Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 73 (2018) 297–303

www.elsevier.com/locate/procedia

10th CIRP Conference on Industrial Product-Service Systems, IPS^2 2018, 29-31 May 2018, Linköping, Sweden

Realizing availability-oriented business models in the capital goods industry

D. Olivotti[a*], S. Dreyer[a], P. Kölsch[b], C. F. Herder[b], M. H. Breitner[c], J. C. Aurich[b]

[a] *BHN Dienstleistungs GmbH & Co. KG, Hans-Lenze-Str.1, D-31855 Aerzen, Germany*
[b] *Institute for Manufacturing Technology and Production Systems, University of Kaiserslautern, Gottlieb-Daimler-Str., D-67663 Kaiserslautern, Germany*
[c] *Information Systems Institute, Leibniz Universität Hannover, Königsworther Platz 1, D-30167 Hannover, Germany*

* *Corresponding author.* Tel.:+49-5154-82-2182. *E-mail address:* olivotti.daniel@bhn-services.com

Abstract

The validation results of a concept for the development of availability-oriented business models are addressed. The developed concept contains five steps by means of primarily design thinking methods. For the validation, the developed concept is applied at Lenze, a German innovative manufacturer of drive and automation solutions for materials handling, handling technology, packaging industry, robotics and automotive industry. Therefore, a use case is defined, business models, extended value networks, persona analyses and customer journey are elaborated. The results show the applicability of the concept for the development of availability-oriented business models for the capital goods industry.

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.

Keywords: Availability; business models; capital goods industry; predictive maintenance; Product-Service Systems

1. Introduction

To fulfill increasing customer demands and to attain competitive advantages, manufacturing companies shift their product portfolio towards the combination of products and complementary, lifecycle-oriented services [1], so called Product-Service Systems (PSS). Within PSS, availability-oriented business models in form of availability guarantees gain significant importance. To guarantee a stipulated degree of product-related availability, a concept to develop availability-oriented business models, smart and communicating sensors as well as a suitable information management are mandatory [2]. Therefore, the usage of information and communication technologies is essential [3]. In this publication, the novel concept for the development of availability-oriented business models, which was developed in an ongoing research project and presented in a previous publication [4], is validated by means of an industrial use case in the capital goods industry.

The publication is structured as follows. The second chapter contains the state of the art of PSS and business models with respect to availability-orientation. The third chapter summarizes the previous research activities, in which the concept for the development of availability-oriented business models was elaborated. For the application and validation within an industrial use case, the description of the use case is presented in chapter 4. The validation results are shown in chapter 5. The paper ends with a summary and outlook in chapter 6.

2. State of the art

According to Mont, PSS are defined as systems of products, services, networks of actors and supporting infrastructure to fulfill customer needs [5]. In contrast to products, PSS can offer superior tangible and intangible values, in contrast to mere product offers, by means of customer-oriented solutions [6]. To offer PSS, suitable business models are required [7]. In general, a business model describes how an organization generates, delivers and captures value [8]. Business models can be distinguished in function-oriented, availability-oriented and

Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.
10.1016/j.procir.2018.03.299

	Function-oriented	Availability-oriented	Result-oriented
Production responsibility	Customer	Customer	Provider
Supply of operating personnel	Customer	Customer	Provider
Ownership	Customer	Provider / Customer	Provider
Service initiative	Customer	Provider	Provider
Supply of maintenance personnel	Provider / Customer	Provider	Provider
Service turn over model	Pay on service order	Pay on availability	Pay on production

Figure 1: Comparison of different business model types [9]

result-oriented business models [10]. The fundamental differences are shown in Figure 1, where the characteristics of the three business model types are compared.

In function-oriented business models, the offer focuses on a physical product. Enhancing services are considered as additional offers. Within availability-oriented business models the PSS provider guarantees a stipulated degree of product-related availability and therefore assumes a part of the customer's production risks. In result-oriented business models the PSS provider takes responsibility for the production process as well as the initiation of the service processes. The customer only pays for a faultless output [10].

