Characterization of Customer Requirements in IPS² creation

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Abstract

Industrial Product-Service Systems (IPS²) integrate product and service shares over the IPS² lifecycle to provide value and create solutions, which fulfil customer needs. To ensure potentials of IPS² the integration of the customer in the entire IPS² lifecycle is a key point to get a customized solution. With a support by an assistance system the interactive acquisition of customer needs can be done. A subsequent configuration of IPS² solutions, obtaining formalized and precise information, is shown. Together with the recommendation for an IPS² business model, the information's form the IPS² requirement specification and thus the basis for further development processes.

Keywords

Industrial Product-Service Systems, support, IPS² development, customer requirements, IPS² configuration

1 INTRODUCTION

Due to the globalization, companies have to deal with different market effects. By this competitive situation new business models, especially with customized solutions, can lead to a higher benefit and a long range customer provider relationship [1].

Machine tool manufacturers often sell with the physical product, the machine tool, add-on services. The influence of service aspects in the design and the use of the product are not considered, but especially the generated revenue of industrial services are increasing. This leads to potentials by the product and service integration over the entire lifecycle [1], [2].

Industrial Product-Service Systems (IPS²) are characterized by the combination of tangible product and intangible service shares. The combined shares provide added value to the customer over the complete lifecycle [3], [4]. IPS² is covering the industrial market, where typical supply chains [5] and industrial standards have to be taken into account.

To ensure an effective IPS², development support must be provided. In contrast to current industrial application, the customer needs ought to be fully gathered in the early IPS² creation phase. The acquired customer needs relate to the entire lifecycle of the Industrial Product-Service System to be developed. The presented methodology takes into account these aspects and ensures the acquisition of customer individual needs in a centralized, convergent way.

Therefore, the identification of influences for a support over the IPS² lifecycle has to be included. The paper presents a lifecycle oriented development process with the implementation of an adequate support.

2 IPS² BUSINESS MODELS

By analyzing the customer needs, an IPS² business model can be identified by the IPS² provider [6]. Three exemplary business models are described [7], [8]. The IPS² business model varies in function, availability or result oriented business models. The business models differ in the risks and responsibilities for the IPS² product and service shares and are distributed over the IPS² provider and the customer [6], [8]. The information about the ownership of product shares and resources needed for the service shares are an important input for the resultant IPS².

In a function oriented IPS² business model the function of e.g. a machine tool is guaranteed by the IPS² provider. The IPS² is operated by and in responsibility of the customer. In this business model the services, which are not combined with the guaranteed IPS² function, e.g. financing, training and process optimization, are planned in advance by the IPS² provider, so that the response time between the customer request and the IPS² provider's answer is short.

For an availability oriented IPS² business model the product share is in ownership of the customer and the responsibility for the availability relevant services is at the IPS² provider side. The IPS² provider guarantees the availability of the IPS² to the customer. Therefore, the IPS² provider must provide all services with all needed resources to obtain the availability. To ensure the IPS² provider to deal with this demand, a condition monitoring system can be used to inform the IPS² provider about the status of relevant product shares of the IPS². For time scheduling of service delivery, the customer and partners of the IPS² provider have to be integrated by the IPS² provider.

When the ownership of the IPS² product shares is at the provider side and the customer pays for a guaranteed result, e.g. parts per hour, a result oriented business model is focused. The responsibilities for the whole IPS² are provider driven.

Looking from the customer perspective on the IPS² service shares in a function oriented business model, the IPS² comprises of less service shares, which are more closely connected to the physical product. In a result oriented business model the service shares take over a dominant part.

Depending on the customer and IPS² provider needs the resulting business model influences the IPS² creation. In order to enable the IPS² provider to deal with this fact a support over an assistance system is constructed.

