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AN EXTENDED KEY COMPETENCE FRAMEWORK TO MASS CUSTOMIZE AFTER-SALES SERVICES

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Abstract: *A common description of Mass Customization is offering individual, customer-specific product variants with mass production efficiency which targets both at manufacturing and distribution. In order to do so, defined degrees of freedom are introduced into a product model or portfolio which are restricted by choices and decisions a customer makes in a co-design process, e.g. in a product configuration system. Although customization itself is already a value proposition, businesses feel the need to further differentiate from their competitors so that accompanying services, such as in the area of after-sales, become more important. In the present paper, the question is raised how after-sales can be integrated into a MC offering and which concepts and tools are beneficial for this purpose. Therefore, current topics in after-sales, like e.g. predictive maintenance and service assistant systems, are related to the three MC key competences choice navigation, solution space development and robust process design.*

Key Words: ***MC, Service Support Systems, Service Modularization, After-Sales Services***

1. INTRODUCTION

Supplier in many industrial sectors face a demand for individualized offerings and a wide range of customer requirements [1]. Business-to-consumer markets, like apparel or the automotive sector, are examples, where Mass Customization (MC) business models have been successfully implemented [2-3]. These may be understood as hybrid competitive strategies that combine cost leadership and differentiation with respect to defined markets [4]. MC is characterized by three key competences: *Choice navigation* supports customers to identify and specify a solution according to their particular needs and involves them in a co-design process [5, 6]. *Solution space development* defines product models that have defined degrees of freedom in order to be configurable and realize a large external variety that is visible to the customer with an internal variety as small and efficient as possible [7]. Robust process design aims at developing and managing a value network that is capable of efficiently realizing variety in production and distribution [8, 9].

However, MC principles have been successfully applied in business-to-business contexts, e.g. in mechanical and plant engineering [10]. A driver for this is the constant request for better performance and efficiency, which leads to increased variety and cooperative business models in that industrial sector, too [11-13]. In particular, solution space development supports such suppliers in raising the quality of design artefacts, shortening lead-time in development and automate routine design tasks by e.g. knowledge-based engineering systems in order to shift human resources to innovative problem solving [14]. Another application is the use of product configuration systems in pre-sales in order to support sales engineers in decision-making, planning, quotation and calculation [15].

Nonetheless, especially mechanical and plant engineering companies face a shift in their value proposition which sets the focus to accompanying services and after-sales [16-18]. As businesses begin to offer solutions instead of selling products, which is also addressed in the discussion on product-service systems [10], it becomes clear that a long-term perspective regarding technical support, maintenance and upgrading is a new source for generating revenues [19]. Hereby challenging is the rising complexity of the corresponding services as they are subject to e.g. individual use behavior and histories as well as the fact that assets are used in a networked environment [20]. Since MC key competences have already established themselves in product engineering for complexity management [21], the question arises if and how MC can be extended towards after-sales and what are tools to support this.

This article thus examines service provision and supporting tools in after-sales and relates them to the three MC key competences. The research follows the Design Research Methodology (DRM) [22]. Our aim is to develop an initial framework for methods and supporting tools to mass customize service offerings with a focus on after-sales.

The remainder of this article is structured as follows: Section 2 presents the research background with respect to after-sales and service support systems and represents the first descriptive study according to the DRM which is used to understand the research problem and identify influences on it. Section 3 then describes the three MC key competences and the tools that are used for them. After presenting the research method in Section 4, Section 5 then extends this framework towards services. Both sections correspond to the prescriptive study of the DRM, where, relying on assumptions and experiences, a solution to the given problem as well as supporting methods and tools are developed. Afterwards in section 6, this framework is applied to develop mass customized after-sales services within a single case study from mechanical and plant engineering. This is reflected and discussed in the subsequent section 7, which also concludes the article and mirrors to the second descriptive study in DRM.

2. RESEARCH BACKGROUND

The life cycle of industrial machines and plants often spans several years or even decades, where operation must be ensured [23]. For manufacturers of such equipment, new potential for value creation results from product-related services, which range from pre-sales (e.g. technical consulting and planning) over sales (e.g. installation and training) to after-sales (e.g. maintenance and repair) [24]. Leveraging this potential offers important differentiating features for companies in comparison to their competitors [16].

