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Transformation Towards Product-Service Systems at the Example of the Wood-Processing Industry

A. Cudok [1,✉], T. Lutz [2] and T. Vietor [1]

[1] Technische Universität Braunschweig, Germany, [2] Michael Weinig AG, Germany

✉ a.cudok@tu-braunschweig.de

Abstract

Offering product-service systems instead of technical products is one way for companies to achieve a competitive advantage and stay viable in the future. This paper presents a workshop series created in cooperation between a manufacturer of wood processing production lines and a research institute for engineering design to develop PSS concepts for a plant. Using the finger jointing line as an example, the progress and results of the workshops are presented. Furthermore, it is discussed whether the workshop series is transferable to other products and industries.

Keywords: product-service systems (PSS), conceptual design, systematic approach, woodworking industry, finger jointing lines

1. Introduction

Producing companies are underlying a volatile, uncertain, complex, and ambiguous (VUCA) environment (Dhir and Sushil, 2018). Challenges arise from ongoing changes in customer requirements, regulations, and influences, such as digitalization and globalization. To keep up with competitors, economic, social, and environmental criteria are of relevance when defining unique selling points for the companies' offerings. In many cases, the transition of business models from selling products to offering product-service systems (PSS) is one opportunity to gain future viability, as examples from the supplier and automotive industry show (Vandermerwe and Rada, 1988; Proff, 2019).

This paper presents a workshop concept that allows producing companies an initial contact with the basic idea of PSS, considering strategic company goals. At the example of a company from the wood-processing industry, the implementation of the workshop is shown and evaluated for further refinement and transferability to other companies. Section 2 of this paper provides essential knowledge about PSS and the product under consideration, a finger jointing production line (FJPL), to prepare the reader for the content of the workshop. The conceptualization of the workshop is presented in section 3, the implementation and results of the workshop are shown in section 4, and section 5 concludes the work.

2. State of the Art

This section gives an overview on the concept of PSS, the evaluation of production plants, and FJPL.

2.1. Product-Service Systems

PSS consist of both (technical) products and services. They are integrated to provide customer value all over the system's life cycle. Various models exist to describe and classify PSS, mostly agreeing on three categories differing in their shares of products and services (Tischner et al., 2002; Tukker, 2004):

product-oriented, use-oriented, and result-oriented systems, cf. figure 2. Tukker (2004) states that PSS by many are seen as "an excellent vehicle to enhance competitiveness and to foster sustainability simultaneously". According to Sundin (2009), manufacturing companies change from offering products to PSS to increase revenues and profitability but also achieve environmental benefits.

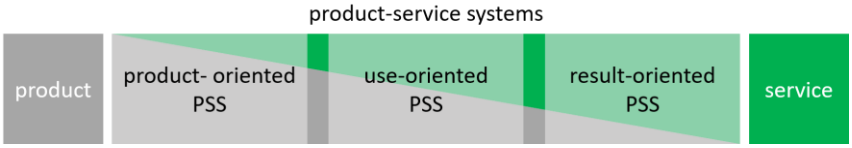

Figure 1. PSS with differing shares of products and services (Tischner et al., 2002)

The three main groups of PSS can be characterized as follows (Tukker, 2004):

a) Product-oriented PSS are characterized by the fact that the product belongs to the customer or user and services, such as the provision of consumables, are added.
b) Use-oriented PSS remain the property of the provider, who hands the product to the customer. Leasing, sharing, and pooling are examples of this category.
c) Result-oriented PSS are strongly service-oriented. Customer and provider agree on an outcome that the provider must achieve.