Availability from a technical point of view can be calculated as the relative share of time in which a component or system is able to fulfill its defined function [11]. The goal of availability-oriented business models is to predict imminent failures in order to initiate service processes in advance to prevent a machine breakdown. For this prediction, specific sensor systems and other technological solutions are needed. In case of a random failure occurrence, which leads to a sudden machine breakdown, the service processes need to be accelerated to rectify the failure and to retrieve the availability. For value creation in availability-oriented business models, different partners of an extended value network are mandatory and need to be considered in the business model development [12].

For business model development, several authors provide different frameworks. One of the most popular framework is the Business Model Canvas by Osterwalder and Pigneur [8]. Köster extended the nine elements of the business model canvas to eleven elements and subdivided them into four partial models [13]. Echterhoff et al. added additional fields for the description of the incentives for participating partners, the advantage of the PSS provider and risks [14]. In the ongoing research project, the business model canvas of Echterhoff et al. was used, because partners of the extended value network are mandatory to realize availability-oriented business models. In the business model canvas of Echterhoff et al. the partners are addressed explicitly and additional elements for the arrangement of risks and incentives between the partners is provided.

To develop PSS means to develop customer-oriented solutions. To attain competitive advantage with PSS, innovative concepts need to be elaborated. Regarding innovation processes in industry, it is important to consider design thinking [15]. Design thinking places the customer in the focus of the development. As stated by Brown, design thinking enables the match of customer needs with technological feasible solutions [16]. Therefore, design thinking becomes more important for the development of PSS [17] and is integrated into the concept for the development of availability-oriented business models for PSS [4].

There exist several evaluation methods in service research. An evaluation method for designing PSS is shown by Yoon et al. by developing a new framework along with an empirical study [18]. In addition, different business concepts are already worked out in literature [19]. PSS is explored in mainly theoretical research [20]. It is emphasized to combine the design of PSS with the industrial practice and empirical research [21]. According to Parida et al., high-value adding services have a positive influence on performance of PSS [22]. After-sales services provide the highest financial return for PSS provider in industrial goods industry. It is recommended to develop a diverse set of PSS portfolio including simple as well as complex PSS to generate high value for customers and secure future competitiveness [22]. Availability-oriented business models offer the possibility to develop a set of various PSS with customized services. There is rare knowledge and experience according to PSS business models [20] and in literature PSS business models has not been discussed extensively [23].

3. Research approach

3.1. Project outline

The novel concept for the development of availability-oriented business models was developed in an ongoing research project called "Innovative services for customized, availability-oriented business models for the capital goods industry". Within this research project, several workshops with partners of agricultural machinery, drive and automation industry, consultancy, component manufacturers and research institutes were conducted, forming an action research approach. According to Levin and Greenwood, the action research paradigm focuses on context-bound real-life problems and their solution by means of a communicative process of collaboration between researchers and participants [24].

The first steps in the project are presented in [2]. The elaborated concept for the development of availability-oriented business models was developed in a previous study [4]. In this article, the concept is applied to an industrial use case. The different steps of the concept are summarized in the next subchapter to get a brief overview.

3.2. Previous research for a novel concept for the development of availability-oriented business models

The concept for the development of availability-oriented business models for PSS is based on design thinking methods because design thinking enables a customer-oriented development of PSS [16].

In the first step, an ideation phase is intended to identify current market and technology trends. Based on these trends, opportunities for new services and business models are elaborated, prioritized and selected as use cases. The use cases are described in a specific use case template. This enables to compare different ideas and select the most promising one. In the second step, the extended value network is worked out, containing mandatory partners, resources and interactions to realize the availability-oriented business model [25]. To get an impression who participates in the PSS and the business model, a persona analysis according to [26] is conducted in the third step. This persona analysis is used as preparation for the customization of the customer journey in the next step [27]. The customer journey focuses on the current needs of a customer. This technique is used to determine how the customer can be supported in the different steps of the problem. The usage of persona is for example applied in a service CAD system, which is supporting Service/Product Engineering [28]. The application of the customer journey enables the validation of the service ideas of the first phase regarding the persona needs. By means of the customer journey, further innovative ideas can be identified, and first high-level requirements can be elicited. In the last step, the addressed business model is detailed and requirements for service and technical development are elicited [4]. The concept is shown in Figure 2.

