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The conceptual design phase of Industrial Product-Service Systems (IPS²) - Learning from an industrial use-case

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Abstract
The promises offered by industrial product-service systems for lasting customer retention and long-term revenue streams are well known. Scientific research in this field is vital and new approaches are offered continuously.
However, the industrial application of these approaches is still sparse. A reason for this is a lack of scientific work on bridging the gap between common understanding and the product-service paradigm shift. As a consequence the advantages of newly developed methods and models are underestimated by industry.
This paper tries to bridge the aforementioned gap in the context of the early development of IPS² by using an industrial use-case for a comparison of traditional and new understanding of terms like concept, business model, service and product. As a result a system theoretical description of an IPS² in the early development stages is provided.

Keywords: Product Service Systems, Methods, Business Models

1 Introduction

On their continuous strive for market success providers of investment goods in b2b markets have always been searching for innovative solutions to solve the customers' problems and thus create value. The ability of creating valuable solutions is considered fundamental to competitive advantages for these companies. In the past these solutions consisted basically of mechanical components. Newly developed physical or chemical effects were utilised and unique selling points were created. Then, the triumphal procession of IT technology began. Today, manufacturing is dominated by integrated, more or less intelligent machines. An interplay of mechanics, electronics and software satisfies certain customer needs. Indeed there is a temporally limitation of value creation due to the vibrant markets of industrial production. The customer is sold a tangible, static system which covers only actual not future demands. There is a risk of insufficiency in case of changing boundary conditions. Therefore, a kind of solution is required which enables flexibility and long-term customer satisfaction.
Because of the growing call for long-termed, flexible value creation it is necessary to extend the tangible, static part of a solution with an intangible, dynamic part. It is believed the integration of products and services cover this requirement. So called industrial product-service systems (IPS²) address dynamic value creation by a flexible configuration of tangible objects and intangible processes throughout the entire lifecycle [1–3]. The customer is given an individual bundle which meets actual and future requirements. Instead of traditional product

selling where design, manufacturing and provision of tangible products is focused now the creation of additional value beyond technological systems is central.
The issue of individual value orientation instead of technical requirement fulfilment affects the way the artefact is designed. Especially the early conceptual design stage alters dramatically. This is owed by two dominant optimisation targets of the design process [1]: adaptive customer benefit and long-term provider risk. Maximizing benefits while minimizing risks requires a lifecycle-oriented design of all objects, processes and their interdependencies. Furthermore involved actors, resources and organizational units need to be considered in order to get evidence on feasibility. Since these conceptual activities are crucial for the outcome numerous tools and methods are provided by research [4,5]. They address certain aspects of analyses, synthesis and evaluation of the conceptual IPS² models and proved to be proper approaches for IPS² conceptual design. Unfortunately the utilisation for real life engineering processes is still relative to traditional methods, sparse. It is argued that reasons for this are the technocratic culture in industrial organisations and a lack of best practices and guidelines [4]. In addition we state that a clear differentiation from traditional comprehension of conceptual design is required to impart knowledge about the application of new design methods and the new mind set because the key term 'conceptual design' has different meanings in different domains and is used in different ways in the same domain. But it has a central part in the design process. It is the conceptual design's goal to generate product-service architectures which aim at additional value creation by synergetic effects [6]. Consequently a clear understanding is most important for valuable solutions.
The importance of clarifying conceptual design of an IPS² is not only concerned with knowledge transfer from science to industry, it is intrinsic in the transformation process of a product seller to a solution provider. A clarification of IPS² conceptual design in a manner that decision makers in industry can identify implications for involved actors, organisations and development processes is vital.

2 Structure of this paper

This paper discusses results of the last years and tries to offer some insights from theory for praxis. The outcomes of this paper are not really new but they can be understand as a first step towards a framework to support the transformation from product to solution selling.
This is done in three steps. In section 3 the new way of value thinking is presented. This new mindset is used in section 4 for a fictional use-case which explains some basic concepts of IPS² conceptual design. Then, this scenario is used for the abstraction from the viewpoint of system theory. Finally, the main differences between traditional and IPS² conceptual design are presented in the conclusion.