Three examples are given now to illustrate possible transformations from a product to a PSS.
The first example is a product-oriented PSS by Tchibo, one of Germany's largest consumer goods and retail companies. Started as a coffee trading business, they now offer 'coffee subscriptions'. Customers own a coffee machine free of charge and pay for coffee delivery on a regular basis (Tchibo, 2021).
The second example originates from the mobility sector: Company bike leasing is an example where the product remains the property of the operator (in this case, for example, a leasing company) and is available to the user for a contractually agreed period of time. The provider baron mobility services GmbH is one example of offering bicycles to employees on a monthly pay rate (Bankowsky, 2021).
The third example includes the biggest change from offering a product to offering PSS: Rolls-Royce (2021) as a provider of aerospace engines has introduced a number of services, all collected within a platform called CareStore® to enable customers from Civil Aerospace to choose from. One concept is the result-oriented service called TotalCare®, offering flying hours instead of engines. This pay-by-the-hour concept aims at providing high customer value like predictability and reliability, availability and efficiency. With the concept comes the shift of risks towards Rolls-Royce but also the benefit of reduction of waste and extending the product's service life (Rolls-Royce, 2021).
Summarized, various types of product-service systems are deployed in practice with different shares of products and services integrated. Offering PSS may provide several potentials, often aiming at higher customer value, better customer relations, and, thus, higher revenues. PSS may have a good effect on environmental benefits, too, e.g., enabling Circular Economy.
Different approaches exist for the systematic design of PSS (see, e.g., Pieroni et al. 2016, Scherer et al. 2016, Blüher et al., 2019). The PSS Tool Book from Hellek et al. (2013) has been chosen as one holistic example for conceptualisation of PSS. It divides the process into the four phases of analysis, definition, conceptualisation, and evaluation, taking the four dimensions of value proposition, the user activity cycle, the offering life cycle and the ecosystem into account. Concrete tools are presented that can be used, such as the PSS Audit Matrix to analyse the PSS for modular and complex product and service subsystems, or the Ecosystem Map to visualize, e.g., stakeholders for the PSS. Approaches differ in, e.g., numbers of steps, focus (product / service), detailing of business dimensions.

2.2. Sustainability of Production Lines

For all industries, efficient production facilities are a fundamental prerequisite for economically successful production operations. Making significant investments, customers (as a producer) expect reliable and well-proven production processes. In addition, they expect more and more all-in-one solutions that enable them to produce efficiently, considering both economic and, for some years now, environmental aspects (Jörissen *et al.*, 2008).

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Economic factors are:

- constructive design of the plants with a reasonable degree of automation as a prerequisite for appropriate personnel deployment in production
- efficient plant ramp-up after commissioning and rapid achievement of the target utilization rate
- robust but not oversized design and simple operation to ensure a stable utilization level
- well-thought-out maintenance and servicing strategies

Environmental aspects are:

- energy efficiency - basically by efficient use of production equipment, but also by using specially designed components with, e.g., recuperation features
- stable production processes and, thus, reduction of waste (and quality costs)
- high material yield, e.g., due to minimal loss during processing

Wood as a renewable raw material is becoming increasingly important (Koppelhuber and Bok, 2019), and plants processing solid wood have changed in recent years. While in the past decades, mainly medium-sized sawmills and craft enterprises were sold, large-volume and industrial production has been growing recently. Suppliers record a higher order intake in large-scale plants than in the standard business and stand-alone machines. In contrast to metal or plastic treatment, additional challenges are found in the woodworking processes. A wide range of input parameters such as dimensional and shape tolerances, raw density, wood moisture, and partly hidden defects (knotholes or cracks) require intelligent processes. Referencing the work piece position or additional measurements, such as residual moisture, are required to adjust the process parameters optimally. Furthermore, the use of optical measuring methods is a prerequisite for the "separation of defects" process, and quality grading.
Today, customers of wood-processing plants expect the requirements mentioned above to be fulfilled as standard. A holistic solution also provides the customer with technology that enables him to monitor the complex system according to the criteria and, if necessary, to take corrective action at the right points. Furthermore, the customer demands professional support from planning to end-of-production.
The all-inclusive package for the customer described above is currently not yet consistently offered within the currently changing wood industry. This requires the supplier to rethink and evolve from a machine supplier to a solution supplier, and that, in turn, means adding new business models to the portfolio in which the technology and the services have a similar status.

2.3. Finger Jointing Production Lines

The so-called finger-jointing technique, recognized as the most stable method of longitudinal wood joints, is one of the central processes in solid wood processing, both for the preparation of residual wood and wood upgrading (Weinig AG, 2021). It enables the creation of continuous lengths to produce arbitrarily defined work piece lengths in downstream processes. Furthermore, work pieces from which defects are cut out can subsequently be joined to form a defect-free work piece (KVH, 2019). Work pieces of different lengths are fed to the FJPL to carry out the jointing process, divided into three steps:

- the milling process to create interlocking finger jointing profiles
- the application of glue or adhesive to the profiles
- the mutual pressing of the wooden work pieces

After curing of the adhesive, a high-strength bond is formed, cf. figure 1.