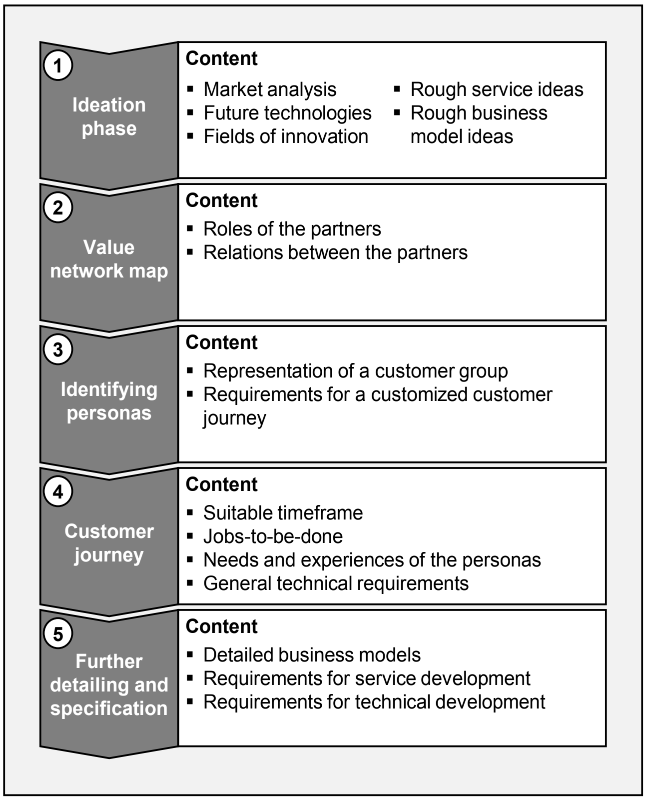

Figure 2: Concept for the development of availability-oriented business models for PSS [4]

4. Industrial use case description

The previously described generic concept for developing availability-oriented business models is applied in a practical example. Component suppliers in manufacturing industries face the problem that their components are built-in in unique machines. This complicates offering services to potential end users of machines, because there is no direct contact except the machine owner is an intermediary. From a component supplier’s perspective, availability-oriented business models are generally limited to its own components. Another possibility is to support manufacturers to realize such a business model.

The use case considers Lenze, a German manufacturing company for automation solutions. The product portfolio of the target company mainly contains inverters, motors and gearboxes as well as programmable logic controller. The components are essential for industrial machines and plants in e.g. intralogistics applications, automotive and consumer goods productions. To develop this use case and the instantiation several partners worked together. At Lenze the involved employees came from the departments of IT, strategic marketing, innovation and strategy as well as after-sales. Employees from another component supplier also formed part and came from the global automation and innovation and strategy department. Also, a management consulting company and researchers from a German university were engaged in the development process. The involved departments, companies and the university aim looking forward to identify promising business models, strategies and technologies.

The described business model is realized with focus on maintenance services. The aim is to avoid and reduce unscheduled downtimes of machines. This is addressed by combining different approaches, such as condition-based maintenance, predictive maintenance and asset as well as knowledge management. Condition-based maintenance focuses on sensor data and further information to identify the current state of e.g. a machine. Based on the known state maintenance activities can be carried out. Predictive maintenance has a similar approach. The objective is to predict when it is the best time to maintain a machine in the future. Asset and knowledge management support these activities. All approaches that are considered contribute to a high availability of machines.

Asset management forms the basis for maintenance activities. It is essential to know where each individual product is located in a manufacturing plant. An advantage is that it enhances maintenance staff to plan routes and to provide appropriate spare parts. This is important because the components that are offered by the target company are individualized. However, it is possible to store specific parameters and software and to transfer the information to a new and unconfigured component when a spare part is installed. To be able to realize this, a digital twin must be created, containing information of individual products, i.e. components.