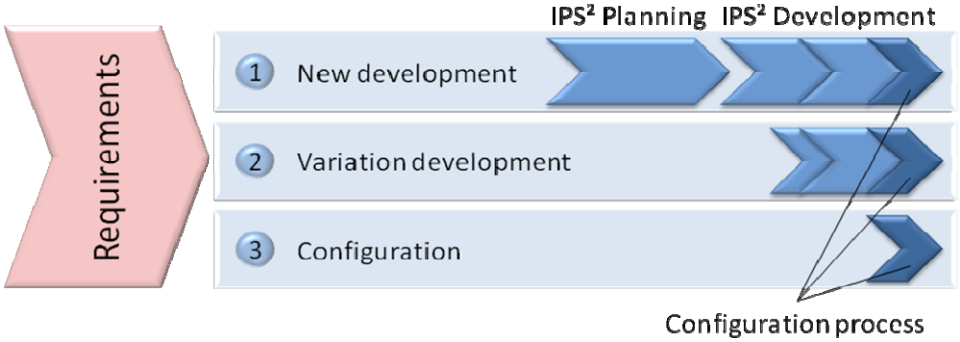

Figure 1: Context of the configuration within the IPS² creation phase

3 IPS² LIFECYCLE

The focussed IPS² lifecycle phases [9] can be divided into two main steps:

4.) Creation of IPS² and

5.) Operation of IPS².

Both steps are subdivided in several other steps. The main characteristic for the IPS² operation phase is the parallelism of the processes of the use of the IPS² product shares and the delivery of the IPS² service shares. In the IPS² creation phase a much more sequential progression is identified. The creation phase consists of the planning and development of IPS².

3.1 IPS² Planning Phase

In this paper the early stage of IPS² creation is focused on. The IPS² planning phase starts with the first customer contact, followed by the acquisition of customer needs by the IPS² provider and the comparison with his needs [2], [5]. The needs are used for the IPS² requirements specification. From these inputs an IPS² business model can be defined. At the end of this phase an IPS² offer is made to the customer that is based on a requirements list.

3.2 IPS² Development Phase

In the IPS² development phase, a functional and a conceptual model of the IPS² are generated from the IPS² requirement specification. The functional structure influences the product and service shares of the final IPS², because the named functions can either be fulfilled by one or more shares or special combination of both. This is the general concept of IPS², which assumes an interchangeability of product and service shares for the realization of a customized IPS². The solution must maintain the needed function; e.g. a product-service module with service processes can be replaced by a physical artefact (e.g. automated solution) and vice versa. This leads to the possibility to combine these solutions to special product-service modules. Thus, product-service modules consist of variable shares of physical artefacts (products) and intangible services. This combination fulfils one or more functions. In the subsequent drafting step, new product-service modules are developed, if they are not included yet in the configuration database.

In general the development phase is characterized by a “forward” process, where every stage only takes input from the preceding stage and generates a solution according to its abstraction level. Feedback loops are realized by iteration of one or more development steps until a suitable solution has been generated. Design methodologies like the V-Model [10] or VDI guideline 2221 [11] constitute the basis, which the development process follows loosely. Depending on the identified customer needs and the knowledge of the IPS² provider, three exemplary IPS² creation scenarios can be characterised (Figure 1):

1.) New development: the entire planning and development phase of IPS² must be passed through,

2.) Variation development: because of existing knowledge and product-service modules, which form the basis for the IPS² solution, the planning phase can be skipped, so that the task can begin with the IPS² development or

3.) Configuration: pre-developed product-service modules or full IPS² solutions can be used to fulfill the customer needs. The development of a draft has taken place beforehand during the development of the product-service modules.

Besides the early IPS² planning and development phase, the configuration step of the IPS² is the main focus for the assistance system being developed at Technische Universität Berlin [12]. The configuration of an IPS² accesses predeveloped product and service shares and combines them to a complete IPS² solution. Therefore, possible outcomes are already known in advance, since the solution set is limited to combinations of existing product-service modules. During the configuration of IPS² variants, possible solutions are generated and evaluated. The configuration module of the assistance system primarily works with data from existing product and service shares and databases with the interactions and compatibilities between both shares [12].

In case of a configuration of the IPS², the development of a draft is of minor importance (Figure 1). This is due to the differences between the two development paradigms new design and configuration (Figure 1). In the case of new design, all development phases are run through one after the other. There is no information beforehand about the solutions, since the development stages consist of creative processes with an open outcome.