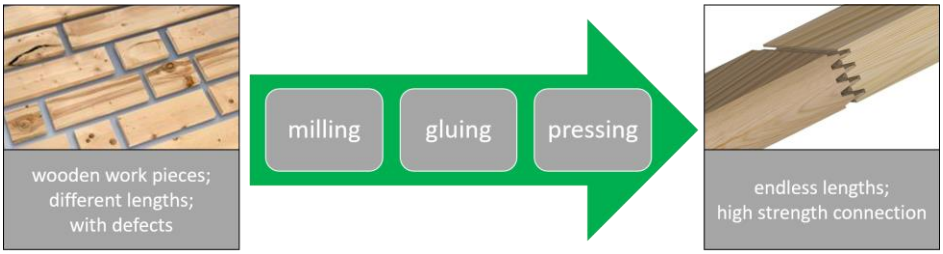

Figure 2. FJPL process including input and output

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The application of finger jointing ranges from small timber dimensions for furniture construction to large dimensions for heavy construction timber. The input material for FJPL are timbers with fixed cross-sections and different lengths, which are, however, limited in minimum and maximum length. Depending on the dimensions and design of the FJPL, this joint can be created at a rate of up to over two hundred times per minute - despite a very imprecisely specified input material. Therefore, producing high-quality output is a significant challenge and requires a high level of process reliability.
In addition to the actual finger jointing process, a downstream cut-to-length process is usually integrated with a FJPL, and fixed lengths with different batch sizes are possible as outgoing material. A FJPL thus represents a self-contained process chain that the customer can use as a stand-alone unit. As a rule, however, the FJPL is an essential component in large production lines, for example, in CLT production (CLT: cross-laminated timber; solid wood panels made of several layers glued together). Furthermore, note that FJPLs mostly consist of mechanical parts, as handling and transportation of wood pieces is the main task. During the last years, the share of electrics and software has increased significantly.
Within the Weinig company, a prescriptive development process exists. However, it includes rather organizational standards than methodical ones. FJPL have been developed by adjusting to customer requirements. Since the FJPL are a manageable and closed system with defined interfaces to the outside, they are ideally suited to be dealt with in a series of workshops to introduce methods to development.

3. Workshop Conceptualization

The necessity of this workshop series originates from a workshop for small and medium-sized enterprises organized by the Institute for Engineering Design as part of a research project that dealt with the transformation of producing companies towards service providers. One core idea was that the future viability of companies depends on this transformation, and some best practices were shown to support this statement. For one of the participants, Weinig Grecon GmbH & Co. KG, a bilateral project has been started to support the company to initiate their way to transformation to PSS offering, and this will be presented as one example for such a workshop series in section 4.
The concept for the workshop series is based on several product development workshops with varying industry partners carried out by the Institute for Engineering Design. Furthermore, PSS design works, such as the above-mentioned PSS Tool Book (sec. 2.1), have been taken into account and a collection of methods and strategies for the development of PSS prepared at the institute was used. The generic workshop concept is presented in the following according goals, participants, structure and methods.

3.1. Determination of Goals and Participants for the Workshop

The workshop's objective is to initiate the PSS transformation process within a company. The following steps should be addressed within the workshop series: 1. The participants should gain a shared understanding and motivation for strategic aims, and the transformation process towards PSS should be recognized as one approach towards it. 2. An initial ideation phase should be run through based on a resilient system analysis to gain an impression of the broadness and potential of transformational solutions. 3. The results should be evaluated within the workshop and offer direct points of contact for further elaboration within the company.
Furthermore, all participants should be actively involved in the whole process and be part of the decision process. The choice of the participants is essential for the PSS transformation process to succeed in the long run, as involving the right people lowers the risk of difficulties that could arise later in implementing the results. Mostly, concepts are expected to concern several subsystems and, thus, departments from the company, such as product and software engineering, service, and innovation management. The applied methods should go hand in hand with the total number of participants.

