The nature of risk management in the early phase of IPS² design

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Abstract

It is well known that Industrial Product-Service Systems (IPS²) are providing added value for both the customer and the provider. Within innovative IPS² business models, risks that are traditionally related to the business processes of the customer are transferred to the provider by linking the revenue streams directly to the usage, performance or value of a system. However the majority of production companies in Germany keep out of that business, despite the high potentials of IPS² for gaining long lasting sustainable competitive advantages. On the one hand side the transfer of risks is the key for new business models but on the other hand side it is one of the most challenging factors that hinder the successful implementation up to now. Therefore it is necessary to identify and manage both values and risks already within the early phase of IPS² design. Due to the heterogeneity and fuzzy understanding of the design object and process itself, the role of uncertainties and risks in this surrounding is not clarified at all.

By literature-based research this paper is able to contribute to the understanding of uncertainty and risk management in IPS² businesses and proposes a new and holistic approach for integrating the concept into the early design phase.

Keywords: Risk Management, early phase of IPS² design

1. Introduction

Industrial Product-Service Systems (IPS²) are well known as a suitable approach to provide added value for both the customer and the provider [1]. Therefore more and more manufacturing companies apply this approach to withstand the increasing pressure on highly competitive B2B-markets. The bundling and integration of product and service elements lead to various possible offerings that theoretically range from product appended after sales services (e.g. spares delivery) up to innovative business models. Instead of selling products in a traditional way by transferring its ownership, these innovative business models focus on inherent needs emerging during the whole customer activity cycle [2]. Because of constantly changing environments (e.g. market, technology) customers value chains are traditionally exposed to various uncertainties during the use phase. Like illustrated in figure 1, these uncertainties can lead to risks (R), quite difficult to cope with.

Fig. 1. Transfer of risks in IPS² business models
2. Industrial Product-Service Systems

In academia the integration of material products and intangible services into a new system is referred to as Product-Service Systems (PSS). To describe these kind of solutions in manufacturing industries, the term Industrial Product-Service System (IPS²) has been established [1]. The comprehended system elements (e.g. mechatronic systems, industrial services) are composed to induce additional values within the customers activities [2]. The emerging integrative and individualized customer relationship is determined within IPS² business models [7].

2.1. IPS² from the perspective of systems theory

A system theory view is indispensable to get a profound understanding of the idea of Industrial Product-Service Systems and to draw the appropriate conclusions for the topic of uncertainties and risks later on. From a static point of view an IPS² is described as a system, consisting of interdependent entities - hardware, software, people, facilities and procedures - that can be merged into the three subsystems "product", "customer", and "service network" [8,9,10]. Due to the innovative and long-lasting business models, IPS² have to be viewed not only from a static but also from a dynamic perspective [10]. Within the several IPS² life cycle phases, the entities of the system as well as the involved stakeholders have to interact with each other to fulfill the overall system goals [8]. To represent the lifetime view of the business relation and the required dynamic behaviour, research uses different approaches to describe IPS² as a system [10,7,1,11]. In analogy to a control loop Sadek proposes the IPS² basic structure (Fig. 2) which arranges the basic system elements (IPS² artefacts and including entities) into the dynamic content (possibility of adaption) and serves as a basis for modelling and developing Industrial Product-Service Systems [11].

2.2. The early design phase of IPS²

Based on the predefined systemic understanding the task of designing IPS² becomes more clearly. In literature the understanding of the IPS² design process and the related content is quite heterogeneous [12]. Nevertheless it can be stated that especially the early design phase is on the one hand related to traditional strategic and economic aspects and on the other hand more operational and classical engineering topics [13]. For example Nemoto et al. define three interrelated design domains, that have to be considered called "Strategy", "Structure" and "Synergy" [14]. In the understanding of the German Collaborative Research Center CRC/TR29 the views are represented within the generic IPS²-development process model [15]. Here in the early phase is characterized by defining the business model as well the as the conceptual design of the system architecture of an IPS² enabling the realization of the business model. Especially in case of not configuring an existing business model and the belonging system architecture but developing radical innovative business models an integrative view on designing business models and concepts of Industrial Product-Service Systems is highly recommended. Business models are subject of research with extraordinary rising attention both in the economic and engineering domain [7]. However the discussion is relatively unstructured so Meier et al. afford a definition of business models in the context of IPS² as follows. "The business model characterizes the relationship between a provider and a customer as well as third value-adding parties over the entire lifecycle of an IPS². It describes the value proposition, the risk distribution, revenue streams and the property rights for all parties in the IPS² network as well as its organizational implementation." [7]. Furthermore the dynamics (e.g. changing customer needs) within the business relationship is one of the most distinguishing feature, implemented into IPS² business models by predefined options.
that allow the customer to activate e.g. a new value proposition if required [16]. The overall goal of designing IPS² business models is to gain a win-win situation in terms of added value for all corresponding stakeholders over time [1]. Like illustrated in Figure 2 the added-value on customers side can be sourced by various categories e.g. performance improvement, cost reduction, environmental friendliness or accessibility to new technologies or fields of application [14,17].