For a supported configuration process, an instantiated requirement specification is needed which is realized in the IPS² planning phase. This specification should be as detailed and concrete as possible to ensure that an IT system, like the assistance system, can use this information. The creation phase of an IPS² ends with the realization and implementation of the IPS² shares and is followed by the IPS² operation phase.

3.3 IPS² Operation Phase

In the operation phase, where the IPS² is used and creates value, two parallel processes are identified. The use and the delivery phase describe two views on the same IPS² solution.

The use is product specific and the delivery is related to the IPS² service share. Beside these two processes a management process is needed. The management process realizes the dynamical configuration of e.g.

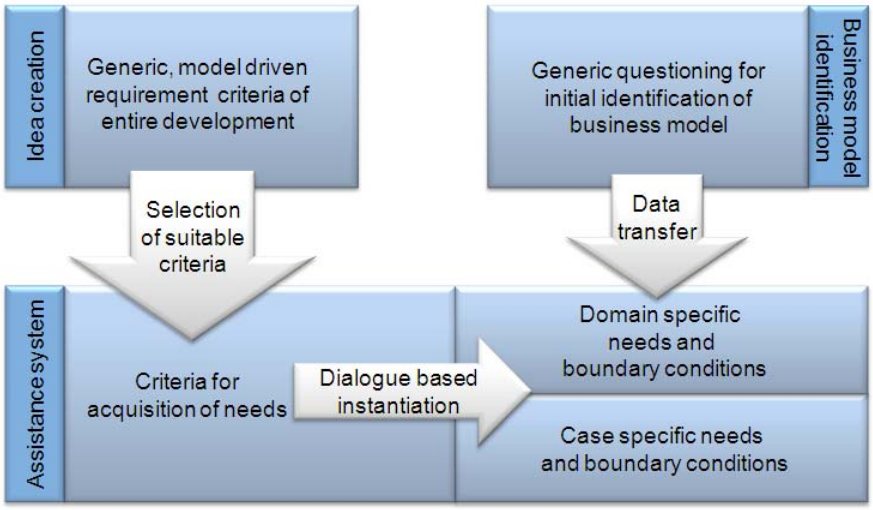

Figure 2: Influences of different information sources for the acquisition of needs

resources. It is important to react in an adequate way on changes in the IPS² operation phase and consists of different views on the IPS², depending on IPS² provider or customer processes [6].

4 FROM NEEDS TO REQUIREMENTS

4.1 Overview

Industrial Product-Service Systems are characterized by the offering of a customized solution. Within the Collaborative Research Project SFB/TR 29, the domain micro production has been chosen as the application example. Different customers have been examined and the results of their use cases have led to a general list of customer needs. The various needs form a comprehensive catalogue, which the IPS² provider uses for the first interaction with the customer in the IPS² planning phase. This procedure also enables the IPS² provider to document the changes of customer needs and requirements during the IPS² lifecycle phases.

The customer integration in the IPS² planning and development phase (see 3.1 and 3.2) is a key point to fulfil the customer needs. The main communication between the IPS² provider and the customer takes place during the interactive acquisition of customer needs by the IPS² provider. By giving the customer feedback on possible solutions, a knowledge transfer takes place which enables the customer to articulate his needs more precisely. Apart from customer specific factors also boundary conditions, like legislation, infrastructure, market and competitors have to be considered at this stage (Figure 2). These aspects are often not explicitly mentioned, or the customer may even not be aware of them, but nevertheless have to be considered for IPS² development.

The IPS² requirements are derived from the obtained needs in the next step. While the explicitly or implicitly expressed needs formulate a problem description that is preferably solution independent, a concrete solution is described by its requirements. The result is the IPS² requirement specification analogous to a product requirement specification in the conventional product development process.

4.2 Customer Needs

Starting with the first customer contact, the IPS² provider has to obtain the necessary information from the customer to clarify the development task (Figure 3). In contrast to conventional product design, this exceeds a technical specification list. The value that the customer obtains by the use of the physical product shares moves into focus. Therefore, the needs of the customer have to be gathered.