3 Limitations of the traditional mind set

3.1 Limitation of technology orientation

In traditional product centric approach improving existing technology and creating new solution architectures is being caused by further competitor differentiation. However, differentiation through technology is limited. Pahl et al. argue that the evolution of technologies and their effectiveness can be described in s-bend shaped curves as they are shown in figure 1 [7]. The technological lifecycle starts with the incurrence over growth and ripeness till age. The asymptotical convergence of the effectiveness to a saturation state is characteristic for technological lifecycles [7]. The nearer a technology approaches to a horizontal tangent of the s-bend the higher have to be the expenses on R&D. The generation of a considerable increase of customer benefit just by technology becomes most difficult. Knowledge the different technology and their lifecycle allows the strategic planning of substituting technologies. If following technology can be developed an abrupt increase of the effectiveness is possible.

However, one will still approximate a natural border; the imitations of performance-thinking 1.0. Even the most advanced technical improvements cannot ensure long term differentiation from competitors. In traditional business relations, which are defined by the ownership transfer between provider and customer differentiation is based on technology and the provider has to improve the technology steadily. This leads to great R&D expenses. It becomes apparent, that a natural question to ask would be whether the marginal utility can be increased in another way then by technological improvement.

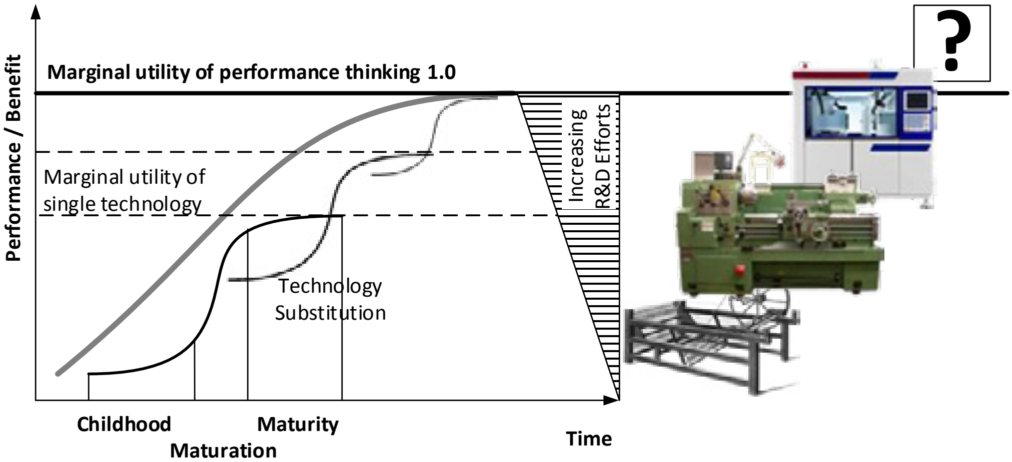

Figure 1. Technological lifecycle and its marginal utility (based on [7])

3.2 Value creation beyond technology

Scientific research identifies the concept of IPS² as promising concept to create value beyond the availability of technological systems. According to Meier et al. an IPS² is defined as "*integrated and mutually determined planning, development, provision and use of product and service shares including its immanent software components in Business-to-Business applications*" [1]. By selling functionality instead of products performance an increase beyond technological optimization can be achieved. The innovative strength of this performance thinking 2.0 is reasoned with a paradigm shift which manifests in novel business models [1-4]. Unlike a company strategy IPS² business models characterize the single relationship of a provider, its third tier suppliers and a customer. Furthermore the value creation over the whole lifecycle of this network is described. Within the business model partial models represent value proposition, risk distribution, revenue streams, and property rights [8]. On the contrary to a discrete sale these new business models focus on lifecycle-comprehensive customer benefit and are often categorized by the cash flow. Beside business models, in which revenues emerge from customer side use (car-sharing), so called operator models are established in different industrial sectors. Here, the cash flow bases on the quantity and quality of the production result. Due to the interrelation of business model and solution the whole lifecycle of the provider-customer cooperation has to be regarded in the design process. Furthermore, the implementation of customer specific business models implies a product- and service-integrated development process, because technologies, resources, operating processes and knowledge about the provider-customer-relation have to be considered [3]. This consideration is necessary to identify points of additional value creation and possible risks. As a consequence, the creation of a business model and the creation of the conceptual problem solution have to be synchronized. For instance, the selling of a new business option like overall availability of a

production process requires changes in the technological product-base which enable the capability of process monitoring. In this case, the business model has implications for the solution space. But also the extension of the solution space like the developments of new technologies, processes or competences in the provider‘s network lead to the capability of offering new business model options.
In summary the determination of WHAT is offered can only be achieved by the answering the question HOW this offer can be realized and vice versa. Non-integrated approaches lead to uncertainties and risks of offering something particular unknown.

