vertical actors, such as the original equipment manufacturers, third-party service providers and customers each contributing their core competencies to the value co-creation process (Gebauer, Paiola & Saccani, 2013). Unlike the traditional value chain thinking still the de facto way of thinking in mining and construction industry and especially with intelligent equipment, value co-creation is a constantly changing process, requiring adaptability from service providers to serve the value network and integrate resources (Vargo, Lusch & Tanniru, 2010). However, the literature has not offered specific frameworks or models for value co-creation for CPSs, especially from the point of view of the CPSs users. Thus, our research question is, *How is value co-created for cyber-physical systems in mining and construction industry and especially with intelligent equipment?*

Next, we elaborate on how value is created in CPSs. Then, the research method is described and results are reported. Finally, we discuss the implications of the study and conclude.

Value co-creation and cyber-physical systems

Vargo & Lusch (2004) challenged G-D logic by introducing S-D logic, which is considered to be the first comprehensive structured service-centered approach to value creation (Vargo et al., 2010a, Vargo & Lusch, 2004). The traditional G-D logic focuses on production and distribution of tangible products, which are embedded with utility. The products are measurable and exportable and exchanged for money when the ownership transfers to the buyer and the value emerges as the value-in-exchange. The value is created during the production and destroyed by customers (Vargo et al., 2010a, Vargo & Lusch 2004). S-D logic is considered to be a logic for integrating goods with services and considering that service, whether it includes goods or services or both, and is the basis of exchange. S-D logic also questions G-D logic's view of value and value creation by grounding its understanding of value in the value-in-use and to the approach of value co-creation (Vargo & Lusch, 2004). Grönroos (2011) has also argued that the service itself should be seen as the facilitator of value creation between different stakeholders.

The conception of the value creation process has also gone through a significant change. Prahaland and Ramaswamy (2004) conclude that the change challenges Porter's (1980) value chain, which makes a clear distinction between the roles of the firm and the customer as the producer and the consumer. However, as the focus of marketing turned toward services, the interactions between the customer and the firm enabling the co-creation of unique experience and the joint creation of value for both firm and the customer became the key concept. All interaction between the provider and the customer are considered as opportunities for value creation (Prahaland & Ramaswamy, 2004). The S-D logic focuses on creating a fundamental basis for the new way of thinking about the value creation. Grönroos and Gummerrus (2014) and Grönroos (2008) have later claimed that customers are value creators and thus the drivers of the value creation process itself. The firm, by preparing skills, knowledge and other resources, is consequently the facilitator by providing a potential platform for value co-creation.

Understanding the underlying factors of value co-creation has been, therefore, an important issue since the literature has embraced the S-D logic perspective. Jonsson et al. (2008) have studied value creation in construction industry. Jonsson et al. (2008) suggest that systems such as CPSs allow firms to enable value co-creation for and by its CPSs users. However, they do not suggest a specific framework or model for value co-creation of such systems. Tuunanen, Myers and Cassab (2010) have proposed such a framework for information technology enabled and digital services (see Figure 1). Tuunanen et al.'s (2010) consumer information systems (CIS) framework views value co-creation from the customer's perspective by emphasizing the system's role as the facilitator or platform for value co-creation. As value co-creation is seen as an outcome of joint processes between the service provider and the consumer, the framework integrates the system value propositions and the consumer value drivers. Furthermore, the framework is divided into two sections. The left side is formed by system value propositions and the right side by customer value drivers. The system value propositions are the social nature of use, construction of identities and context of use, which represent features of the system that enable value co-creation. The customer value drivers are participation in service production, service process experience and goals and outcomes indicating the values that are driving the user to co-create value. These six factors affecting value co-creation are rooted in IS, marketing and service research literature offering theoretical approaches to enable the handling of these factors in design and development.