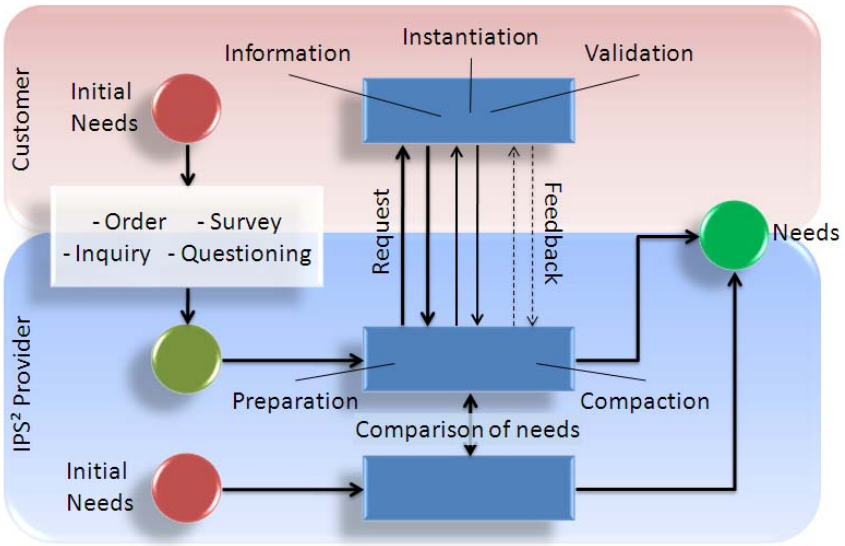

Figure 3: Acquisition of needs and boundary conditions

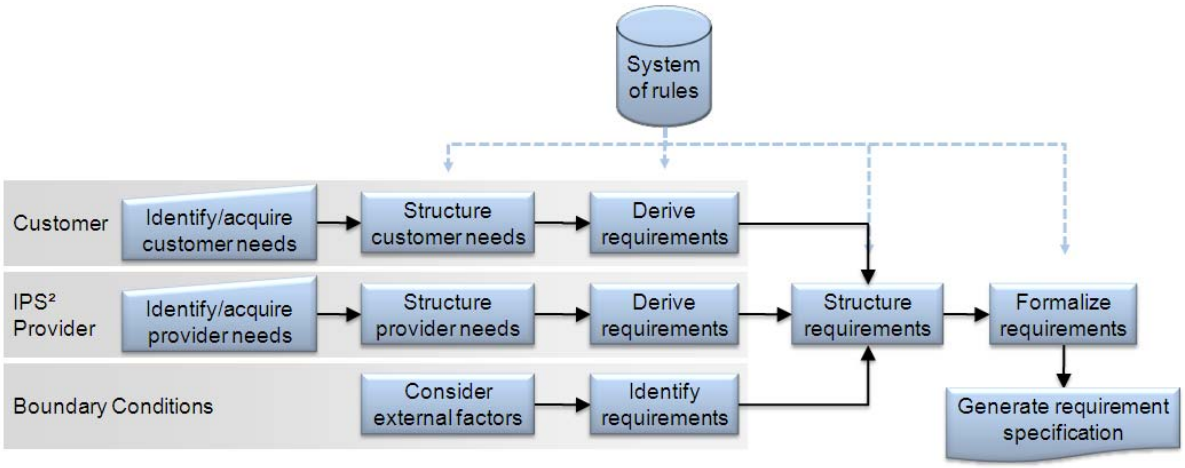

Figure 4: Process for the generation of the IPS² requirement specification

The areas of aspects to be considered for the IPS² development phase (see 3.2) are very broad and are specific for the application domain. The needs consist of a criterion and an associated value. They constitute the primary input for the assistance system and depend on the type of customer. The criteria for which information has to be acquired can originate from different tools and methods. In case of a direct configuration process without any variation development and where the field of application is known and narrowed down, the criteria can be predefined in a fixed set (Figure 1). In case of a flexible, multi domain use of the assistance system, the customer and IPS² provider may specify the criteria list manually or use e.g. the layer method, which is a method to analyze and synthesize ideas and concepts for IPS² [13].