2.1. After-Sales

After-sales services include e.g. supplying the customer with spare parts, carrying out maintenance and repair measures or technical support and training. Thus, they extend and intensify the relationship between manufacturer and customer beyond simply purchasing repeatedly [19]. As such, these services do not only contribute to customer loyalty, but also significantly to revenue and profit in modern industries [25].

Technical services in after-sales have a high level of complexity [26]. Installation tasks follow a plannable, linear process sequence, but maintenance measures have non-linear, dynamic sequences of action [27]. Customer-specific machine configurations, third party components and retrofitting deepen this problem, as individual circumstances and boundary conditions must be taken into account during process execution. In addition, the digitization of products, as currently discussed under the term *Smart Products* [20], introduces a digital degree of freedom, which on the one hand enables new product functions, but on the other hand also further increases the complexity of maintenance measures [28].

The documentation of knowledge required to carry out maintenance measures is often limited and static in form of design and process information, decision trees or fault images. Accordingly, the performance of knowledge-intensive services like performed in after-sales places high demands on the service technician [26].

2.2. Service Support Systems

Service support systems provide relevant information at the point of service to raise work performance. As such, e.g. operating instructions, maintenance histories or fault diagnosis queries are made available in a comprehensive way at the right place and time [26]. Hereby, beneath the actual information system and the data backbone, the tool dimension needs to be particularly considered for two reasons: First, the tool must fit to the use case of the technician, e.g. when he or she needs both hands for measuring current in a control unit, a handheld device is not beneficial for increasing productivity. Second, the tool itself restricts the way in which information can be transmitted and visualized and sets time and space constraints [29, 30].

The use of smartphones and tablets allows, in comparison to paper-based media, to visualize more complex data and interactivity, e.g. querying sensor data directly from the service object and linking error images with repair processes. Due to the heterogeneous landscape of devices, a large variety of product features (e.g. display size, interfaces or interaction mechanisms) is available. In comparison, smart watches are more limited in display size and interaction possibilities, and thus the supply of information, are more limited. For this reason, smart watches are used for visual, acoustic or haptic (warning) messages or work instructions [31]. Head-mounted displays, such as smart glasses, can be operated by speech and gesture recognition without physical interaction and can directly capture the user's field of view via an integrated camera. The display is also located in the field of view, so that the distraction of the information supply during process execution can take place without interruption [32]. A current disadvantage is also the small display area, which limits the variety of applications compared to smartphones, as well as wearing comfort and a low battery life. Augmented reality (AR) glasses are intended to reduce this problem. AR allows the representation of and interaction with virtual (3D) objects directly in the real environment and as such is not limited to a single technology [33]. In the context of service support systems, AR applications on mobile devices as well as on glasses like the Microsoft HoloLens are investigated [34]. Compared to smart glasses, AR glasses have a semi-transparent display with a larger display area and overlays the real environment with virtual objects. The interaction is done by speech recognition or gesture control. Especially early devices are criticized for their low field of view, wearing comfort and inaccurate tracking of input gestures [35]. As mentioned before, the choice of a service support system must always be made for the specific use case. A combination of different devices to compensate the limitations of individual ones is generally possible [36].

Existing research work on service support systems shows that, in addition to the choice of technology, the scope of the system also must be designed flexibly. Kammler et al. [35] have developed an AR assistance system and investigated whether it is suitable for supporting knowledge-intensive services. In addition to taking into account existing requirements for technical customer service and HMD-based assistance systems (e.g. [26, 37]), a modular concept was developed and implemented with the help of service experts. The system can take over the guidance of complex processes and proactively provide information on required spare parts and tools. Through the connection to the service object, sensor data as well as context-sensitive warning messages are displayed in case of e.g. increased temperature. A channel to the back office can be established via a communication interface to provide technical support for process execution. The AR assistance system is perceived as advantageous in the evaluation, but the technology used is criticized with regard to the display area and interaction mechanisms.

Another example shows the application-specific requirements based on the documentation and measurement of chronic wounds in the healthcare sector [38]. Here, hygiene standards and time expenditure pose a particular challenge. The developed tablet application was discarded due to additional disinfection effort and instead an AR application was developed that can be operated without physical interaction.

Current research work is further developing the concepts towards context-sensitive, adaptive service support systems, introduced as *Smart Assistance Systems* [39]. However, the development effort for such systems means that they are not only developed for single individual services, but for a service portfolio.