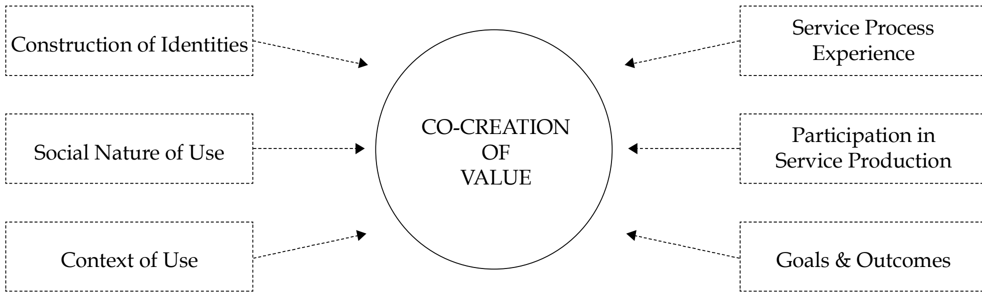

Figure 1. Framework for value co-creation in consumer information system (Tuunanen et al., 2010)

For manufacturing companies, shifting the focus of business toward a service-centered perspective requires managing the entire business from the service perspective. Grönroos and Helle (2010) argue that the basic problem of many product manufacturers is that their business logic is traditionally product oriented, and the service-centered approach is considered achievable by focusing on separate service activities. In practical terms, adopting the service-centered perspective on business would require that all the activities and processes of the manufacturer that are relevant to its customer's business are coordinated with the customer's corresponding activities and processes to form a stream of actions (Grönroos & Helle, 2010). Instead, in the traditionally product-oriented industry, the companies tend to add more features to the products or create new supporting services instead of reorientation around the customer's processes (Salonen, 2011).

The lack of understanding service and value co-creation in the manufacturing industry is evident even though there can be seen a clear shifting from goods-centered to service-centered strategy. The service revenues, regarding machinery and spare parts sales, have stayed at a marginal level. The reason for this is that the benefits for the manufacturer itself can be easily envisioned, but without the understanding of what the service phenomenon is, it is difficult to describe the benefits for the customer, which decreases the customer's willingness to buy (Laine et al., 2007). Grönroos and Helle (2010) argue that even though the evidence in support of adopting the service-centered perspective and gaining competitive advantage is clear, the majority of the research in the field of manufacturing studies service has a separate function, and only the strategy, management, marketing, innovation and relationships are studied from the service perspective. On the contrary, product management is often studied from the product-centered perspective (Grönroos & Helle, 2010).

The value for the customer and the value for the firm are usually understood as separate and non-interactive phenomena in manufacturing companies. However, the service-centered perspective involves both the customer and the service provider. The focus should be on the realized value-in-use for the customer, not the value at the point of sale (Grönroos & Helle, 2010). Adopting the service-centered perspective challenges the traditional view of the value chain and the linear value flow from the raw material provider to manufacturer to supplier to customer (Basole & Rouse, 2008). The S-D logic views the service provision as the outcome of internal and external resources, such as the employee-level knowledge and skills, and also includes the customers and other beneficiaries that contribute to value co-creation. The value is co-created through the network of resource integration and includes various different actors (Vargo et al., 2010a). As the service-centered perspective is more dependent on resources such as knowledge and skills, the organization adopting the service-centered perspective needs to broaden the perspective on value creation from selling services to co-creating value by supporting the customers' business. When service is adopted as a perspective on business, it is not a separate business function. Instead, service is a networked process and includes various actors, both from the service provider's and the customer's side, participating to the value co-creation process. In the network, the value is co-created by different horizontal and vertical actors, such as the original equipment manufacturers, third-party service providers and customers each contributing their core competencies to the value co-creation process.

Furthermore, the objects of the physical world are increasingly able to sense, communicate with and interact with the physical environment (Baheti & Gill, 2011), extending the intelligent capabilities of systems. The fundamental economic and technological trends have created an environment requiring a variety of new capabilities and characteristics such as safety, efficiency, adaptive behavior, communication, self-optimization, monitoring and automation (Sanislav & Miclea, 2012). Geisberger, Gengarle, Keil, Niehaus, Thiel and Thonnißen-Fries (2011), referring to Moore's law about the exponential growth of processing power of digital systems, state that the close interplay of technological innovations, economic dynamics and social changes has stimulated the emergence of CPSs that integrate the cyber world and the physical world (Geisberger et al., 2011). CPSs are networks of interacting appliances with physical inputs and outputs as compared to standalone devices (Lin, Zeadally, Chen & Chang, 2012). Typically, the CPSs connect objects from the physical world called actuators, which are embedded with sensor nodes. The sensor nodes convert the various measurement metrics into digital format and send those as inputs to the cyber world. The CPSs make decisions based on the inputs, and as outputs, the network of actuators in the physical world acts correspondingly to the computational process in a coordinated way (Lin et al., 2012). In CPSs, the interactions between the cyber and physical world are seamless, and the cyber world is able to continuously monitor and perform intelligent actions by adapting the applications and services to the physical world's needs (Conti et al., 2012).