The criteria are being detailed, and questions considering the application domain are assigned. An interactive, dialogue based instantiation takes place where specific values are attributed.

In principle customer and provider needs can be distinguished (Figure 3). The needs at the IPS² provider side should generally be known, e.g. because of the company strategy. This list of needs has to be compared to and put into context with the identified customer needs. Certain provider needs may be subordinated to the customer needs, but the IPS² provider must be able to fulfil his minimal needs.

The IPS² provider gathers areas of the initial customer needs and prepares information requests in order to obtain more detailed information from the customer (Figure 3). For further processing, the needs have to be sufficiently concrete which is reached by inquiries or questioning of the customer. At the customer side specific information about the need is provided and instantiated and in further steps validated. The obtained information has to be compacted on the IPS² provider side and finally merged with his own list of needs. As a result the IPS² provider is able to balance the respective needs and build a list of unified customer and provider needs (Figure 3).

Apart from obtaining the customer's needs, boundary conditions, which are not implied in the needs, but affect or determine the solution, have to be considered additionally (Figure 2). The customer may not be aware of these factors, may have no knowledge about them or omits them while formulating his needs. Examples are laws and regulations, infrastructure, information about suppliers and technical features that are state-of-the-art, but unknown to the customer. Last, but not least, the needs and boundary conditions of the IPS² provider also have to be considered in the development, see Figure 4.

Thus, three sources for the acquisition of needs can be identified, which are the customer, the IPS² provider and boundary conditions (Figure 4). This acquisition with the assistance system has to take place interactively. The main reason originates in the IPS² development as a customized solution. This implies a very close interaction with the customer throughout the entire planning and development phases and requires some degree of integration of the customer into these processes (Figure 3). Furthermore, in the above mentioned cases, where the customer is unable to specify exactly his needs, a knowledge transfer on decision areas will help him express his needs more precisely.

The needs and boundary conditions are queried interactively by the use of dialog based forms in the assistance system. Depending on the type of customer, two different ways to use the assistance system are possible. The user can either be the IPS² provider or the customer.

The customer is guided through the acquisition process by questions that are applicable to most use cases. Context sensitive help has been added to support the customer. Additional needs and boundary conditions that are not covered by the dialog system can be added in an expert form, which requires a user trained by the IPS² provider. While the dialog based forms provide a high level of user support, but lack in flexibility, the expert form allows for customer individual entries of needs and specifications with a very high degree of flexibility.

The acquired needs are being structured by assigning them to categories, which the developer can define dynamically according to the field of application (Figure 4). The obtained needs and boundary conditions form the base from which the requirements for the Industrial Product-Service System are determined.

4.3 Transformation to IPS² Requirements

Figure 4 depicts the process of transformation of IPS² needs to IPS² requirements in an IT specific view. The acquired needs, the boundary conditions and derived requirements have to be structured and finally formalized in order to generate the requirements list, which is sufficiently detailed and concrete so that a configuration process can be carried out.

The IPS² requirements are derived by a knowledge based process. Depending on the level of information, this process is executed fully automatically, interactively or manually by the assistance system. The knowledge about