3.2. Structure and Methods of the Workshop

The workshop has been developed by the Institute for Engineering Design and is structured according to the above-mentioned steps into the three sections *I Goal Definition*, *II System Analysis & Concept Design*, and *III Detailing & Evaluation*, each corresponding to one workshop day taking place within two months. The same structure is used in this paper to explain the concept shown in table 1.

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Table 1. Workshop structure incl. goals and chosen methods

Section	Goal	Methods/Tools
Goal Definition	- introduction ws context & PSS idea - getting to know the participants - shared understanding of the situation & aims - shared motivation for participation	presentation of PSS think-pair-share brainstorming
System Analysis	- system analysis to build foundation for PSS ideation	system boundary definition system context diagram collection of data and information life cycle visualization pain & gain analysis
Concept Design	- understand the broad range of PSS - develop various PSS solutions	presentation of categories & examples variation of 6-3-5
Detailing	- shared understanding of solutions - detailing solutions	recap of solution elements personas, prototyping, blueprint
Evaluation	- systematic evaluation of solutions - conclusion	weighted utility value analysis, SWOT presentation & discussion

3.2.1. Goal Definition (WS I)

Workshop I starts with a presentation of the current research work of the institute to introduce the context for the workshop topic. Future viability and sustainability are introductory topics.
In a further step, an overview of the company's situation and context is used to motivate the workshop: Does it find itself in a VUCA environment, as discussions within SMEs had carried out in the prior to the workshop? The growing strength of competitors and customers' desire for new business models and better services lead to the quintessence: Quality and technology - that have for a long time been unique selling points - are not sufficient for differentiation in the long term. These are often major challenges for the companies.
As one approach to solving such challenges, PSS examples and their potentials like increasing customer value, leverage of economic profitability, closing material loops, or creating and using information flows, are shown to the participants. Success stories of other producing companies show the desired transformation from a producer to a producing service provider.
A partner exercise called 'think-pair-share' initiates the active phase of the participants. The participants are able to get to know each other and share what they already know about product-service systems and ideas. In a further step, the participants introduce their partners to the entire group of participants.
Immediately following, the group moves on to the object of consideration: influences on the product, as well as goals for the workshop are identified in successive brainstorming phases. The first workshop is closed by giving an outlook on further methods, such as utility value analysis and introducing a first collection of criteria for the later concept evaluation.

3.2.2. System Analysis & Concept Design (WS II)

The second workshop aims at developing various and diverse concepts for a PSS. A two-stage process allows a common equal understanding of the system under development before ideating PSS solutions. In the first stage, the foundation for development is laid by analyzing the product. The definition of the *system boundary*, a *system context diagram*, *collection of data and information* within and surrounding the system as well as the *life cycle* and *pain & gain analysis* are analysed or defined to identify potentials within the system. For each method, basic methodical knowledge is introduced and examples from other products are used to clarify their implementation and outcome. One example for theoretical input is the basic concept of systems understanding. The participants get to know the different approaches of describing hierarchical, structural and functional system concepts, taking elements, relations, inputs, outputs and the system's surroundings into account. Another example is a pain and gain analysis along the system's life cycle - or an excerpt of it - to identify potentials for improving user experience.

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Within the stage of conceptualization, first of all, the scope of possible solutions is set to open the solution space and stimulate the creativity of the participants. The concept of PSS as described in section 2.1 is used to visualize the wide range of possible solutions and to motivate solutions with an increasing share of services, targeting use and result orientation.
The ideation process is covered by a variation of the creativity technique 6-3-5 Brainwriting to generate as many ideas as possible in a short time. Within this technique, all participants are generating ideas, giving and getting feedback while passing on and developing further the ideas within the group. The subsequent presentation of the ideas and their elements by all participants concludes the second workshop. After workshop II, the concepts have to be processed and prepared for further detailing.