The ability to perform in real time is a defining characteristic for CPSs, as it can provide emergent intelligence for the components, and with the capability of memorizing and learning from history and situations, the components are able to adapt to unpredictable or emergent environmental circumstances, execute non-planned functional interactions and act proactively (Horváth, 2014). Wan et al. (2013) define more specifically that the cyber capability is in every physical component and resource constraint, enabling the closed-loop control and high degrees of automation (Wan, Yan, Suo & Li, 2011). The closed-loop control is essential in order to achieve the real-time requirements.

In this study, CPSs are studied from the service-centered perspective and follow the definitions of Conti et al. (2012) and Broy et al. (2012) in the following way:

> CPSs are open socio-technical systems that are able to understand and interact with the physical world while supporting continuous value co-creation through the cyber world's adapting capabilities.

Research Method

The object of this study is to understand how value is co-created for CPSs from viewpoint of its users. The focus is on value co-creation in one specific area, the mining and construction industry, where intelligent equipment is an example of CPSs. More specifically, the aim is to explore the value propositions and value drivers related to value co-creation in this context. From this premise, the interpretive research approach supports this objective. In IS research, the interpretive approach has emerged as an important enabler in understanding human thought and action in social and organizational contexts and produces deep insights concerning the information systems (Klein & Myers, 1999). Gordon (2005) also notes that qualitative approaches allow the observation of emerging themes in situations where relatively little is known about the area of interest. According to Walsham (1995), the single case study design allows the in-depth investigation of a phenomenon, providing rich description and deep understanding (Walsham, 1995). In this research, the interpretive case study is expected to improve the ability to understand how the value is co-created for CPSs, and the single case study is deemed an appropriate way to investigate it because the object is not to contrast results.

This study investigates one particular CPS: intelligent equipment in the mining and construction industry. The case company is a part of a global engineering group specializing in high-technology equipment. It provides tools, equipment and components, such as drills and crushers, for the mining and construction industry. The case company is shifting toward intelligent equipment because its product development has evolved from direct operated hydraulic control systems into intelligent ones that enable distributed automation. Intelligent equipment, as an example of CPSs, is integrating the cyber world and the physical world, controlling the processes and facilitating continuous interactions between these worlds at multiple levels in the networked environment, where various actors are operating. However, even the case company is at a very early stage of development in intelligent equipment, and the intelligence in this article mainly concerns drills, while progress has also been made in other product lines.

Data collection and analysis

The interviews were done using the laddering technique of Reynolds and Gutman (1988). The technique develops understanding about the participants' personal values related to product preferences through the linkages between the attributes of the product (means), the consequences of those attributes and the value that the consequences reinforce (ends). The linkages form association networks, or ladders, which represent how the product-related preferences are processed and reveal the underlying personal motivations or reasons why an attribute or a consequence is important. The context of consumer behavior provides a meaningful context for preceding the laddering interview, as the products are not used or consumed in general, but rather in a particular context (Reynolds & Gutman, 1988). Peffers et al. (2003) used a list of stimuli that was developed during the pre-study phase. In this research, the list of stimuli was created based on the consumer information systems framework that includes the elements of value co-creation. The consumer information systems framework was used as a lens for the literature review and formed the themes for the stimuli list based on the factors that emerged in the frames of the consumer information systems. Before the fieldwork began, the case company's representatives approved the stimuli list (see Table 1).