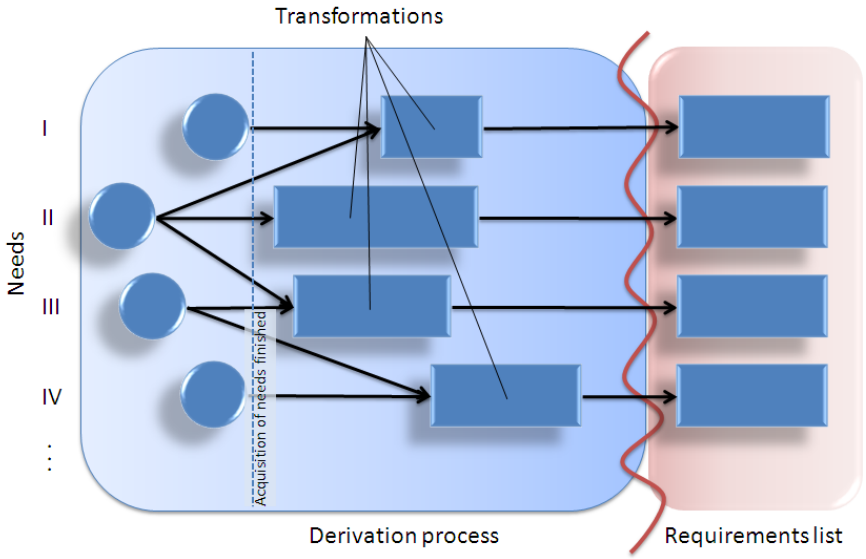

Figure 5: Derive requirements - Transformation of needs to requirements

interrelations between the acquired needs and the requirements can be classified into three categories: quantitative statements, qualitative statements and general statements. Quantitative relations are associated by mathematical formulas, database entries or tabular work. For example the geometrical dimensions of the product range determine the working space of the machine tool and can be expressed in a mathematical relation. Fuzzy logic and directional influences are means to describe qualitative relations, e.g. the competence level of the customer influences the degree of services that the IPS² provider has to cover. Finally, interrelations without attributable associations fall into the third category of general statements about the existence of an interrelation. Here it is known that a linkage is present and has to be taken into account. Information about the quality of the influence cannot be specified, however. Additional information of its importance towards the derived requirement may be attributed.

In the assistance system these interrelations are implemented as links between the needs and the requirements to be generated. The links can be associated with transformation processes, which take one or more needs as input and transform them automatically or with user interaction to requirements. This process for “Derive requirements” (Figure 4) is detailed in Figure 5. The transformation process is implemented in the assistance system via user definable scripts, which assure a very high degree of flexibility and a customer individual processing of the specified needs. The technical basis for the transformation scripts is based on the .NET platform. The scripts are compiled and executed within the assistance system, which allows transformation processes from simple calculations to database access or user interaction.

4.4 Application Example

The development of the IPS² product shares are mainly influenced by the IPS² requirements (see 4.3). The requirements are built upon and lead in the IPS² development phase to customized IPS² solutions, which are represented in the IPS² product model. By the transformation of the IPS² provider, his partners and customer needs (see 4.3) concrete solutions of IPS² product-service modules (see 3.2) can be generated, e.g. a micro milling spindle. The IPS² business model influences the choice and realization of solutions (see 2).

The acquisition of needs and the transformation is supported via the assistance system. The dialogue based software module of the assistance system to obtain the needs from the customer is shown in Figure 6 on the left hand side. The user is presented with detailed questions