In case of a machine error leading to a machine breakdown, the identification of the cause, and thus the remedy, is very time consuming in most cases. The identification of possible causes using the digital twin shortens the identification process. Additionally, by analyzing the digital twin main causes for failures can be identified precisely. Appropriate tools and the suitable number of spare parts that should be provided to reduce downtimes can be identified consequently [29].

A further approach to reduce unscheduled downtimes is to maintain only when it is necessary and not to use predefined maintenance schedules. This is achieved by applying predictive maintenance of key components in machines. As an example, sensor data can be tracked and analyzed. Mathematical models and algorithms can be used to determine the condition of a component. The information can be used to initiate required actions regarding maintenance activities. In a further step, maintenance activities of different components can be grouped to further reduce maintenance costs [30].

Asset management needs to be combined with knowledge from previous processes to continuously improve measures regarding e.g. the evaluation of possible causes or suggestions for future events. Component suppliers have extensive knowledge about their own products. Using remote access, problems can be solved without a field technician on-site, leading to faster problem solving. With the help of continuous learning, knowledge can be stored in databases and used efficiently. Knowledge is not limited to few employees but stored centrally. Graphical user interfaces, e.g. in form of dashboards, designed for each role in the value network support the previously described processes and help to track important key performance indicators.

5. Instantiation of the availability-oriented business model for PSS

In accordance with the previously defined general use case description the main output of the five steps is described.

5.1. Ideation phase

The ideation phase is performed by several focus group discussions, where participants from the previous described companies and departments participated. Initially, search fields for availability-orientation in capital goods industry are defined and categorized. These search fields are clustered according to future technologies, fields of innovation as well as business models and service ideas. For all defined search fields, market analyses with focus on maintenance are performed to get an overview about already existing approaches and solutions. Future technologies include cloud platforms for cross-company collaboration. These platforms aggregate data from different sources in various companies and provide role-based authentication to data and services. Another mentioned aspect is the analysis of heterogeneous data. Data analytics is identified as a key technology to tackle the problem of predictive maintenance addressed in the use case. Artificial intelligence might be a suitable approach. Technologies for processing sensor data are also included in the analysis and various communication protocols and standards are reviewed.

The field of innovation is based on the previously described technologies. Herein, the support during machine operation with focus on maintenance is discussed. This enables availability-oriented business models in capital goods industry.

5.2. Value network map

Along with the second step of the concept, the value network map of the presented use case is developed, shown in Figure 3. Manufacturers of industrial goods integrate several components from different component suppliers into their specific machines or manufacturing lines. Component suppliers also have sub-suppliers for products. For the cross-company process “exchange of data” the need for a central cloud platform arises. External data analysts and other service providers can be integrated into the value network. Component suppliers have detailed knowledge about their own products, e.g. mathematical models, algorithms and prediction rules, and can offer them to machine owners as well as manufacturers. This could go along with the product engineering, supporting the design of the machine, or during operation to ensure product quality and productivity while keeping machine downtimes low. Machine operators can provide information regarding current usage of machines and components as well as failures. This information can be used for product improvements of manufacturers and component suppliers and is essential to monitor availability. Production optimization or condition-based maintenance becomes possible. Several partners of the value network can conduct the maintenance of components. Consulting an external service provider is possible as well. Depending on the size and technology experience of the partners in the value network, tasks are realized by different partners. The business model addresses this challenge in a flexible way.