3.2.3. Detailing & Evaluation (WS III)

Workshop III aims at detailing the concepts developed. Furthermore, the participants shall evaluate them to form a good jumping-off point for strategic decisions. The evaluation is prepared at the workshop's beginning: All participants weigh the previously defined evaluation criteria, e.g., using adhesive dots. By collecting and comparing all participants' opinions, the weighting can be determined for the further course of the workshop.
To start the detailing process of the concepts, they are presented to allow all participants to recapture all solution elements. Then, concepts are further developed in groups, taking the goal features and evaluation criteria into account. For detailing, other brainstorming methods are used and complemented by prioritizing sections within the groups. Next, the groups evaluate the concepts based on a utility value analysis and a SWOT analysis. Subsequently, the finalized concepts are presented in a large round, including the evaluation results. Finally, all participants' discussion of the results prepares the common derivation of a 'roadmap' for the product. A summary of several possible concepts, their strengths and weaknesses, and relevant stakeholders concludes the content part of the workshop.
Finally, feedback is collected on the workshops' structure, content, delivery, and outcomes.

4. Implementation & Results

In the following, the workshop's implementation at Weinig Grecon is presented according to the structure from section 3. Selected results are presented for each workshop section.
The context for this workshop series at Weinig Grecon is that the transformation towards more sustainable production systems is particularly relevant as wood is a renewable resource that becomes increasingly important. For a company developing wood-processing plants, this results in competition for sustainability. The workshop has been adapted to the Weinig Grecon background to take the first step towards PSS. Leaders from mechanical design, product management, software engineering, and service from Weinig Grecon have been chosen to take part. Furthermore, two participants from the superordinate group of Michael Weinig AG from new business and innovation management department have been invited. A total of 12 members of Weinig Grecon and Weinig Group have been chosen to take part in the workshop series.

4.1. Goal Definition (WS I)

Within the first phase, the workshop concept as well as the basic idea and wide range of PSS was introduced by showing several examples of successfully transformed companies. Questions about the examples, e.g., regarding the benefits and the risk shift when switching to results-oriented business models, were clarified directly. The participant's active phase started with brainstorming in small groups, addressing the following key issues: "What goals are to be achieved by new concepts?", "Which target criteria for the evaluation of concepts can be established?" The brainstorming revealed several shared goals, such as differentiating from competitors to continue leading the market (meeting the intended strategic goals). This also includes the goal of being able to anticipate customer requirements to achieve higher customer loyalty, resulting from new USPs, such as increased wood yield. It should even be possible to proactively arouse customer demands. Additional businesses and profits shall result from developing benefit- and result-oriented PSS. Overall, new concepts should improve both the

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economic and environmental properties of the product range. Information from current business (e.g., service cases) shall be used for future developments and different time horizons should be included.
In addition, two other essential characteristics of the company were identified: the mindset for systems thinking and transition from the supplier view to the customer view are prerequisites for achieving the goals. Competition, customers, trends, the company (structure, competencies), and technologies were identified as relevant influences to be taken into account for the transformation to a PSS provider.
As preparation in between the workshops, a list of possible criteria for concept evaluation was shared with all participants. The participants' input has been collected and harmonized before workshop II. Each criterion was given a name, a leading question, and the definition of ratings from 0 to 5. Examples of these criteria are a) Potential additional business; asking 'How high will the additional revenues from added functionalities or services be?' (0 = no additional revenues expected, 5 = high additional revenues expected), and b) Production line availability; asking 'How big is the impact of the concept on line availability?' (0 = no impact expected, and 5 = high increase expected). In total, 15 criteria have been defined and, categorized into 'effort', 'benefit', and 'customer value'.

4.2. System Analysis & Concept Design (WS II)

In the second workshop, focussing on the system analysis and first ideation, the resulting evaluation criteria were presented, and last questions or discrepancies were clarified.
The *system analysis* was used to create a shared understanding of the FJPL. The participants first developed a black box representation with inputs and outputs, internal and external disturbing influences concerning material, energy and information flow. An excerpt of the findings is shown in figure 3.