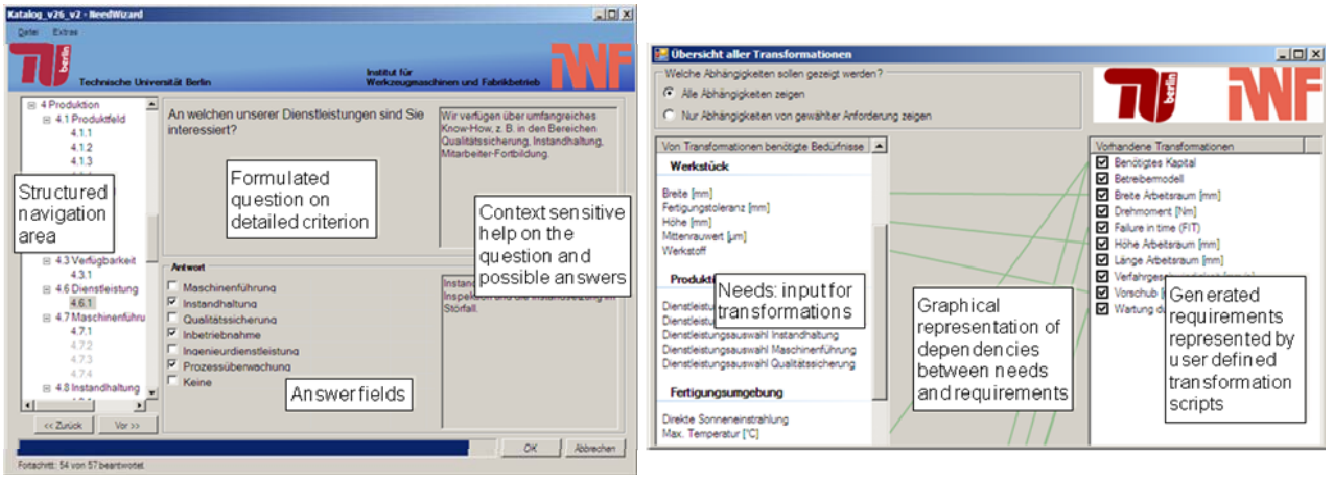

Figure 6: Implemented software modules of the assistance system for the acquisition of customer needs (left hand side) and transformation of needs to requirements (right hand side)

and one or several options to answer them. On the right hand side explanations and context sensitive help is displayed. The questions can be filled in in sequential order or be directly accessed via the navigation pane on the left hand side. The questionnaire is not static in order to take the customer individual aspects into account. A dynamic adjustment has been implemented to the list of questions depending on preceding answers of the customer. Partially completed lists of needs can be saved to allow for an iterative process of need acquisition.

The transformations of the acquired needs to IPS² requirements are depicted in Figure 6 on the right hand side. A graphical representation of the dependencies between the inputs and outputs of the transformations, the needs and requirements, respectively, allows to provide a domain specific set of rules and interdependencies for requirement generation.

Beginning with exemplary customer needs a milling spindle for a function oriented IPS² business model is described as

- lean design to realize the needed function with minimum costs and
- hampered intervention possibilities for the customer to reduce the customer influences on the functions of the spindle and to cause the relevancy for service shares of the IPS² provider.

For the use of the milling spindle in an availability oriented IPS² business model the spindle can be characterised as follows:

- integration of sensors for condition monitoring and
- easy to maintain to realize the guaranteed availability.

In the result oriented IPS² business model the realized function is mainly driven by strategically decisions of the IPS² provider, because the spindle remains in the ownership of the provider. The spindle can be designed with basic or with flexible elements for reuse in e.g. another IPS².

The spindle is generally designed concerning different main functions, which fulfil the customer needs (see 3.2 and 4.2). The exemplary functions of the spindle are:

- clamp milling tool,
- rotate milling tool,
- control rotary motion,
- true running accuracy and
- transmit cutting forces.

These functions can be attributed in the drafting step of the IPS² development by concrete technical requirements and implementation details (see 4.3) as follows:

- milling tool (2 mm shank diameter) fastener clamping: short taper,
- rotational speed of milling tool: 10000 RPM to 50000 RPM,
- control unit: Frequency converter,
- minimal true running accuracy: 0.01 mm and
- necessary torque: 60 Ncm.

The information shown above is example content for the different supported steps by the assistance system. Both general and concrete needs and requirements are shown.

5 SUMMARY

The early phase of IPS² development is in the focus of this paper. Industrial Product-Service Systems are characterized by the development of customized, integrated solutions. Therefore, the integration of the customer in the whole IPS² lifecycle is a key point. To ensure a support needs can be fulfilled according to different IPS² business models, of which three basic, exemplary business models are described. After an explanation of the IPS² lifecycle and its division into phases, the IPS² planning phase is examined in detail to characterize the potentials of IT support. A support for this phase is shown within a framework of an assistance system. In particular the acquisition of the needs and boundary conditions from the customer as well as the IPS² provider and their transformation into IPS² requirements are described under special consideration of a subsequent configuration process.

The support as shown is an important tool for an adequate and effective generation of IPS². This gives an IPS² provider the possibility to increase his revenue, strengthen his market position and to reach a strong customer provider relationship.

6 ACKNOWLEDGMENTS

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