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The Impact of Cyber-Physical Systems on Industrial Services in Manufacturing

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Abstract

Besides selling tangible products, manufacturing companies have also started to compete by offering product-related services throughout the product lifecycle. In this context, the recent rise of cyber-physical systems (CPSs) and smart, connected equipment paves the way for additional opportunities for the service business among the lifecycle and pivots of traditional maintenance, repair and overhaul (MRO) service business. Based on 11 case studies, we investigate service innovations driven by digitalization and CPSs and their impact on the service ecosystem. We identify affordances that effectively exploit the new technological capabilities in existing and future service scenarios.

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Keywords: cyber-physical systems; product-service systems; servitization; case study; technology affordances; manufacturing

1. Introduction

The manufacturing industry as a whole is subject to major paradigm shifts and faces new opportunities based on both a business and technical perspective. Traditionally, manufacturing organisations have sold tangible products. Besides selling products, those organisations also incrementally compete by offering product-related services throughout the product lifecycle. Over the last decade, these organizations have continuously increased their revenues coming from the service business and have started to expand their business by offering product-related services [1–4]. In particular, they offer maintenance, repair and overhaul (MRO) services as well as technical support for their products resulting in an increased importance of the service business for manufacturing organizations. In research, this trend is taken up as 'servitization in manufacturing' [1,2,5,6]. Hence, industrial products and services have become more and more interlinked and combined to so-called industrial product-service systems (IPSS) [7–10]. As the traditional goods-dominant (G-D) paradigm exhibits some shortcomings with regard to explaining the exchange of value, a new service-dominant (S-D) logic [9,11,12] has recently been well received among scholars to understand better the new business models in the traditionally goods-driven industries. Although organizations in manufacturing struggle to drive servitization [13], the service business is becoming more and more important, as it generates more steady revenue streams, compared to the rather cyclical product business. In addition, a market pull for providing integrated full-service offerings and performance contracting instead of just selling spare parts and reactive maintenance can be observed.

Industrial machinery and industrial capital goods are traditionally composed of mechanical and electrical parts. Breakdowns of such industrial machinery are expensive, as they result in downtime. There is a loss of earnings and expensive and time-consuming repair work. However, a transformation is taking place: Due to increasingly pervasive digital technologies [14], both consumer and industrial products are equipped with sensors and connectivity. Particularly in an industrial context, where considerably

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higher requirements in terms of reliability, equipment utilization and capabilities that cut across and transcend traditional product boundaries exist [15], these new technological capabilities can particularly be harnessed to create new hybrid business models and transform the service business. For instance, condition monitoring, and preventive and predictive maintenance scenarios can be realized to minimize product downtime. Manufacturers strive for leveraging the emerging technological capabilities of industrial CPSs to engineer better products, increase efficiency of their technical customer service processes for MRO and come up with new added-value services. However, case studies indicate that they struggle in systematically identifying and evaluating relevant service models.

As competition in the service business increases, traditional field services in manufacturing are under pressure. With the increasing importance of the service business, those new technological capabilities are becoming more and more important. Hence, manufacturers strive particularly for service innovations and an increased service process efficiency enabled by CPSs. For service organizations, new opportunities emerge, as they are able to identify breakdowns and send technical customer service (TCS) to do predictive service or fix the problem to minimize downtime. Furthermore, it becomes possible to increase the amount of remote service provisioning: Minor problems can be diagnosed or even fixed remotely. In short, digital innovation drives business models of various service stakeholders among the product lifecycle. To realize those scenarios, a tight integration between industrial products and service delivery is necessary. In this paper, we aim to provide clarity in this field by investigating the impact of CPSs on the service business and identifying service business models. Hence, this work addresses the following research question:

What are the effects of cyber-physical systems on industrial field service and what are corresponding business models?

To answer the research question, the remainder of this report is structured as follows. First, related literature is identified and relevant concepts are defined. Second, the research methodology is described. Third, results with regard to the research question are presented based on the findings from multiple case studies. Finally, this paper concludes with a critical discussion and an outlook on future research in this context.

2. Background and related literature

In the following, we present related literature in the interdisciplinary field of research and relevant concepts for this contribution.

Drawing on the S-D logic [9,11,12], service science [16] as an emerging field of research, so called Product-Service Systems (PSS) are introduced and conceptualized as a combination of tangible products and services offering value to the customer beyond the sum of its parts [17]. Industrial Product-Service Systems (IPSS) add an industrial context to such product-service bundles [10]. It is claimed that not only the service sector should focus on developing and offering innovative service offerings, but also traditional industries such as manufacturing. In this industrial context, the term servitization was first coined by Vandermerve and Rada in 1988 [6]. Lightfoot et al. [1] conceptualize servitization in manufacturing as innovation of organizational capabilities and processes, from product sales to integrated product services.

Parida et al. [18] recognize that with servitization, different types of industrial services exist. In their empirical study based on multiple case studies, they identify bundled MRO services as the most valuable services in terms of revenue generation, while add-on services are often not profitable. The largest revenues are generated by simple service offerings or (traditional) static MRO activities and speculate that returns could decline from such services [18,19]. Therefore, continuously monitoring products and analyzing operational product data might help to increase efficiencies of existing service processes and by creating new hybrid business models based on smart, connected products [20]. With initiatives such as Industry 4.0 [21–25] or the Industrial Internet [15], the term cyber-physical systems (CPSs) has gained attention in information systems (IS), computer science (CS) and operations research. In the domain of CS, primarily technical topics are addressed, such as security aspects or design and research challenges [26,27].

Both IS and operations research focus on product and service business models [28–31], as well as the transformation [18] towards the effective use of the new technological capabilities. In this interdisciplinary triangle, the term cyber-physical systems (CPSs) has emerged to describe the integration of computation and physical processes [26]. In his pivotal study, Lee [26] identifies technical requirements of CPSs and identifies them as being a cornerstone of the 20th century IT revolution. Dworschak et al. [32] identify technical as well as organizational competencies and critical success factors that are crucial for implementing CPSs in manufacturing. In IS literature, the concept of CPSs is likewise on the rise. CPSs can be defined as 'systems with embedded software [...] which:

- directly record physical data using sensors and affect physical processes using actuators;
- evaluate and save recorded data, and actively or reactively interact both with the physical and digital world;
- are connected with one another and in global networks via digital communication facilities (wireless and/or wired, local and/or global);
- use globally available data and services;
- have a series of dedicated, multimodal human-machine interfaces' [33].

Mikusz [10] shares this view. Based on a comprehensive literature review, he paves the way for further research in the field of CPSs by arguing that CPSs can be understood as industrial software-product-service systems (ISPS²). Hence, CPSs are a special kind of smart IPSS fuelled by digital parts. In an industrial perspective, distinguishing between major phases in the product lifecycle of industrial equipment is a