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Improving Functional Product availability: software-related measures planned and taken

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Abstract

The paper, based on an empirical study involving five companies, concerns software-related measures that are planned and taken by providers together with their customers to improve the availability of Functional Products (FP) or similar offers. The manufacturing industry is showing an increasing interest in adding offerings based on additionally complex business models, as opposed to merely offering products and services. This supports innovation and helps companies to stay competitive and profitable. Considerable focus is placed on performance- or result-based business models. Functional Products (FP) is one such business model, where the provider offers a function to customers at an agreed-upon level of availability, productivity or efficiency. FP comprise four main constituents: hardware, software, service-support system and management of operation, which together deliver value to customers on a long-term basis. The paper highlights nine software-related availability measures planned and taken by manufacturing companies and proposes additional potential software-related availability measures.

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Keywords: Availability; Functional Products (FP); products; software.

1. Introduction

The paper, based on an empirical study involving five companies, concerns software-related measures that are planned and taken by providers together with their customers to improve the availability of Functional Products (FP) or similar offers. A current trend for manufacturing companies is to incorporate service offers and soft parts into their regular product offers and also to extend the providers' ownership of the product throughout the entire product lifecycle. This is a business opportunity for the provider, but it is also a requirement from customers, since it allows them to focus on their core business and processes. There are a number of additionally complex business models, compared to products and services, such as performance- or result-oriented business models, which may be used to stay innovative, competitive and profitable over time in global competition. One example of such a business model is FP, and the concept of FP [1-4], incorporates hardware, software, service-support system and management of operation into a combined effort providing a function to customers with an agreed-upon level of availability or improved productivity or efficiency. Thus, the FP concept has a basis in the cyber-physical systems and industrial internet-of-things paradigms. Throughout the FP lifecycle, operation of the FP must be managed, further developed and optimized, since the intent with FP is to optimize long-term value for both the customer and the provider, i.e., create a sustainable win-win situation [5-7]. Further, the concept of FP has similarities with, for instance, Functional Sales (FS) [8], Extended Products [9], Total Care Product (TCP) [1], Product-Service System (PSS) and Industrial Product-Service Systems (IPS^2) [10, 11], Servicizing [12], Service Engineering [13] or Through-life Engineering Services (TES) [14] in the sense of increasing the focus on soft parts such as services, knowledge and know-how etc., additionally offered. The FP, originating from hardware aspects, has most commonalities with PSS/IPS^2, TCP, TES and FS, however adding additional complexity development-wise. FP availability can be seen as a function of reliability and maintainability [15] of the main constituents that are part of delivering the function.

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The FP lifecycle, whose contracts for customer instances can range up to 30 years, contrasts significantly from offering the same hardware and software as a product with services. Some of the significant differences are that the provider retains ownership, takes on risks and responsibilities which are transferred from the customer, and further co-creates value together with the customer. In addition, as the provider is compensated for providing a function, the provider needs to honour the agreed-upon level of availability or contract parameter specified. This requires that the provider can monitor the function and foresee potential problems before they occur and, preferably, act in a proactive manner rather than a reactive one when a problem or breakdown is a fact.

A trend is that the FP software constituent grows and becomes additionally important as more functionality is added, and it is commonly easier to add new functionality via software than hardware-wise. Traditionally, most manufacturing companies have a hardware-centric approach towards availability management, whereas the software field offers new and interesting developments to improve availability. As the software constituent can be different than the hardware one, by being situated on-board/locally, distributed/federated, centrally or cloud-based, etc., some additional consideration may be necessary in order to uphold the desired level of availability versus the cost level accepted. Using central or cloud-based software commonly has an economy-of-scale advantage as long as it is possible to maintain the agreed-upon level of availability. Depending on what the software does and how it is possible to combine on-board/local software with the other software options, information security, connectivity, response times (i.e., latency), criticality as well as the coupling to other parts of the FP limit where the software or parts of software need to reside. Thus, the use of cloud services or central software may not be an option in many cases, although they are attractive from an economical and scalability point of view. Thus, it is necessary to make an assessment of what software functionality is reasonable and adequate to have on-board/locally, distributed, centrally or in the cloud, so as to avoid availability issues. In addition, changes in, for instance, EU and US data legislation require that management of the overall FP must adhere and adapt to the appropriate data legislation in cases where personal data is transferred.

The current research on FP has mostly been directed towards the hardware and service-support system by modelling and simulation of these two constituents (and in particular the reliability and maintainability). For instance, Löfstrand et al. [16-17] propose a simulation framework and Reed et al. [18-19] outline a language facilitating modelling of the service-support system. A high-level outline of the challenges and need to model and simulate the whole FP has been made by Pavasson et al. [20] and FP availability, legalities, information security, criticality and adequacy, when planning to use cloud services in FP have been assessed by Lindström et al. [21]. Currently, there is a lack of literature addressing FP availability focusing, in particular, on the software constituent. Thus, the research question addressed in this paper can be formulated as: which software-related measures to improve FP availability are planned and taken by FP providers? The purpose of the paper is to highlight a number of software-related availability measures which can be used by FP (or similar offers) providers together with their customers in the manufacturing industry.

2. Related work

Many products or similar offers which include hardware are used a lot longer than initially anticipated due to economic reasons, and thus the lifecycle is sometimes extended far beyond what was originally planned for [22]. This causes issues related to asset management and in particular how to manage the availability level expected or agreed upon. An asset management problem is how to manage the obsolescence [23] of the hardware and, in particular, of the often rapidly evolving software (including operating systems and platforms used to run the software). Additive manufacturing may solve some of the asset and obsolescence management issues related to hardware and spare parts, since it allows spares with the right quality and properties to be crafted on demand. Further, Muñoz et al. [24] posit that as software starts to become one of the most valuable assets in the aerospace industry, the portfolio of (critical) software should be monitored performance-wise in order to minimize costs and avoid risks. It can be assumed that the same goes for many other industries as well (including the manufacturing industry and FP).

Optimizing the level of availability versus cost is an ever-present concern, as is optimizing the FP lifecycle towards the duration of the customer contract and sustainable win-win situation between the provider and customer [5-6]. Thus, the initial FP planning, design/development, realization and operation, are all subject to planning or taking measures regarding availability or improvement of it. To avoid most of the expensive and long-term testing, simulations (preferably using data from actual monitoring of FP in operations or test activities) are a common tool to use either on a framework layer for the FP main constituents [16-17, 20, 25-27] or for important/vital components of FP [28-29]. Up to now, most modelling and simulation efforts have targeted the hardware and service-support system constituents. Guided by the simulations, the necessary actual testing can be performed and test cases mapped out based on simulation results in order to improve designs, system/component reliabilities as well as system/component maintainability. Of great importance is to find or locate the potential large cost drivers (such as number of service engineers, number of locations for spare parts, which spare parts to have in stock, driving distances to customer sites, etc.), and decide upon how to deal with them in terms of improving reliability, maintainability or opting for re-design/re-thinking if deemed necessary [2, 25].

New ideas are needed in order to minimize availability issues originating from the software in FP. An idea is a concept including morning gymnastics tests and digital envelopes proposed to minimize errors in automation software [30]. This may complement the other (software-related) availability measures taken or planned for FP.

In order to maintain the agreed-upon level of availability, planning and operation of FP require thorough risk management during the creation/delivery/capture of value for