2.3. Service Engineering

Although services differ fundamentally from physical products since (1) production and consumption coincide, (2) they cannot be stored and (3) are immaterial, services are subject to design and development activities in the field of service engineering. A detailed discussion of service engineering in context of after-sales is beyond the scope of this article, nevertheless the dissemination of methods and tools from product development delivers valuable insights [10, 40]:

In his work about product-service systems, Morelli provides various processes for development, which are mainly based on so-called *blueprints*, i.e. on the workflows and flowcharts of various already successfully planned and executed services [41]. It is inspired by an established process for the development of physical products and software artifacts, which as *templates*. Templates may be understood as a parametric, updatable, and reusable building blocks within a digital prototype [42].

Another product development concept that is applied for service engineering is modularization [43]. Individual services are broken down into numerous elements with corresponding interfaces to provide a basis for personalization [44, 45]. Analogous to product platforms, service platforms have been established to manage the complexity of modular and configurable services, defining standard and personalized service elements and relate them to operational resources [46, 47].

Regarding computer aided design and configuration of services, single approaches have been introduced but the maturity of comparable systems as in the product design domain is not reached yet [10].

Sakao et al. [48] developed the Service Explorer to provide such a computer-aided service modeling tool based on a vendor-consumer system. In this system, first the requirements and the state of a buyer are modeled. Afterwards the transformation rules into a desired state of the consumer follow. This is realized by decomposed functional units of the service provider, similar to the feature-based modeling in geometry design. With the service design catalog, Akasaka et al. [49] provide an extension for the Service Explorer. The catalog described there is developed as a support system for the synthesis of service parts of a product-service system. It provides service modules for functions to be implemented in such a system.

3. FRAME OF REFERENCE

In order to develop a reference framework, existing MC literature reviews have been meta-reviewed [2, 50-54]. This framework is used and extended towards after-sales in the following section 5.

3.1. Choice Navigation

The idea behind choice navigation is that information systems, e.g. a sales configurator, help customers to explore an offering and to specify a product variant that best meets his or her individual requirements. The information system assures that this specification is complete (users without direct product knowledge and expertise can determine all requirements in a structured and intuitive manner) and consistent (conflicting requirements are recognized and resolved) [5]. The following tools are dedicated to choice navigation:

- <u>Sales Configuration</u>: These are a tool to let customers participate in a co-design process. Functionalities include translation from customer requirements into product variant specifications, highlighting differences between multiple variants and aid in decision-making, product visualization, calculation and generation of order documents [54]. As benefit for the supplier, sales configurators allow to track the configuration process and record multiple interactions of the same customer, e.g. to generate purchase suggestions [55].
- <u>Recommender Systems</u>: A recommender system combines the product model that is used in a configuration system with a user model to extrapolate which configurations (or more generally which items) could be of interest for the user. Basis for this may be e.g. demographic data or preferences [56].
- <u>Customer and Customer Relationship Management Systems</u>: These allow for creating a customer collaboration strategy instead of simply keeping records about customer transactions. The supplier uses data acquired during the co-design process to learn about preferences and occasions with respect to purchase decisions. Used in a trust-worthy way, this enables a learning relationship and thus deepens customer relation [57].

3.2. Solution Space Development

Solution space development determines the success in eliminating the contradiction between individual product and mass production efficiency that is required in MC [4]. The solution space defines degrees of freedom, choices and options, which the customer determines during the co-design process [58]. It takes into account responsive production and distribution of product variants and is kept stable over a longer period of time [8]. Regarding the discussion of the design solution space itself, refer to [7]. Solution space development involves, amongst others, the following tools:

- Product Family Design: In order to reduce variant-induced costs, product families share common features and components accross multiple product variants and allow variance only in defined areas or components [59]. Further on, product platforms integrate components and the necessary interfaces which provide basic functions for a large number of product variants [60].
- Modularity: Modules are self-sufficient building blocks that fulfil defined functions and that can be designed, manufactured and validated independently from each other and the later assembled system [61]. Modular designs offers not only the possibility of exchanging faulty modules during maintenance, upgrading the product through improved modules or quickly dismantling a product for disposal but allows for creating a large solution space due to the combination possibilities. Different types of modularity, like e.g. component swapping modularity or bus-modularity, have been proposed [8].
- Design Parameter Variation and Forward-Variance Planning for Multi-variant Products: The concept of design parameters describes geometry based on topology, shape, dimension, count, sequence, tolerances, material and surface finish. In order to explore the solution space, a corresponding design methodology describes alteration rules to these parameters, e.g., changing the sequence of machine elements or to change the topology of a structural component [62]. Based on these design parameters, a specification language for multi-variant products was implemented to combine design parameter variation and solution space development [63, 64].
- Design Prototypes and Templates: A design prototype represents a space where a design artefact may be altered in a defined way and serves e.g. as a template for variant creation [65, 66]. From a computer aided design point of view, such templates accumulate several model elements into a reusable building block of a part or assembly model and implements task-dependent knowledge of previous development projects and a scheme how it is applied to a new situation [43].
- Knowledge-Based Engineering Systems: KBE systems are computer-aided problem-solving tools for engineering tasks that combine computer aided design, object-oriented programming and techniques from artificial intelligence to e.g. automate routine design tasks. Instead of individual product variants, a common master model is set up as an image of the solution space [7].
- Design Automation Systems: As particular type of KBE systems, design automation systems fully automate a design task from specification over conceptual design to detailed design and definition of product and production data [10].

3.3. Robust Process Design

The design of robust processes has two consequences: First, it enables to quickly connect organizational units and resources in order to configure a customer order-specific value creation network [8]. Second, it leads to a description of the portfolio of capabilities of this value creation network and the incorporated manufacturing processes. Fed back into solution space development, it formalizes production knowledge and describes limits of the solution space [7]. Robust process design uses as tools and methods e.g.:

- Postponement: Postponement means to shift the order penetration point towards the end of the production process. All manufacturing stages before may be treated as standard, what raises efficiency [67].
- Cross-domain and Cross-Enterprise Information and Knowledge Sharing: This enables (1) product development to quickly communicate customer requirements, demands and habits with the goal of speeding up new product development and introduction, (2) production to coordinate the supply chain and optimize daily operations and responses and (3) operations and finance to strategically integrate manufacturer and suppliers [68].
- Supply Network Coordination and Management: In order to organize for product variability, manufacturing needs to be set up as flexible, even redundant production units which offer their resources to the organization. Scheduling, decoupling and optimizing the trade-off between variety and costs are the major points of interest here [51].
- Resource-based Configuration: This is a special configuration approach that is dedicated to balancing resource allocation and consumption in a technical system, which can be a product or a production facility. The resource is a conceptualization of a relationship between components and / or their environment [69].
- Product-Process Configuration: This approach uses constraint networks to integrate a domain model of selectable product features and characteristics, product components or features and manufacturing processes used to produce and assemble the individual product variant. When resources such as production equipment and processing times are assigned to a manufacturing process, the selection of a product variant also leads to a configuration of the necessary process chain [70].

4. METHOD

While some of the above approaches from product engineering are applied to make the high complexity of after-sales offers manageable, the MC key competences point at further tools and methods. Their application in Service Engineering can be ascribed to cross-disciplinary theory integration [71].

As such, two aspects in particular need to be considered. On the one hand, the theories to be integrated must follow similar assumptions (compatibility). In the present case, the tools within the disciplines follow a comparable understanding, so that, e.g. the modularization of service and product components is accompanied by the decomposition and definition of interfaces. On the other hand, the concepts used must be comprehensible across disciplines (communication clarity).

By considering preliminary work from service and product engineering, it is ensured that the developed framework meets the requirements of real business cases. As stated above, we follow the DRM, which has already successfully been used for the development of interdisciplinary frameworks and design support tools [22].

With the help of expert interviews, relevant tools and methods were identified to ensure their practical applicability [72], the coding of the results, i.e. the integration in the key competence framework, was carried out by three independent experts.

5. AN EXTENDED MC FRAMEWORK FOR AFTER-SALES

The framework developed here (Fig. 1) integrates the discussion from the research background and enriches it with experiences from pre-studies in the field of service support system integration.

5.1. Solution Space Development of Services

Taking the implementation for traditional product offerings mentioned above as a basis, an implementation for service is defined as follows: The solution space model describes units of service, their corresponding resources and interfaces as well as the composition of such entities to valid service offerings.

Considering the solution space as a container representing the external variety of an offering [7], the service equivalent is a *service catalog* that includes all possible services that a company can provide. As services can be descibed according to Bullinger [40] by product model (what does a service offer?), process model (how is the outcome achieved?) and a resource model (which resources are needed to provide the service?), similar services may be merged into a parametric design: Resources and the process may be written as degrees of freedom, the instantiation of the product model then determines resources and the process accordingly.