The result of the IPS² conceptual design phase, the IPS² concept includes the overall principle solution of an IPS² and describes on a mid abstraction level the structural interaction (system architecture) of material and immaterial system elements as well as their logical functionality [11]. Köster et al. extend this understanding in context of IPS² domain allocation [21] and concretize the design task due to the IPS² specific disciplines "Production/Use", "Maintenance", "Logistics" as well as "Support" and the corresponding four viewpoints "Time", "Functionality", "Stakeholder interaction" and "Spatial distribution". Accordingly during the conceptual design phase it is task to define e.g. the network partners necessary for the provision of tasks, distribution of information and risk among stakeholders, the adaption principles of the IPS², the spatial allocation of certain system elements as well as the chronological sequence and rate of task provision [22].

Due to the heterogeneous nature of the design object the corresponding development process is characterized by a high degree of interdisciplinary.

- Extraction, selection and structuring (modular, integrated) of main functions out of the development problem.
- Search and selection of suitable solution principles.
- Combination of solution principles to IPS² concepts that consequently predefine the interaction of system elements (related to product and service domain) during the provision and use phase.

In traditional product development a concept is defined as a set of essential strategies and measures intended to realize a planned development problem [20]. Sadek transfers this understanding and defines the content of the conceptual design phase of Industrial-Product Service Systems as follows [11]:

![Image](image-url)
3. Managing Uncertainties in the context of IPS² design

The topics of uncertainties and risks are inevitable concomitants of IPS² business models. Like addressed in the first section of this paper, linking the revenue streams directly to the usage, performance or value of a system enables the transfer of occurring risks from the customer to the provider side. Recognizing the diversity of the term, the author follows the understanding of Erkoyunçu, who defines uncertainty as the stochastic behaviour of any physical phenomenon that causes the indefiniteness of outcomes meaning the expected and actual outcomes are never the same. He notes that the variation could have a negative, positive or no impact on the overall performance. Further he concretizes that risk is a special case of uncertainty where the outcomes of a specific event or a number of events have a negative effect on the overall performance of a project [23]. Literature about uncertainties and risk in the context of IPS² is numerous. However the understanding is quite unstructured due to the large solution diversity associated with the addressed innovative business models. Because of that it becomes necessary to clarify the categories of uncertainties based on the systemic understanding as well as the domains participating in the design process.

3.1. Understanding of uncertainties within the IPS² context

Erkoyunçu presents the so called “70-6-3 uncertainty guide” where 70 of the most important uncertainties specifically arising in industrial service delivery in availability-contracting are listed [24]. They are categorized into six uncertainty types (performance, affordability, commercial, training, operation, engineering) and structured according to three so called IPS²-building blocks that address both, the strategic (business model) and operational (IPS² concept) level of consideration. Due to the generic designation of the categories it is possible to use them as a basis for this work. However the listed uncertainties are limited to only availability oriented contracts and usual realized solutions in this field. A more widespread perspective is pursued by Sakao et al. who focus on PSS in general, independent from any business model category. In an interview based research the authors find out that customer-related uncertainty factors were the most prevalent for more experienced companies whereas the service provision itself was the major factor for less experienced ones [4]. By conducting industrial studies Kumar et al. are able to evaluate and subsequently categorize the most important types of uncertainties out of the company perspective. Beside uncertainty types that are not necessarily peculiar to the concept of IPS² (Market and Environment uncertainty) the authors identify the uncertainties going along with innovative services as well as the integration of product and service elements as being ostensible relevant. In addition this study shows that the risk perception is coupled to the offered IPS² business models [5]. With regards to this content Reim et al. use empirical insights from manufacturing companies to find out which types of uncertainties and risks are related to different types of business models (service as an add-on vs. FP) and with which intensity [6]. Considering the approaches above it is possible to find an useable systematic typology which is able to bring all the different business model specific views together. The corporate generic categories where extended by additional uncertainties mentioned in IPS² literature as shown in figure 4. In adaption to risk management approaches in new product development the uncertainties are either related to system goals or requirements, the system (and the belonging) elements itself or the new development processes to better understand which types have to be considered specifically during the early phases of IPS² design [25].