Figure 3. Excerpt of the findings from a black box analysis of the FJPL

Furthermore, they have put up the FPJL's *system context diagram*, identifying stakeholders and neighboring systems. Exemplary stakeholders come from the operation, assembly (internal and external service personnel), planning (production and manufacturing), purchase (raw wood and spare parts), sales, as well as owners and investors. Possible neighboring systems are conveyor belts, an upstream saw, spin feeder (short wood), tools (e.g., parallel grinding), stacking, other downstream saws, planers, and presses, as well as stacking systems. In addition, the environment, like influences from the production hall, also play a role. Moreover, *data and information* within or surrounding the FJPL was identified. The participants were encouraged to add data and information that might be of interest for stakeholders and that have not yet been exploited. Notable examples are wood quality, moisture, position as the wood enters the plant, and wood yield. Apart from that, the participants understood the FJPL *life cycle*. Touchpoints were identified to serve as starting points for new PSS concepts. Note that two views were derived: customer and provider views. With this comprehensive and detailed knowledge of the system under consideration, the participants started the conceptual design phase. The participants then used a modified form of the creativity technique *6-3-5 Brainwriting*. Up to three ideas per person were passed on within six rounds of 5 minutes to modify them. Afterwards, the participants presented solution elements and got feedback. It could already be determined that the ideas or elements were on different PSS levels. Duplications or similarities, as well as recognizable differences and unique features, were mentioned here. With the collection of the ideas, the second workshop was successfully concluded.
In between workshop II and III, the concepts were processed. Categories were found to develop the ideas further, being *Product Improvements, Production Optimization, Services, and Training*.

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4.3. Detailing & Evaluation (WS III)

The four identified categories were made available to the participants in advance of the third workshop to enter the detailing phase quickly. Within the process, all elements were assigned to the categories as annotated images so that all participants received a complete overview of the solutions.

Before jumping into the detailing phase, the participants weighted the evaluation criteria via dot voting. The highest priorities were for the two criteria of customer benefit and retrofittability. These were followed by scalability for the corporate group (concept should also be transferable to other subsidiaries). It was noticeable here that the economic criteria predominated. The efficiency of the plant at the customer's site as a further criterion has both an economic and an environmental component.

Within four groups according to the categories, the participants further developed the initial ideas, using different creativity techniques like 'Yes, and…', blueprints or prototyping. Towards the end of the detailing phase, the groups evaluated their concepts with the weighted criteria and defined the final concepts' strengths, weaknesses, opportunities, and threats. Finally, they presented their results to all other participants. In the following table, all categories, strengths and weaknesses are presented in brief.

Table 2. Concepts within the four identified categories with selected strengths and weaknesses

Category	Product Improvement	Production Optimization	Services	Training
Concepts	sensors for data acquisition; intelligent interface; standardization of user interface for group; compatibility with other plants; expansion of the product portfolio (upgrades)	data from FJPL (industry 4.0); predictive maintenance; offer status 24/7; run-up support for customers; parameterization according to wood type, quality and dimensions; transfer best practices from other customers	configurator to support pre-planning and planning at the customer's site; simulation of the (whole) FJPL; proposing updates and upgrades on customers' plants → database of plants in operation incl. configuration; cost-benefit analysis for customers	occupational safety, plant planning, troubleshooting, ramp-up, upgrades & updates; goal: qualify employees (customer/Weinig); support by VR techniques; gamification; media (e.g.): video channel/chat, trainings portfolio & calendar, e-learning
Strengths	higher plant availability; scalability; retrofittability; higher process stability	higher cust. value; better cust. relations; scalability; higher plant availability; retrofittability	short term implementability; scalability; USP; high potential for sales increase; better cust.relations	scalability; higher plant availability; high potential for sales increase;
Weak-nesses	low potential for sales increase; high plant complexity	high personnel expenses; high planning effort	high personnel expenses	high personnel expenses (e.g., videos)

In addition, the approach of offering equipment for lease or selling production equipment instead of plants should be mentioned. However, such changes in the business model require enormous changes in the company and are listed separately here due to the significantly longer implementation period.

After the final discussion of the concepts, a recap was given for the whole workshop series. Goals, influences, the PSS understanding as well as possible PSS levels of the FJPL were briefly recalled and the concepts were summarized. Together, the participants derived further steps for Weinig Grecon and the Weinig Group: The concepts developed are to be examined at a strategic level for feasibility, prerequisites (e.g., technical and organizational) and resources (commitment, financial and human resources). To this end, teams involving the relevant departments are to draw up business plans and

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compare them with strategic developments at Weinig Grecon and the Weinig Group. A short-, medium- and long-term roadmap for the FJPL is to be established, including prioritization, scheduling and implementation of the concepts developed here. A feedback round concluded the workshop series.