3.3 Conceptual design of IPS²

Because of the strong interdependencies between business models and solutions IPS² conceptual design has to be reinterpreted and what is more circumscribed from product centering. Traditional, conceptual design is defined as a continuous concretion path which leads from an abstract problem description to a final principle solution [7,9]. On this path the requirement analyses, the establishment of functional structures, the search for working principles and the alignment of a working define it as a sub process where the solution architecture of the future product is created. The higher goal is the generation of a model which describes the future product‘s behavior on an abstract level. Its purpose is the clarification of command variables like costs or feasibility. Restrictions from adjoining processes and organizational units are considered via requirements and boundary conditions.
In the context of IPS² the meaning of conceptual design is altering. Within the triangle ‘provider-customer-solution’ several business units have to participate in the transaction either explicit or implicit. Each of them has a different understanding of conceptual design. At least the following actors and activities are required to design a customer specific solution:

- Business & sales engineers
- Domain experts in the field of production, infrastructure, logistics and services
- mechatronic engineers
- service engineer

Without an integrated mindset on how to create a product-service system all these participants have their own conceptual models to design an architecture which creates customer value. The emerging need for the integrated conceptual design is exemplified by a following use-case scenario.

4 Descriptive Study

For the deduction of theoretical findings on conceptual design a representative use-case is introduced. This use-case has been developed within the German collaborative research centre CRC-TR29 (http://www.tr20.de). Starting with a micro-milling station, this technical system serves as a fundament to integrate the participating researchers in a multidisciplinary way like shown in figure 2. Hereby a whole business relationship between an IPS² customer (‘Omichron’) and the provider (‘Micro S+’) has been created so as to expand the isolated technical view.

4.1 An use case: Initial position

One imagines the producer of valuable, mechanical wristwatches named *Omichron*. This producer wants to get share in the growing market of luxury watches. For offering in this market segment watch industry dictates the insourcing of the whole production process. As a consequence the clockworks have to be manufactured by the producer. This poses to be a challenge since to this day an external supplier provided the clockworks. Because of quality, accuracy and aesthetics at small dimensions the production of clockwork components requires micro-production technology. Especially the cut processing of the clockwork-plate is of vital importance and necessitates the micro-milling-station (see Fig. 2).

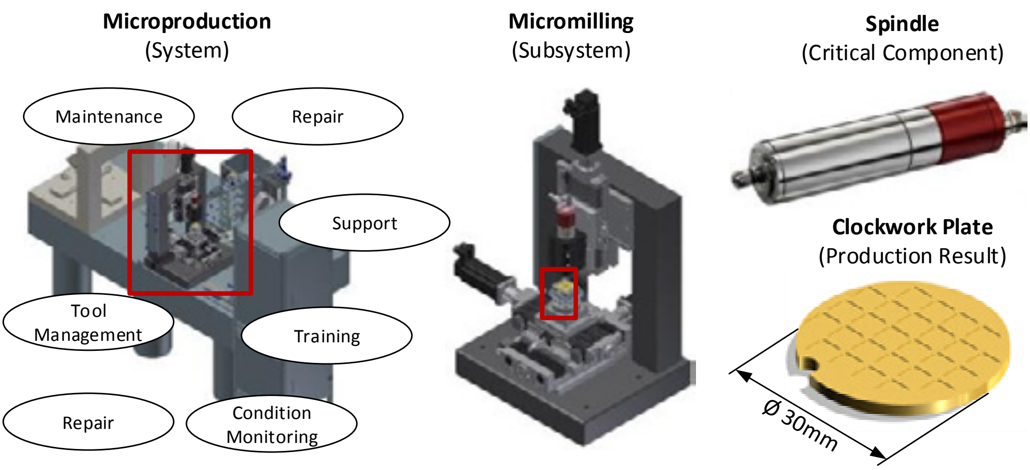

Figure 2. The ‘Omichron’ use-case szenario

Due to present core-competencies, the customer lacks knowledge which is necessary to execute the micro-milling process independently. In a traditional business relationship this circumstance would lead to a delayed entry into the market of luxury watches.

The conflict of goals can be described as follows:

- **Goal 1:** Inhouse micro-milling of watch plates to enter new markets immediately.
- **Goal 2:** Learning about the process to be ready for autonomous execution in the long term.