Service Engineering offers methods to develop decomposed service parts. *Service modularization* was already charcterized. A specialization of this is the concept of *elementary services*. The assumption is that an elementary service describes a not further decomposable task or action. A service may then be composed by combining and layering of multiple elementary services [72].

In after-sales, a service aims at a state change of an installed physical product, considering its individual history and the individual circumstances for service provision. A simulation can help to raise the quality and speed the service in two senses: First it can be understood as training activity for the later service provision, second it allows to determne long-term and side effects of the service. A supporting concept therefore is provided by the *Digital Twin*, which is to be understood as digital representation of an active unique artefact which records and processes characteristics, conditions and behaviors using suitable models and information systems [73-75]. In the context of solution space development, the Digital Twin supports service engineers as computer aided, and potentially knowledge-based, engineering environment [76].

5.2. Robust Process Design of Services

As robust process design describes the infrastructure to realize variety, the according definition for services is infrastructure for safe execution and orchestration of services as well as provision of required resources.

As discussed in section 2, *service support systems* like smart glasses are a valuable building block in such infrastructures. As central operational resource, matched

	Mass Customization Key Capabilities		
	Choice Navigation	**Solution Space Development**	**Robust Process Design**
Techniques	- Sales Configuration - Recommender Systems - Customer and Customer Relationship Management System - ***Case-based Service Advisor*** - ***Digital Service Portal*** - ***Service-Configuration***	- Product Family Design - Modularity and Parametric Designs - Design Prototypes / Templates - Knowledge-Based Engineering / Design Automation Systems - ***Service Catalog*** - ***Service Modularization*** - ***Elementary Services*** - ***Digital Twin***	- Postponement - Supply Network Management - Resource-Based Configuration - Product-Process-Configuration - Portfolio-of-Capability Modelling - Cross-domain and Cross-Enterprise Information and Knowledge Sharing - ***Remote Monitoring Systems*** - ***Service Support Systems*** - ***Service Platforms***
Implementation for Traditional Product Offering	Product Configurator helps Customers to explore an offering and specify best-matching variant.	Solution space model clearly describes options and degrees-of-freedom as configurable entities.	Supply chain configured from loosely coupled networks of modular, flexible processing units.
Implementation for (After-Sales) Service Offerings	Service configuration allows customer-specific development of highly-responsive and dynamic service offers according to varying conditions.	Solution space model describes units of service, their corresponding resources and interfaces as well as the composition of such entities to services.	Infrastructure for safe execution and orchestration of services as well as provision of required resources.

Fig. 1. *MC Implementation Framework for Product and Service Offerings*

to the task to be fulfilled, they do not only enable information provision, but interacting with the service object (e.g. visualization of sensor data) and interaction with other services as well (e.g. connecting the field technician with the backoffice).

As information system, *digital service platforms* take the role of coordinating required functions and therefore necessary resources. Additionally, such platforms orchestrate service execution.

Regarding interaction with the service object, streaming of e.g. sensor data and diagnosis of operating states is an important factor that supports the technician in making decisions. A *remote monitoring system* allows to track machine data already from the back office and plan service execution already in advance.

5.3. Choice Navigation for Service Offerings

Following the idea that choice navigation helps customers to exactly specify what they want, a corresponding definition is Service configuration allows customer-specific development of highly- responsive and dynamic service offers according to varying conditions.

The concept of the Service Explorer mentioned above is an example for a *service configurator.* Although reasoning capabilities are not reported, the concept uses a model for consumer state change, which could be used as a basis for model-based reasoning.

Another approach that is already in use in practise is the *case-based service advisor*. Like in case-based product configuration, problem and solution, here e.g. the maintenance process, are stored in a database. If an event that corresponds to the problem occurs, the according process can be proposed and executed. It has to be noted that a robust design of such a service-advisor depends on a robust formulation of events, ideally independent from wording (just relying on a combination of sensor data) or using a glossary.

A less knowledge integrative solution is a *digital service portal*, where a customer can overview the services offered for a machine, add services to the contract or organize sequential service execution and e.g. the supply with resources like spare parts.

It is noteworthy that the framework may be used in two ways: On the one hand it allows the implementation of single building blocks, independently from each other, in order to design after-sales services more flexible and more agile. On the other hand, all three key competences are logically linkable. A possible implementation sequence can be found in the following case study.