In total, 20 participants were interviewed individually via phone. The interviews lasted 40 to 45 minutes on average. The participant details are provided in Table 2. At the beginning of each interview, the participants were informed briefly of the object of the research in general and requested to consider the intelligent equipment and the services related to them from the perspective of what elements would be important or relevant for them, not what would be technologically possible. The list of stimuli worked as the starting point for the interview, as the themes were explained with the potential elements or operations that would be enabled by the intelligent equipment. Then, the participants were asked to choose two themes that they considered to be the most important or interesting to them. The interviews resulted in 201 individual chains from 20 interviews. Each participant provided approximately 10 laddering chains within the two themes that they had selected and almost 1420 individual statements. For each laddering chain, the interviewer recorded system features, the reasoning of the participant why this is important, and a person's goals or values for the CPS in question. This follows how Peffers et al. (2003) have applied the laddering technique (Reynolds & Gutman, 1988).

For the analysis, a two-step thematic approach was adopted to cluster the laddering chains and to turn the data into meaningful graphic presentations. The analysis followed similar studies (Tuunanen & Govindji, 2011, Tuunanen et al., 2006), Tuunanen & Kuo 2015), and graphical network maps were used for visualizing the chains of attributes or features, consequences and values and for every theme that was used as a stimulus. During the interviews, the data was recorded using the participants' own expressions. For ensuring the correct interpretations, the recorded interviews were heard twice to fill the data set, and the statements were simplified for shortening the expressions. After this, the next step was interpretive clustering analysis for developing consistent constructs from the unique statements that the participants had used when expressing their ideas. The aim of the clustering process was to find similar expressions and to create clusters including similar concepts, without losing too much information. In order to maintain the information referring to the origin of the chains, each chain was numbered consecutively and marked with the theme number during which it had emerged.

Findings

In this study, the consumer information systems model was used as a framework for value co-creation to investigate how value is co-created in the context of intelligent equipment. The stimuli list that was used in the laddering interview included six themes representing the six elements of the CIS model from the perspective of intelligent equipment. During the interviews, the participants emphasized some themes more often than others, as can be seen from Table 3.

ID	CIS elements	Stimuli themes
1	Construction of identities	Own role and intelligent equipment
2	Social nature of use	Sharing and receiving information related to intelligent equipment
3	Context of use	Use and operating environment of intelligent equipment
4	Service process experience	Use and service experience related to intelligent equipment
5	Participation in service production	Able to influence the functioning of the intelligent equipment or participate in service creation
6	Customer goals and outcome	Goals and objectives enabled by intelligent equipment
7	Additional theme	Own choice

Table 1. Elements and stimuli themes of the consumer information systems framework

ID	Position	Organization	Gender
1	Product Specialist	Case Company	Male
2	Domestic Aftersales	Case Company	Male
3	Product Specialist	Case Company	Male
4	Domestic Service Manager	Case Company	Male
5	Service Offering Development Manager	Case Company	Female
6	Product Specialist	Case Company	Male
7	Territory Manager	Case Company	Male
8	Documentation Engineer	Case Company	Male
9	Technical Customer Service Support Manager	Case Company	Male
10	Product Manager	Case Company	Male
11	Product Specialist	Case Company	Male
12	Product Specialist	Case Company	Male
13	Product Specialist	Case Company	Male
14	Head of Construction	Mining contractor	Male
15	Team Leader / Chief Design Engineer, System Engineering	Case Company	Male
16	Product Line Manager	Case Company	Male
17	Head of Mining	Mining operator	Male
18	Technical Training Development Manager	Case Company	Male
19	Site Manager	Case Company	Male
20	Technical and Field Support Manager	Case Company	Male