To solve the conflict, the IPS²-provider *MicroS+* offers an innovative business model, which consists out of two stages. In the beginning of the relation (stage 1) a “provider driven business model” is offered. The provider operates the micro milling process. Revenue stream follow from the amount and quality of produced parts. During the execution of the production process itself, the provider transfers necessary knowledge. This empowers the customer to operate the micro-milling process autonomously. If a predefined grade of readiness is reached, the initial business model changes. Now an “intensive cooperation business model” (stage 2) is launched. The customer operates the whole system and it is the provider’s duty to guarantee its functionality. The provider gets paid for technological and organisational availability of the micro milling machine.

4.2 An IPS² for value creation

After the introduction of the provided business models in stage 1 and stage 2 a short overview on the solution will be given in the following section.

In stage 1 the revenue stream arises from to produced parts. Consequently components like the spindle are of highest importance because product quality and processing time is put down to them [10]. To avoid downtimes of this critical system sensors are integrated. These sensors enable the communication with a software agent-based control system [11].

The above mentioned control system is able to adapt the micro-milling process on a machine-level by adjusting process parameters. Furthermore it interacts on a planning level with organizing service processes like maintenance, repair or overhaul. Executing the IPS² within a complex network of service suppliers, it is able to realize an optimal service planning due to time, cost and quality parameters [11]. The teaching process (see business model stage 1: transfer of knowledge) is supported by a human-machine interface that is able to monitor the motion of the customer's personnel. Erroneous processes can be avoided and the quick integration of the customer into the running production process (learning by doing) is possible. Furthermore the risk for both parties can be minimized.

The second stage of the business relationship is based on technological and organisational availability. In this context the existence of spare parts like cutting tools is crucial. Therefore an intelligent tool management system is introduced. Together with the mentioned execution system, it is possible to order and provide the needed cutting tools in advance and thereby response times are minimized.

5 IPS² through the lens of system theory

5.1 The Design Artefact

To answer the question of novelty and differentness of conceptual design in the context of Industrial Product-Service Systems, one has to understand the basic characteristics of the *design object*. Based on the presented use-case a system theory based analysis is conducted.

According to system theory there are three important perspectives on systems: the hierarchical, structural and functional point of view (see fig. 3) [12]. The **hierarchical system** term states, that a system consists of sub-systems and is part of a super-system itself. An IPS² comprises *hardware*, *software*, *people* as well as *infrastructure.* These are entities belong to the socio-technical IPS² subsystems called *performance artefacts*. Within the IPS² context it is no longer reasonable to distinguish clearly between products and services. Although depending on their structure, performance artefacts are either more or less product or service-oriented, the grade of materiality is of minor importance. Rather the performance that can be realized is in focus, because the IPS² is part of the super-system, the *IPS²-business model*.

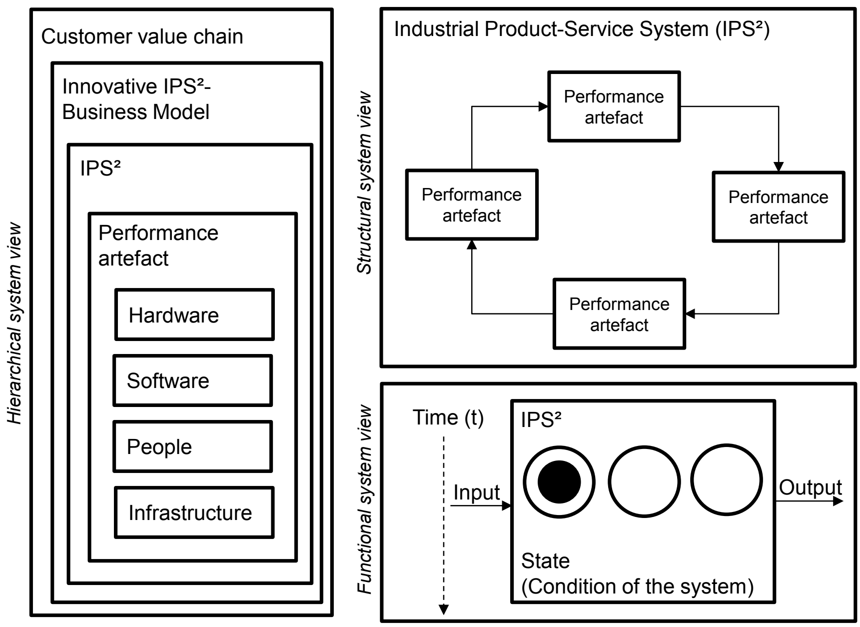

Figure 3. Hierarchical, structural and functional point of view of IPS²

As mentioned in chapter 2.2, the business model comprises the value proposition (Which value is offered to the customer, e.g. result of a process), the revenue model (How does the customer pay for this value, e.g. pay for produced parts) as well as the organizational model (How is this value created). Within this framework the IPS² represents the organizational structure of the business model. That means: *who executes which activities by running which subsystem* *elements* during a certain stage of business relationship? Again IPS²- business models refer to certain areas of the *customer value chain* that means e.g. the production or other business processes.