4.4. Review

The workshop resulted in a shared motivation for transformation towards PSS. The initial concepts are very comprehensive, and cover a wide spectrum (product, production, services, trainings, and business model changes). They therefore have the potential to expand the current offering in the direction of PSS. The participants consider the results to be "realistic and implementable". The prerequisites for many of the concepts are the creation of the necessary infrastructure, a change in mindset of the provider and, to some extent, the customer. Measurable criteria have also been derived for the subsequent evaluation of the concepts, such as the shortening of commissioning times, the reduction of downtimes, or the maximization of wood yield. It can be seen that both economic and environmental characteristics of the FJPL are addressed. The follow-up development of business plans and prioritization of concepts have been stated goals and are seen as a good starting point for further work. For the Weinig Grecon GmbH, it represents a crucial building block for strategic alignment, even scalable for the group.
Some further points of the feedback shall be briefly addressed here: Basic knowledge was introduced a bit too quickly for some of the participants but the examples from other branches have been rated as impressive and inspiring. Approaches found in the workshop were completely new and promising for most of the participants, which was considered very positive. The same applies to the exchange with other departments, understanding their views, and getting to know new aspects of the system.
Nevertheless, PSS business cases are continuously being developed and implemented at Weinig Group in cooperation with customers. The requirements for implementing different business cases are permanently worked on to realize the various possibilities identified in the PSS workshop series.

5. Conclusion

Summarizing this paper, a workshop series has been developed aiming at initiating a company's transformation towards PSS and at giving a first outlook on the range of possible PSS concepts. The workshop series has been taken out in a company developing wood-processing production lines.
The workshop contained the following phases: Goal Definition, System Analysis, Concept Design, Detailing, and Evaluation and has been exemplarily split into three days with preparation and follow-up before and after each workshop. Several methods have been presented supporting each of the phases. Within the application example, a group of 12 participants from different departments (engineering, service, product management, and innovations) has been chosen to take part in it. The common definition of goals, a shared understanding of the system, and basic knowledge from the field of PSS enabled concepts at various PSS levels to be found and evaluated.
Apart from the feedback that has been presented in section 4.4, it can be discussed whether the drawing up of business plans should be part of an expanded series. This step could still be supported methodically to make it easier for the involved company to continue the work afterward. Furthermore, the choice of participants can be discussed depending on the system under development and according to the aims. For example, marketing and sales could be included. Other limiting factors for the workshop in its applied form were: time (three days within the company), focus on one product only, and the requirement that only internal staff was allowed to participate. For further developing the presented approach, the workshop concept to initiate transformation could be expanded, and a variety of methods that has been collected could be used. Therefore, other existing work could be drawn upon, and the repertoire of methods could be brought together, particularly for the initial phase of the transformation process. Scalability of the results needs to be addresses within further activities, and the close coordination with customers is essential when developing or detailing PSS ideas. In the example, a central "New Business & Innovation" department has been installed for the identification, planning and processing of PSS business models. However, for the creation of, e.g., highly complex diagnostic tools, technical requirements in software engineering must be created to develop and implement business models at all. The big challenge here is planning of resources, since currently and in recent years the focus has been on new and more flexible manufacturing processes and individual customer solutions.

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Another direction for the outlook would be to support the long-term transformation of a company (personnel development, change in mindset, competencies) that is necessary for many concepts. This could be a connection point towards research from industrial/organizational psychology.

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References

Bankowsky, R. (2021), "Dienstrad-Leasing: Fahrrad & E-Bike", available at: https://www.mein-dienstrad.de.

Blüher, T., Amaral, D.C., Lindow, K., Costa, J.M.H. and Stark, R. (2019), "Research opportunities in PSS design focusing on the potentials of agile approaches", Procedia CIRP 84, 29th CIRP Design 2019, p. 832-837. DOI: 10.1016/j.procir.2019.04.275

Dhir, S. and Sushil (2018), Flexible Strategies in VUCA Markets, Springer Singapore, Singapore.