![Fig. 4. Typology of uncertainties](image)

3.2. Addressing uncertainties during IPS² design

The uncertainties going along with innovative business models induce the main challenges, Industrial Product-Service Systems are exposed to. Therefore the existing uncertainties have to be considered while designing the system [23]. The management of these uncertainties in terms of generating business opportunities and managing the arising provider-related risks become new critical elements to address when designing IPS². In order to understand how and in which content uncertainties are addressed in IPS²-design an overview on existing approaches is reasonable. Sakao et al. address uncertainty as a critical concept in the customer business processes and the corresponding value-chain [4]. By means of modeling and analyzing e.g. the production processes it is possible to understand, how value is created and perceived by the customer. Furthermore the identification of potential value-disturbing events (crisis, emergence) and related risks enables both finding inherent customer needs and first ideas for business opportunities. More focusing on quality assuring aspects in the service context Schmitt et al. emphasize the integration of risk management into the service innovation process [26]. Therefore they offer methodical support and instruments for
risk identification, analysis and evaluation based on the gap-model which is well known for the detection of faults and gaps in the information flow between the service provider and the customer [26]. Recognizing uncertainties related to IPS² and innovative business models various authors emphasize the need for systems changeability on strategic as well as operational level. In this context Dill highlights the need for realizing robustness as one changeability-mechanism in order to enable systems (here related to physical products in the context of service provision) for not being affected by emerging risks [27]. Therefore specific robust principle solution portfolios are proposed as methodical support. Other authors focus more on flexibility as a success critical factor. This system feature can be realized both within the business model throughout business model options and also by the systems architecture itself by e.g. partial substitution [16,28,1]. In order to evaluate and validate contracts for availability Erkoyuncu estimates costs associated to the uncertainty within Industrial-Product-Service Systems [24].

Summing up there are approaches existing in research that address uncertainties in the context of IPS² design. However these approaches concentrate either on specific uncertainty types (e.g. uncertainties that arise in the interaction with the customer) or specific impacts (e.g. project costs) caused by uncertainties and motivating to integrate the topic into the design phase. Due to this heterogeneous and unstructured understanding in literature the need for clarifying the nature and characteristics of risk management becomes obvious. Based on this the author emphasizes the need for proposing a holistic view and an understanding of how uncertainties and risks, together with creating added value drives the whole development process.

![Fig. 5. Categorization of existing approaches](image)

### 4. The nature of risk management in the early phase of IPS² design

Based on the before mentioned identified need, the objectives of the presented framework is to relate and to bring together the existing approaches that address uncertainties by integrating them into the value-risk driving logic of the early phase of IPS² design. Existing research underlines the importance to integrate risk management into design processes as early as possible. However the design process is seen as a black box. To really understand the nature of risk management and its consequences it is necessary to go one step further. This step is of high importance to guide an IPS² developer and to make clear when to consider uncertainties within the design process to finally realize system architectures that are able to cope with the risks that occur during the use-phase. Due to the fact that the positive effects of uncertainties are addressed additionally in an explicit way, the traditional understanding of risk management has to be expanded to the management of uncertainties like shown in figure 6. This value and risk related approach accompanies the design phase continuously and ties together the strategic business model level and the operational IPS² level.

![Fig. 6. Framework for Risk management in IPS² design](image)

The iterative process is about creating new added value for the customer by taking over customer related uncertainties and developing an organizational structure (IPS²) that is able to handle these uncertainties along the whole lifecycle and thereby create a win-win situation among all participating stakeholders.

### 5. Summary and Outlook

The concept of IPS² business models is drawing attention both in research as well as in industry. By taking over customer related risks these business models offer added value in long-lasting contractual relationships. Due to this fact the management of uncertainties is highly recommended already in the early phase of IPS² design. However the basic understanding and the holistic view on uncertainties and risks is not considered within the design process and existing development approaches up to now. Therefore this paper reviewed aligned literature to build up a new understanding and theoretical framework. Applying this framework to various industrial use-cases (e.g. cement industry, chemical leasing) allows the validation of the framework in the first place. Moreover it becomes possible to identify standard cycles within the design process as well as common IPS² solution principles related to risk respond mechanisms. In addition the high degree of novelty and the heterogeneous and inter-functional character related to this design process is challenging for the participat-
ing actors. Therefore teaching approaches will be examined to derive promising concepts to impart the relevant knowledge.

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