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Impact on production systems from recent and emerging complex business models: Explicit and tacit knowledge required

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Abstract

The paper addresses, based on an empirical study, what impact the use of recent complex business models, in particular, Functional Products, may have on production systems in terms of the explicit and tacit knowledge that is required. Requirements for new knowledge currently lacking or in the process of being acquired have been of specific interest for the study. The study focuses on the customer side, involving both manufacturing and process industry companies. A set of explicit and tacit knowledge aspects has been identified. The current set of knowledge aspects found during the literature review has largely been corroborated and the new specific knowledge identified is highlighted.

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1. Introduction

By tradition, manufacturing and process industries have previously to a large extent used products and services in their production systems (a production system may span a number of sites, processes, products, services, etc.). The products i.e., production equipment such as machines, tools, sensors, etc., have commonly been bought, rented or leased, whereas the services have usually been paid for per occasion or as part of a maintenance contract or agreement. Services may be provided by internal and/or external service providers. The traditional as well as the new or emerging production systems have during recent years also started to develop in terms of using new types of offers and business models, which often originate from the providers. Instead of traditional products and services, the providers have started to increasingly offer, for instance, products with integrated services and potential additional constituents. There are a number of such offerings ranging from simpler ones to increasingly complex ones, which are based on business models or concepts such as solutions [1, 2], servitization [1], Extended Products [3], Through-life Engineering Services (TES) [4], Product-Service Systems/Industrial Product-Service Systems (PSS/IPS^2) [5], Functional Sales (FS) [6], Total Care Products (TCP) [7], and Functional Products (FP) [7-10]. However, in this study the focus is on the concept of FP, which is far more complex than the corresponding product based on the same hardware/software, and thus significantly more demanding for, in particular, the provider side. However, the use of FP also poses new demands on the customer side.

Knowledge has many definitions and can be seen from many perspectives. However, one way to define knowledge is to divide it into explicit (codified, formal) and tacit (know-how) [11], where explicit knowledge can be codified and is easier to transfer compared to tacit which is hard to codify/write down on paper and thus commonly needs to be acquired through practical experience in a relevant context. To adequately benefit from the knowledge, a company needs to employ a sustainable method or system for knowledge management. Knowledge management can be considered as a process for creation of new knowledge, identification of sources of new knowledge, as well as elicitation and distribution of knowledge [12]. Further, how to transfer tacit knowledge and how to convert tacit to explicit knowledge

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(codify) are additional important aspects of knowledge management [13].

Regarding the complexity of the business model, FP integrate the four main constituents: hardware, software, service-support system and management of operation, into provision of a function with a guaranteed or agreed-upon level of availability to the customers. Other potential guiding parameters for contracts are, for instance, agreed-upon levels of performance, productivity, or efficiency improvements, which all transfer risk and responsibility to the provider side from the customer side. This forces customers, e.g., manufacturing and process industry companies, to develop and acquire new explicit and tacit knowledge regarding how to best manage FP (or other new offerings) in order to improve profitability and total-cost-of-ownership. Of further interest for FP customers is also to minimize capital expenditure and asset building, minimize risks, create simplicity and avoid unnecessary complexity, as well as being able to focus increasingly on their core business instead of spending many hours maintaining and monitoring machines, tools or other production equipment that are part of the production system. The same goes for the provider side, but it differs compared to the customer side due to the transfer of risk and responsibility. The transfer affects, for instance, organization, structures, processes, resources, risk management, consortium/partner management, need for capital and financial stability. Further, this requires the provider to acquire knowledge and multi-disciplinary understanding of the customers' operations (i.e., production system/process(es), production/maintenance engineers/operators and their knowledge, application of the FP, etc.) as well as the limitations of the provider (consortium) and FP.

The provision of FP commonly involves a long-term relationship, often ranging from five to thirty years, between the provider and the customer. Providers and customers are often keen on developing a long-term relationship in order to find a sustainable win-win situation and lower the overall total costs. From an efficiency and cost perspective, adequate knowledge is required to achieve sustainable long-term management of operation, which is key, as the operational costs often commonly exceed the initial costs. Thus, for the FP providers and customers, it is of great interest to understand which existing and new knowledge is required.

Co-creation of value is seen as a key aspect in FP scenarios to achieve long-term relationships and necessary win-win situations [14, 15]. Co-creation of value [16-18] adds new dynamics to the provider/customer relationship by involvement of customers in the creation and capturing of value. Thus, the co-creation of value may also affect how the requirements for necessary knowledge are distributed (between the provider and customers).

Detailed and comprehensive descriptions of knowledge that is required during the FP lifecycle for customers are scarce in the current literature (see related work section). In many cases FP customers need to be involved both prior to and after the operations/usage phase in order to customize and optimize the FP as well as to make sure that any potential down-cycling elsewhere or the end-of-life phase are managed in an appropriate manner. Therefore, this paper attempts to address this gap by identifying which knowledge customers and potential customers of FP consider as necessary and crucial during the FP lifecycle and highlights, in particular, any new knowledge needs found. To assume that everything gets easier, there are no risks and that it is possible to only focus on the core knowledge and thus no additional knowledge is required by the customers is at first a convenient assumption; however, this is somewhat naïve, as the customer still retains the total responsibility for their own production system.

2. Related work

The current research on knowledge that is required for FP providers during the FP lifecycle comprises a number of publications and concerns one or more of the phases: initial planning, design/development and realization, operations/usage and end-of-life [7-10, 14, 15, 19-22]. However, regarding the FP customers, research related to the knowledge that is required when introducing FP in production systems is limited. Further, the existing research related to some of the mentioned business models/concepts includes:

- **TES** – Masood et al. [23] posit that digital feedback is necessary from the through-life service to the design and development stages of the lifecycle in order to transform tacit knowledge to explicit knowledge. Further asserted is that a knowledge management system is needed to capture and reuse knowledge efficiently, which may lead to reduced maintenance costs, improved root-cause analysis and problem solving, mitigation of operational risks, improved repair policies and recommendations for repair margins. In addition, the knowledge/feedback can also be used to prioritize high-cost areas, provide feedback for improved design/development/manufacturing/ assembly as well as maintainability/serviceability.
- **PSS/IPS^2** – Lienert and Schiffer [24] have investigated which competencies and abilities are required in IPS^2 work environments and listed competencies such as: negotiation, communication, conflict management, interdisciplinary thinking, organizing, problem solving, self-dependent work, use of existing knowledge to solve new problems, and analytics. Meier et al. [25, p1176] posit that the customer "*wants to be placed in a position to operate these plants optimally*", indicating that a certain amount of knowledge must be transferred from the provider to the customer as well as from the customer to the provider in order to be able to understand how to optimize an IPS^2 in the customer's production system and process(es). Tan et al.'s [26] observations are in line with Meier et al.'s. This requires the provider to understand and gain knowledge regarding the customer's production system, process(es) and application of the IPS^2. Further suggested by Meier et al. [25] is that knowledge management and know-how feedback, involving both the provider and customer, are needed and should be managed in a structured manner throughout the IPS^2 lifecycle. Trevisan et al. [27] state that the provider and customer also need to