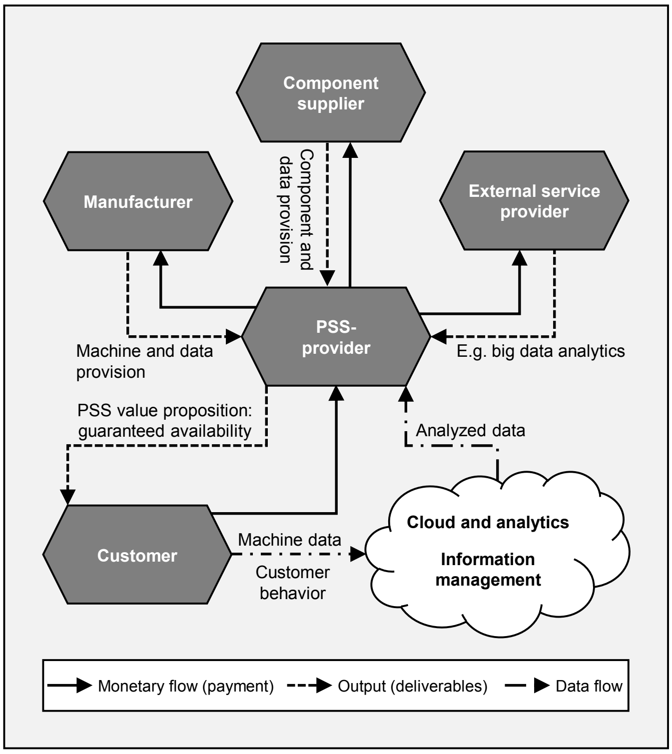

Figure 3: Value Network Map

5.3. Identifying personas

When elaborating availability-oriented business models, the intended target group has to be specified in the third step. From the perspective of a component supplier, generally there are two possible target groups. The first one is the machine user. Machine users represent companies which buy a machine from a manufacturer. In most cases, they operate in manufacturing industries. Due to requirements related to high and reliable output, machine users are interested in securing their availability [2]. A guaranteed availability of the drive unit components is interesting for manufacturing companies that do not have the capacity and knowledge for tracking a component's condition. Small and medium-sized companies form the target group for this business model. The same applies to machine manufacturers, the second possible target group. As they do not only operate machines, they are not necessarily the end user of availability-oriented services. However, it is possible to support them through providing knowledge of the drive unit as well as human resources.

Large manufacturers are interested in providing services in addition to the offered product. They usually have capacity to collect and manage data, information and knowledge. Therefore, they are not interested in component suppliers forming a part of the service business. Additionally, they have service locations all over the world and they do not rely on service partners providing human resources. However, apart from size and capacity, the advances in technology of the manufacturer are important. Some manufacturers observe technological advances and adapt them to provide services by their own. They partially already use approaches such as cloud solutions within the company. Consequently, supporting availability of components to improve services does not add value for large, technological advanced manufactures. Small and medium-sized manufacturers usually do not have the capacity to build up knowledge regarding availability and worldwide support.

In the presented use case, different personas were identified, which are part of the value network. The four personas considered in the following belong to different stakeholders of the value network. The first one is the machine operator. Machine operators are employees who work right at the machine. Usually, they are first in noticing differences in machine condition. The second group of employees that is considered to be relevant regarding availability-orientation are the service technicians. Usually, they are supervised by another group of employees, the maintenance staff. The tasks of the maintenance staff includes to evaluate error reports and to manage maintenance activities. They coordinate service activities in order to ensure a high availability. The last persona is the management of the service provider. These employees have an overview of machines and companies but also of e.g. branches, similar applications, components and customers, often in form of key indicators.

5.4. Scenarios arising from the customer journey

To further concretize the presented use case, three possible scenarios are explained in the following. It is assumed that an error occurs in a machine resulting in a machine breakdown. With respect to availability-orientation, rapid action is required. To reduce the process time of troubleshooting, the so-called system support is used. The system contains information and knowledge of past errors and problems. Additionally, smart evaluation of probability of an error cause is implemented. Step-by-step instructions are deposited to solve the errors. The idea is that the system analyzes the error and evaluates what cause most likely caused the error. Subsequently, it is estimated if it is an error that can be removed by the machine operator. If the answer is positive (scenario 1), a step-by-step introduction is shown, leading the machine operator through the fixing process. At the end of the process, the machine operator is asked by the system whether the machine is ready to produce again. In case of a successful repair, the incident is stored in the activity history. If the machine is still unable to produce, the machine operator has to wait until an employee of the maintenance and repair department acts. At this point, the first and the second scenario converge. Although the maintenance staff does not have any active part so far, they are able to monitor all activities. This includes that they are able to see the condition of all machines, next planned maintenance activities and further customizable information.