Hellek, K., McAloone, T. C., Avlonitis, V., Garcia i Mateu, A., Andersen, J. B., Mougaard, K., Neugebauer, L. and Hsuan, J. (2013), PSS Tool Book: A workbook in the PROTEUS series, PRO-04, Technical University of Denmark. ISBN: 978-87-90416-90-4

Jacob-Freitag, S. (2020), "Hohe Häuser und ganze Stadtviertel als Holzbauten. Das 25. »IHF« zeigt beispielhafte Großprojekte im Wohnbau und ein Kulturzentrum mit Hotel in Nordschweden", Holz-Zentralblatt, 17 January, pp. 48–49. DOI: 10.1007/978-981-10-8926-8

Jörissen, J., Schippl, J., Dieckhoff, N., Gronwald, N., Grunwald, A., Hartlieb, N., Mielecke, N., Parodi, O., Reinhardt, T. and Stelzer, V. (2008), Roadmap Umwelttechnologien 2020: State-of-the-Art-Report, (Kurzfassung), Wissenschaftliche Berichte, FZKA 7425, Karlsruhe, available at: http://bibliothek.fzk.de/zb/berichte/FZKA7425.pdf (accessed 11 November 2021). DOI: 10.5445/IR/270072581

Koppelhuber, J. and Bok, M. (2019), "Paradigmenwechsel im Hochbau. (Holz-)Systembau und Industrialisierung als ökologische Chance und strategische Herausforderung – Perspektivenmodell und Opportunitätenportfolio zur technologischen, ökologischen und wirtschaftlichen Effizienzsteigerung im Hochbau", in Hofstadler, C. (Ed.), Aktuelle Entwicklungen in Baubetrieb, Bauwirtschaft und Bauvertragsrecht, 50 Jahre Institut für Baubetrieb und Bauwirtschaft der TU Graz, Springer Fachmedien Wiesbaden, Wiesbaden, pp. 261–276. DOI: 10.1007/978-3-658-27431-3_19

KVH (2019), "Konstruktionsvollholz KVH® und Balkenschichtholz (Duobalken®, Triobalken®)", in KVH (Ed.), holzbau handbuch, Reihe 4 Baustoffe, Teil 2 Vollholzprodukte, Folge 1, 4th ed., Wuppertal.

Pieroni, M. Marques, C., Campese, C. Guzzo, D. Mendes, G., Costa, J. Rosa, M. Gouveia de Oliveira, M., Macul, V. Rozenfeld, H. (2016), "Transforming a traditional product offer into PSS: a practical application", Procedia CIRP 47, Products-Service Systems across Life Cycle, p. 412-417. DOI: 10.1016/j.procir.2016.03.036

Proff, H. (2019), Multinationale Automobilunternehmen in Zeiten des Umbruchs, Springer Fachmedien Wiesbaden, Wiesbaden. DOI: 10.1007/978-3-658-26759-9

Rolls-Royce (2021), "Our Stories - TotalCare(R)", available at: https://www.rolls-royce.com/media/our-stories/discover/2017/totalcare.aspx.

Scherer, J.O., Kloeckner, A.P., Duarte Ribeiro, J.L., Pezzotta, G. and Pirola, F. (2016), "Product-Service System (PSS) design: using Desgin Thinking and Business Analytics to improve PSS design", Procedia CIRP 47, Product-Service Systems across Life Cycle, p. 341-346. DOI: 10.1016/j.procir.2016.03.062

Sundin, E. (2009), "Life-Cycle Perspectives of Product/Service-Systems: In Design Theory", in Sakao, T. and Lindahl, M. (Eds.), Introduction to Product/Service-System Design, Springer London, London, pp. 31–49. DOI: 10.1007/978-1-84882-909-1_2

Tchibo (2021), "Kaffee-Abos bei Tchibo", available at: https://www.tchibo.de/kaffee-abos-c400004284.html (accessed 12 November 2021).

Tischner, U., Verkuijl, M. and Tukker, A. (2002), First Draft PSS Review: SusProNet Report, draft 15, Delft, The Netherlands, available at: suspronet.org.

Tukker, A. (2004), "Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet", Business Strategy and the Environment, Vol. 13 No. 4, pp. 246–260. DOI: 10.1002/bse.414

Vandermerwe, S. and Rada, J. (1988), "Servitization of business: Adding value by adding services", European Management Journal, Vol. 6 No. 4, pp. 314–324. DOI: 10.1016/0263-2373(88)90033-3

Weinig AG (2021), "Jointing technology with WEINIG. use your residue wood to produce a valuable, high-quality product.", available at: https://www.weinig.com/en/jointing-technology.html (accessed 11 November 2021).