Table 2. Interviewee details

Value/Theme ID	**1**	**2**	**3**	**4**	**5**	**6**	**Σ**
Support customer's process	1	6	1	18		2	28
Reliability		12	5	5			22
Efficiency	1	3	3	12		1	20
Real-time awareness	3	6	3	5			17
Reduced downtime		4	3	8		1	16
Simple to use	3		1	12			16
Timely maintenance		2	5	8		1	16
Systematic process	1	4	4	6			15
Continuous follow-up		5	5	1		2	13
Easier to adopt		2		11			13
Prevent problems (Failure, oblivion or environmental)		4	2	7			13
Faster problem solving	1	5	3	3			12
Safety			5	3			8
Accuracy	1	1		4			6
Increased utilization rate		1	1	4			6
Justify benefit		2		3		1	6
Increased useful life of equipment			2	3			5
Targeted training		1	2	2			5
Easily interpretable information		3		1			4
Integrate into customer's process				4			4
Support geological interpretations		2	1	1			4
Cost-effectiveness			1	1			2
Total number	11	63	47	122	0	8	251

Table 3. Distribution of value per theme

In the context of intelligent equipment in the mining and construction industry, the use and service experience related to intelligent equipment (ID 4, n= 122) was clearly the most significant theme for the participants, whereas the theme regarding being able to influence the functioning of the intelligent equipment or participate in the service creation (ID 5, n=0) was not chosen by any participants. After the most often chosen theme, there was a clear gap before the second and third most emphasized themes, which were sharing and receiving information related to intelligent equipment (ID 2, n= 63) and the use and operation environment of the intelligent equipment (ID 3, n=47). The two last were emphasized similarly.

When observing more specifically the distribution of values, they seem to be divided into broad top-level values, more specifically emphasized and linked values and values that have broader implication than the number indicates. Efficiency (n=20), reliability (n= 22) and support customer's process (n=28) seem to be clear broader top-level values. Also, the accuracy (n=6), safety (n=8) and cost-effectiveness (n=2) are top-level general values. Some values seem to be linked to others, like support of geological interpretations (n=4) and integration into customer's process (n=4), seem to be linked to the support customer's process. Simple to use (n=16) and easier to adopt (n=13) seem to be also linked to each other. Furthermore, the values related to real-time information formed a clear group, including real-time awareness (n=17) and, as a result of that, continuous follow up (n=13). These two values can be creators of the systematic process (n=15) where the timely maintenance (n=16) reduces downtime (n=16) and increases useful life (n= 5) and utilization rate (n=6). Some values seems to have broader implication than their numbers indicate, such as prevention of problems (n=13), easily interpretable information (n=4) and targeted training (n= 5), support and enable other values to emerge. As an outcome, justify benefit (n=6) seems to be a broad overall objective for revealing the benefit that can be achieve with intelligent equipment when compared to traditional equipment.

The analysis of the data resulted in five theme maps of the six themes, excluding theme five, which was not selected by any of the participants. The maps present the network of attributes, consequences and values based on the associations that the participants expressed (see an exemplar theme map in Appendix 1). The theme maps present the elements of the consumer information systems framework, which was used as a research lens. The maps illustrate how value can be co-created in the mining and construction industry in the context of intelligent equipment, presenting the attributes or features related to intelligent equipment on the left, the outcomes or consequences in the middle and the emerging values on the right. Tuunanen et al. (2006) underscores that when reading the maps, it should be noted that the links in the maps reflect the associations of the participants, rather than analysts' rationale. Therefore, it is suggested to be cautious not to seek causality or particular logic from the linkages (Tuunanen et al., 2006).

Discussion and Conclusions

This study applied the consumer information systems framework to explore the value co-creation in the context of the mining and construction industry. Our findings show how value is co-created in the use of intelligent equipment in this particular industry. The utilitarian values and goal-oriented perspective toward values were revealed to be more relevant than the hedonic values.

In more detail, supporting the customer's process, efficiency and reliability were clearly the most important values. Integrate into the customer's process is a value that indicates that a better understanding of the customer's process could enable richer interactions between the manufacturer and the customer, and the value 'support geological interpretation' is an example of this. The values called continuous follow-up, real-time awareness, reduced downtime and timely maintenance are closely related to the value systematic process. Also, accuracy, increased useful life of equipment and increased utilization rate are values that indicate that the better planning capability in the challenging environment includes various different actors who could improve the efficiency in general. In addition, easier to adopt, faster problem solving and simple to use indicate that the transition from traditional equipment into intelligent equipment requires special attention for being able to support the users, which is also emphasized by the value targeted training. As the competence levels among users might vary, so does their readiness to adopt new equipment and new processes as well. Safety in the challenging environment can be considered a self-evident value, but the value prevent problems is an interesting perspective to this, as it can prevent the decrease of utilization rate but also prevent human errors. Furthermore, the justify value is noteworthy, as the findings indicate that, for example, the targeted training based on data collection could reduce downtime and prevent problems for which customers could justify the benefits of intelligent equipment compared to traditional equipment. Surprisingly, cost-effectiveness is less emphasized.