In the second scenario it is assumed that the most suitable error cause cannot be fixed by the machine operator which is why no step-by-step instruction for the machine operator is displayed. The machine operator has to wait, as in the second possible result of the first scenario. Both the consideration of the current machine condition and the history of past problems and activities contributes to this. Through the maintenance staff's knowledge in combination with the knowledge managed in the system, the suitable service activity can be conducted. A service technician receives the service order subsequently. The service order contains all information that is already extracted and estimated to be helpful to solve the problem as fast as possible. After solving the problem, the repair process is documented. An advantage of documenting all activities is that the forecast of error causes is improved continuously.

Not only rapid troubleshooting contributes to a high machine availability but also smart maintenance planning (scenario 3). To be able to determine the optimum time for maintenance, machine conditions have to be tracked. Life prediction models and further indicators help to determine the current condition of a machine or a component resulting in an optimum time for maintenance. Then, the maintenance activities can be assigned to a service company. Their employees are able to see the assignment including information regarding place and past activities connected to the respective machines. As in case of the other scenarios, maintenance activities are also documented.

5.5. Further detailing and specification

Coming from the scenarios, the business model can be complemented in step five for the explained use case. In order to ensure a high availability, several services are offered. In case of a machine breakdown, the operational state needs to be re-established as fast as possible. On the one hand, this is enabled by detailed instructions for the machine operator, directly on-site at the machine. On the other hand, all error reports are bundled for a central overview. This makes remote support possible as well as taking actions to fix the problem. A fast and purposive troubleshooting prevents production losses and thus reduces costs. Additionally, smart maintenance planning contributes to a high machine availability. A precondition is that the current machine condition is known. Data and information from several sources are used to estimate the current machine condition. Mere sensor data are not sufficient. Therefore, a reliable mathematical model is required. A necessary precondition is that the models are customized for the different types of components. The mathematical models are continually adapted and optimized, using already gained knowledge of component characteristics. Furthermore, connected machines and systems are required to determine the machine condition reliably. A continuous data flow is a precondition for the usability of mathematical models. Software is necessary to collect data, to handle data transition, to filter and to save it. Additionally, software is used to display dashboards and enables predictive maintenance tools.

Software systems have to be developed to be able to collect, transmit and process data and information. Further information and knowledge must be collected and structured. This includes mathematical models, which must be developed and evaluated. All costs must be considered when pricing a service. Additionally, potential risks must be considered and evaluated by experts. Based on this, it should be determined whether it is possible and appropriate to outsource risks. These aspects do not have to be neglected when pricing a service.

Connected to this, key activities and key resources can be derived. The named activities have to be carried out to be able to start providing availability-oriented services. During the provision, the customer's workflows have to be known as well as requirements of spare parts and further equipment. Customer specific information helps to reduce machine downtimes and to prevent errors. Further, service calls have to be coordinated, key performance indicators have to be monitored and maintenance schedules have to be planned for the customers. Apart from the possibility of carrying out each of the named activities on their own, it is also imaginable to outsource activities. In case of outsourcing, coordination activities also must be included.

6. Discussion of results and implications

From a customer's perspective, making use of availability-oriented PSS provides several benefits. In case of a machine breakdown, the customer does not have to have employees that are specialized in the different machines and components. Step-by-step introductions support employees that are not technical specialists. Additionally, they have the certainty that the error will be fixed within a predefined period. This allows the customer a better planning of manufacturing. Uncoordinated maintenance activities are avoided what both reduces costs and machine downtimes. It results that maintenance activities are efficiently planned and carried out. Through condition monitoring, further knowledge, e.g. regarding the suitable number of spare parts, can be generated. Partners in the value network have the possibility to win new customers or to strengthen the relation to existing ones. They have the chance to build up know-how e.g. around condition monitoring.