The **structural system** perception states, that a system – consisting of system elements and relations – is more than the sum of its individual parts and that this 'more' originates in the diversity of the relations between elements. Thus structural system-thinking is based on the idea not to contemplate single system elements isolated, but always consider their interaction in the complete system [12]. So, an IPS² is able to generate an added value, which primarily aims at the fulfillment of customer needs such as production results and not at the implementation of technical specifications.

The **functional system makes** a statement about the intended purpose of a system [12]. Its system function describes how input variables are transformed into output values. This transformation may vary depending on the status of the system and therefore it is time-dependent. Since an IPS² is supposed to be a long-termed problem-solution, in- and output values as well as system inherent attributes may alter during the long lasting business relationship. For example it may become necessary for the system to react on contractual agreed options within business model (e.g. new revenue models) or to the retirement of performance-relevant subcontractors [8].

5.2 The design process

The system theoretical understanding of IPS² can be used for sketching its design process. In order to identify IPS²-specific characteristics of the design process it is necessary to understand its role and function as a system of actions within an overall IPS² provider view. In general action systems follow a certain hierarchy and again include so called goal systems, information systems as well as execution systems [12].

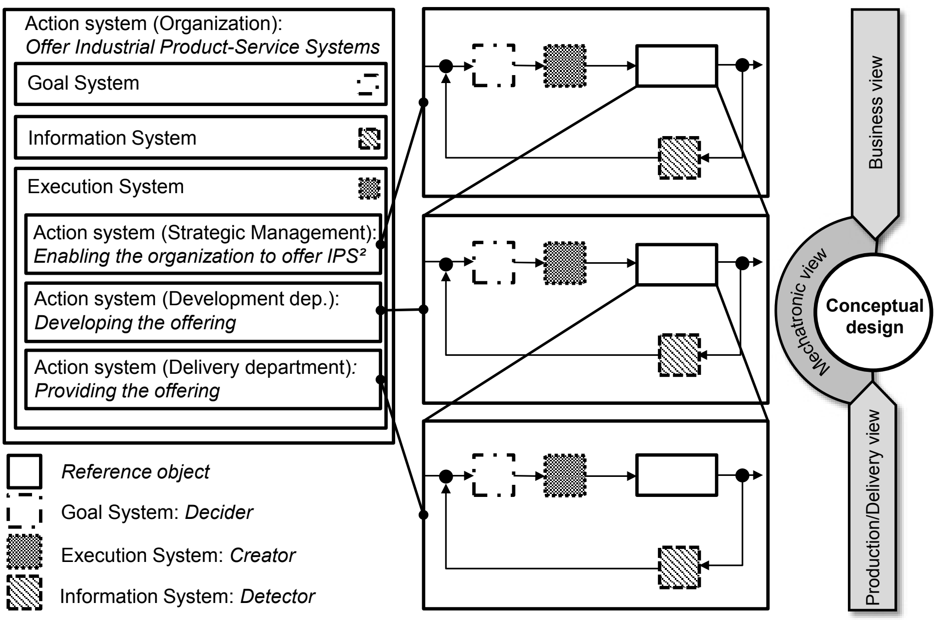

Figure 4. IPS² Conceptual design within a cascaded control system

Figure 4 illustrates these three subsystems from the viewpoint of an IPS² provider (Figure 4 – left). The organization that offers Industrial Product Service Systems is the super-system. This organization is led by company or network related goals (goal system) and processes the