While the framework by Tuunanen et al. (2010) focuses on consumer IS, our findings indicate that it also can be adapted to study IS in organizational contexts. We argue that the consumer information systems framework enables understanding of value co-creation in the context of CPSs, by integrating the cyber and physical world, which the previous research has often separated due to the lack of suitable models and frameworks (Baheti & Gill, 2011). Tuunanen et al. (2010) also argued that the balance between hedonic and utilitarian use of the system may differ between consumer and organizational users. More recently, Valkonen et al. (2015) have argued that hedonic and utilitarian values form a continuum in information systems use and that different systems have varying compositions of hedonic and utilitarian value to its users. The study by Vartiainen and Tuunanen (2013) investigated value co-creation in the context of geocaching, and their findings show that the values from the participants were more hedonic than utilitarian. On the contrary, in the study of Tuunanen et al. (2006), the outcome indicated that in the mobile finance service field the values of the participants were considered to be more utilitarian. Additionally, Tuunanen and Govindji (2011) focused on interactive television services and the development of an online IPTV learning system for university students. The values from the participants in that context were goal-oriented and more utilitarian than hedonic, indicating that the participating university students wanted the system to support their learning activities. Our findings also revealed some hedonic aspects, as the participants described the required attributes for usability and user interface from the perspective of hedonic value when we more closely analyzed the theme maps derived from the laddering interviews (please see the exemplar of a theme map in Appendix 1). These maps also described some applications that they are used to using in personal life that have better usability than the ones that they use at work.

This research has some limitations. First, the used framework for value co-creation ignores the technical issues, such as the linkages to cloud computing and other enterprise systems, and it does not cover how the organizations should be managed from the service-centered perspective. Second, the mining and construction industry is also a challenging environment for CPSs and therefore might emphasize some features or elements that are not as relevant in other domains of CPSs. Also, because the participants were usually from the manufacturer's side, the view of the equipment manufacturer is emphasized; therefore, the perspective of the customer's side is relatively limited and therefore some valuable knowledge might have been missed. Third, although the case company acts globally, possible participants from abroad or from the operationally important areas other than Finland could not be contacted due to schedules, which might influence the results. Despite this, it can still be assumed that the participants formed a comprehensive sample because the snowballing method was used to find the participants who were the experts or well aware of intelligent equipment.

As a research implication, we argue that more research is needed that views CPSs as socio-technical systems: Understanding the link between human strengths and weaknesses with the corresponding strengths and weaknesses of the intelligent equipment are central issues in order to understand the reasoning behind the adoption of CPSs and to further study the areas such as changing competence requirements and training. For obtaining better understanding and a broader perspective on the networked value co-creation in the context of CPSs, the subject should be studied with more participants and from the global perspective. The human-machine interactions (HMIs) are also a central issue when further investigating the interactions between the cyber and physical world and between the different actors and intelligent components in physical world. The direct interactions, according to Grönroos (2011), enable the value co-creation. This leads to the one central question of how to design CPSs as socio-technical systems capable of recognizing the different needs of different actors in the network in order to facilitate value co-creation. Currently, the technical capability of CPSs is there, but, for example, without a clear objective regarding why to collect data, who analyses it and who is interested about it, the results are relatively weak. Also, the ability to monitor the performance, process, users and environment exists, but without the link to the practical implementation and capability of real-time process planning, the benefit is non-existent.

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APPENDIX 1 – Exemplar theme map

This theme map focuses on the use and service experiences that intelligent equipment enables. This refers to how intelligent equipment is expected to operate, how the maintenance should be designed or how the manufacturer could better recognize different needs or requirements of different customers or users in order to perform better with intelligent equipment.