PSS can be designed very differently. Depending on the industry and the customers, the offer and form of provision varies. For example, a small company has not the infrastructure to receive and save large amounts of data. Therefore, it is necessary that the PSS includes a cloud server where the customer has access to. Another point is the sensitivity of data. It varies across companies and must be considered when developing an availability-oriented business model. Concepts for access rights have to be developed. On the one hand, it must be ensured that each participant of the value network has the information needed. On the other hand, privacy concerns must be considered. A possibility is to anonymize data so that it is not possible to relate information to specific customers or machines. A confidentiality agreement between all participants further contributes to privacy.

Generally, the value network plays an important role for the success of such a business model. Depending on the design of the PSS, the participants of a value network must be selected carefully. For service providers there is the risk that a partner of the value network uses shared knowledge to offer availability-oriented services on its own. This would lead to a competitive situation of former partners. As it is usually not possible for a single company to realize an availability-oriented business model, it is important to have partners of trust. In contrast to a value chain, it is possible to work more interactively leading to a more flexible adaption of the PSS. This is advantageous because customer requirements might change over time.

Looking from a research perspective on availability-oriented business models, it is a challenge to design a concept that is suitable for such a complex system. The balance must be found between a general concept that can be applied to many different availability-oriented business models and a concept that is useful for concrete problems in practice. The developed model is designed in a way that it can be used as guideline for developing availability-oriented business models. This is shown within the use case from the capital goods industry. It consists of different steps that can be adapted individually. Nevertheless, it is a helpful model to design that kind of business models. The steps guide the developer through a comprehensive and complete development process. The industrial use case shows exemplarily how the developed concept helps to draw a comprehensive picture of an availability-oriented business model.

7. Conclusions and outlook

This publication presents the validation results of a concept for the development of availability-oriented business models for PSS. In total, five phases support the development process. The concept claims to be generally applicable. For demonstration purposes the concept is applied to a use case from a German manufacturer of drive and automation solutions. Maintenance services are in focus of the use case to avoid and reduce unscheduled downtimes of machines. The use case shows that the concept is valuable to achieve availability-oriented business models.

In further research the concept should be applied to more companies from different sectors. Also, detailed concepts for each phase should be worked out to support the development process. As a new business model is a major step for companies, integration and migration concepts should be considered. Determining key performance indications to evaluate the developed availability-oriented business models is a helpful approach for further research. Extending the presented concept by additional steps would lead to a concept not only for strategically developing business models but also for the implementation phase. Support for continuous improvement should be given to companies since the business models underlie a rapidly changing world due to new technologies and the digitization.

Acknowledgements

This research and development project is funded (funding number 02K14A001) by the German Federal Ministry of Education and Research (BMBF) and managed by the Project Management Agency Karlsruhe (PTKA). The authors are responsible for the content of this publication.