emerging information (information system) in its ERP systems. Focusing the related execution system of the organization, the IPS² design process itself represents an action system integrated into the comprehensive development process of the offering [8].
After identifying the potentials to offer a long lasting IPS² business model, a multidisciplinary development process is triggered. Organized by a multi-project management (goal system) the business model design, the conceptual design and the detailed design processes (execution system) iteratively generate an IPS² solution.
Following the V-model approach presented by Müller, validation processes (information system) are executed by simulations that address the customer value instead of technical parameters [13]. After realizing a validated IPS² solution, the system is implemented and executed by the delivery department. Being clearly distinguished in traditional business models, the three described action systems are strongly interrelated in IPS² context. Therefore a mindset of conceptual design as a controller within a cascaded control loop has to be established. It should connect the corresponding viewpoints of mechatronic, production and business.
Due to the strong connection towards the business model, the conceptual design of IPS² has to cope with aspects, traditionally related to the strategic management. Within the conceptual design of IPS², system elements like technical systems or personnel are allocated towards partners within the execution network that are responsible and take over corresponding risks. Customer individual IPS² business models go along with a high degree of novelty. So it is possible that the organization does not own the needed competencies and therefore has to cooperate with new suppliers. In this case the goal system of the development process is not able to adapt to the requirements of the solution principle, so this design decision is escalated to the action system that enables the organization to offer IPS² (Strategic Management).
Due to the long lasting business relationship and corresponding changing requirements, the IPS² have to be highly changeable. This has to be considered in the development process [14]. However it is only economically efficient to implement changeability mechanisms to a certain grade. In the case that the action system of IPS² delivery has to cope with endogenous or exogenous factors that have not been implemented in advance, it becomes necessary to re-escalate the situation towards the development department. So certain concepts have to be redesigned.

6 Conclusions

If the system theoretical view on IPS² is used for the use-case szenario the following differences to traditional conceptual design can be identified:

Table 1. New paradigms in conceptual design of IPS²

Change	**Challenge**
Problem Analysis	Value identification requires detailed analyses of the customer's environment. It has to consider the complex business and production processes (super system) and their interfaces to the problem solution (system). This activity demands extensive expert knowledge and methodological skills. Furthermore the higher premise for a successful outcome is a confidential relationship between the provider and the customer. Both parties plan, design and operate in a cooperate manner.
Principle Solution	Principle solutions of IPS² extend the traditional model which describes the physical behaviour. In the new understanding the intangible part of the solution – the service – has to be included. The so called human factor comprises the following features: *Functional* (Interplay between operators and technology), *Temporal* (Training, knowledge acquisition, process schedules), *Spatial* (service

Change	Challenge
	availability on-site), *Interaction based* (Further partners for additional services)
Disciplines & Roles	If services, actors and organizational units become a part of the design artefact the development has to consider management decisions at an early time. Functional and company comprehensive roles for designer and decider have to be assigned.
Meaning of 'Green Field'	Each customer environment discloses new potentials for value creation. The principle solution which consists of tangible and intangible components is not known and so, a conceptual model has to be developed. Unlike traditional understanding the design on the green field comprises actors, technologies and failures or risks on an operational and strategic level. Therefore, the synthesis of the supersystem is necessary.
Ideation	The interrelation of business and conceptual models changes the way of idea generation. IPS² conceptual design has to consider top-down and bottom-up approaches. Within a top-down approach new business models are searched for existing technologies (Leasing). This approach is rather management oriented. This view is contrary to the bottom-up approach. Here, newly developed technologies enable new business model options. For instance new developed sensors or IT systems enable condition monitoring.
Consider Changeability	IPS² conceptual design needs to consider dynamic changes of the systems due to the long-term relationship. This demands a deep analysis of the whole lifecycle because the risk of changing requirements has to be identified. By this a corridor of flexibility which considers all identified uncertainties is defined. If new uncertainties occur beyond this corridor the concept of the solution has to be adapted. The analogy of a control system can be used for this.

7 Summary and Outlook

In this paper a new understanding of conceptual design is proposed. A revision of the term 'Conceptual Design' is necessary because it becomes crucial for providing industrial product-service systems. The revision is subdivided in three parts. First the superior paradigm shift of providing performance instead of technology is motivated. Then a use-case is presented to show the potentials of product-service bundling and business models. The use-case is abstracted in order to derive a system theoretical understanding of conceptual IPS² design. Finally, certain differences of traditional and conceptual design are identified.

There is a lot of scientific work on providing industrial product-service systems. However, these approaches suppose, that companies have already a deep understanding of the mechanism behind product-service integration. But the fact that many companies just have started the servitization process. Especially within technocratic company cultures the establishment of a new mindset is very difficult and clarifications, guidelines and use-cases have to be provided. This paper provides just a first jigsaw piece. More detailed clarifications of technocratic key terms will and have to follow.

Acknowledgement

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