References

[1] Geng X, Chu X, Xue D, Zhang Z. An integrated approach for rating engineering characteristics' final importance in product-service system development. Comput Ind Eng 2010; 59(4): 585-594.
[2] Mert G, Herder CF, Menck N, Aurich JC. Innovative services for customized, availability-oriented business models for the capital goods industry. Procedia CIRP 2016; 47: 501-506.
[3] Belvedere V, Grando A, Bielli P. A quantitative investigation of the role of information and communication technologies in the implementation of a product-service system. Int J Prod Res 2013; 52(2): 410-426.
[4] Kölsch P, Herder CF, Zimmermann V, Aurich JC. A novel concept for the development of availability-oriented business models. Procedia CIRP 2017; 64: 340-344.
[5] Mont O. Product-Service Systems: Panacea or Myth?. Doctoral dissertation, Lund University, Sweden; 2004.
[6] Tukker A, Tischner U. Product-services as a research field: past, present and future. Reflections from a decade of research. J Clean Prod 2006; 14: 1552-1556.
[7] Aurich JC, Mannweiler C, Schweitzer E. How to design and offer services successfully. J Manuf Sci Technol 2010; 3(2):136-143.
[8] Osterwalder A, Pigneur Y. Business model generation: a handbook for visionaries, game changers, and challengers. John Wiley & Sons, 2010.
[9] Meier H, Roy R, Seliger G. Industrial Product-Service Systems – IPS2. CIRP Annals - Manufacturing Technolgy 2010; 59(2): 607-627.
[10] Meier H, Uhlmann E. Hybride Leistungsbündel – ein neues Produktverständnis [in German]. In: Meier H, Uhlmann E, editors. Integrierte Industrielle Sach- und Diensleistungen. Berlin: Springer Vieweg; 2012. p. 1-21.
[11] Eberlin S, Hock B. Zuverlässigkeit und Verfügbarkeit technischer Systeme [in German]. Eine Einführung in die Praxis. Springer Vieweg, 2014.
[12] Zott C, Amit R, Massa L. The Business Model: Recent Developments and Future Research. J Manag 2011; 37(4): 1019-1042.
[13] Köster O. Systematik zur Entwicklung von Geschäftsmodellen in der Produktentstehung [in German]. Doctoral Dissertation, Paderborn: Paderborn University; 2014.
[14] Echterhoff B, Gausemeier J, Koldewey C, Mittag T, Schneider M, Seif H. Geschäftsmodelle für die Industrie 4.0 [in German]. In: Jung HH, Kraft P, editors. Digital vernetzt. Transformation der Wertschöpfung. München: Hanser; 2016. p. 35-56.
[15] Liedtka J, Ogilvie T. Designing for gowth: A design thinking toolkit for managers. Columbia Business School Publishing, 2011.
[16] Brown T. Design Thinking. Harvard business review, 2008 (6).
[17] Scherer JO, Kloeckner AP, Ribeiro JLD, Pezzotta G, Pirola F. Product-Service System (PSS) design: using design thinking and business analytics to improve PSS design. Procedia CIRP 2016; 47: 341-346.
[18] Yoon B, Kim S, Rhee J. An evaluation method for designing a new product-service system. Expert Syst Appl 2012; 39(3): 3100-3108.
[19] Lay G, Schroeter M, Biege S. Service-based business concepts: A typology for business-to-business markets. Eur Manag J 2009; 27(6): 442-455.
[20] Hänsch Beuren F, Gomes Ferreira MG, Cauchick Miguel PA. Product-service systems: a literature review on integrated products and services. J Clean Prod 2013; 47: 222-231.
[21] Clayton RJ, Backhouse CJ, Dani S. Evaluating existing approaches to product-service system design: A comparison with industrial practice. J Manuf Technol Manag 2012; 23(3): 272-298.
[22] Parida V, Sjödin DR, Wincent J, Kohtamäki M. A Survey Study of the Transitioning towards High-Value Industrial Product-Services. In: Procedia CIRP 2014; 16: 176-180.
[23] Kindström D. Towards a service-based business model-Key aspects for future competitive advantage. Eur. Manag. J. 2010; 28(6): 479-490.
[24] Baskerville R, Wood-Harper AT. Diversity in information systems action research methods. Eur J Inf Syst 1998; 7: 90-107.
[25] West S, Di Nardo S. Creating product-service system opportunities for small and medium size firms using service design tools. Procedia CIRP 2016; 47: 96-101.
[26] Aoyama M. Persona-and-scenario based requirements engineering for software embedded in digital consumer products. Proceedings of the 13th IEEE Internation Conference in Requirements Engineering 2005; p. 85-94.
[27] Lemon KN, Verhoef PC. Understanding Customer Experience Throughout the Customer Journey. J Marketing 2016; 80: 69-96.
[28] Sakao T, Shimomura Y, Sundin E, Comstock M. Modeling design objects in CAD system for Service/Product Engineering. Comput-Aided Des 2009; 41(3): 197-213.
[29] Dreyer S, Passlick J, Olivotti D, Lebek B, Breitner MH. Optimizing Machine Spare Parts Inventory Using Condition Monitoring Data. In: Fink A, Fügenschuh A, Geiger MJ, editors. Operations Research Proceedings 2016. Cham, Switzerland: Springer Nature; 2017. p. 459-465.
[30] Olivotti D, Passlick J, Dreyer S, Lebek B, Breitner MH. Maintenance Planning Using Condition Monitoring Data. In: Kliewer N, Ehmke JF, Borndörfer R, editors. Operations Research Proceedings 2017. To be published.