6. TEST CASE FOR AN AFTER-SALES SERVICE PORTFOLIO IN PLANT ENGINEERING

The implementation framework was tested with regard to its applicability with a medium-sized company from the mechanical engineering sector. The manufacturer of industrial production plants sells its products worldwide to customers from various industries. Due to the heterogeneous requirements, the plants are highly customized for the use case. The product life cycle sometimes spans several decades, during which spare parts supply and maintenance must be ensured. The knowledge about the corresponding service processes is partly documented, but due to oftenly customer-specific problems and partly thirty year old machines installed, it is mainly available by the know-how of the manufacturer's service technicians. In addition to very complex services such as fault diagnosis when the machines are down, classic wear part replacement and maintenance work complement the company's service portfolio. The customer can select these services and their term from a list when purchasing the machine. Spare parts supply, safety stocks and the scope of the maintenance work can be defined individually. The fleet of service technicians processes the specified maintenance dates and is sent to the customer at short notice in the event of unplanned machine downtimes. Due to the high costs associated with such downtimes, the time and quality of service are key targets for the service offering.

A redesign and expansion of the after-sales service offering was initiated in order to aquire additional market share. As indicative objective, the involvement of customers into service provision and the performance enhancement of own service technicians were defined.

The design of the according service system was guided by the proposed framework. As a starting point, the service solution space was determined in the way that existing services were collected and condensed in a service catalog. Afterwards, these services were broken down into modular building blocks in order to be able to configure them according to customer requirements. As far as possible, modules represent an individual process, like component replacement, including necessary resources.

In the next step, the manufacturer defined a role model that described who should be able to perform which service. It was agreed that for less complex processes, like exchanging specific wear parts, the customer should be qualified to perform them as a self-service. For a second group of processes, the customer is to be connected to the local diagnosis center via a video/audio link in order to carry out the fault diagnosis in a cooperative manner and save time.

Then the focus was switched to robust process design and according to the requirements, service support systems were implemented. Having the requirements in the plant in mind, AR glasses were chosen as main tool. In order to guide a customer through a self-service, the manufacturer developed a process visualization that shows each step and which operational resources (tools, spare parts, another helping hand) are needed. A confirmation system was not implemented, the technicias use voice commands to step through the process. In case of an unexpected event, an online link to the back office is possible to involve experts from the manufacturer. The same counts for the replacement of system-relevant components that requires supervision by an experienced service technician using AR glasses. For own service technicians, the manufacturer started to implement a case-based service advisor for fault diagnosis. Also using AR glasses, the technician logs on sensor data and uses the voice interface to navigate through the machine documentation.

Since customers refuse to integrate remote monitoring, the service support systems were designed to communicate directly with the installed machine, e.g. for data streaming. So the AR glasses allow to log on sensors in a guided way and stream data in short range.

As choice navigation tool, the manufacturer implemented a digital service portal. Here, the customers can continuously monitor and adjust their service portfolio. The manufacturer's experience with the machines or that of other customers is incorporated by offering recommendations for the service portfolio.

7. DISCUSSION AND CONCLUSION

The application of the implementation framework offered tools that can be used to make after-sales more flexible. In particular, the interaction of service modules, technologies and the associated complexity are addressed. At the same time, the tools can initially be implemented as isolated solutions, e.g. in the form of a service configurator, so that the existing service business does not have to be replaced in total.

By concretizing causal relationships between the elements in the service solution space, dependencies and information gaps can be identified. The advantages of this approach lie in the agile development of solution building blocks independent of new technologies or service ideas, so that both new customer needs and current trends in service development are taken into account.

Regarding the tool dimension of the service support system, the project has confirmed the iterative nature of such implementation projects. Testing the equipment in the later real environment is a necessary task. For example, technologies such as AR require the adaptation of visualization forms, since they offer only a limited display area and peculiarities of human vision (e.g. blind spots, peripheral vision) have to be taken into account when displaying information [77]. Since these findings often only come to bear during the operation of a new technology or the execution of a service, an adaption and feedback into process design is necessary.

Linking product and service, a knowledge base with service information (processes, sensor data from service objects, error patterns and solution approaches) is successively built up and condensed, which can then be used both for further development of the service support systems and also for the optimization of the product, e.g. the redesign of susceptible component geometries.

A further integration of product solution space and service solution space would then be a logical consequence since service relevant design parameters could directly be fed back and examined regarding their influence on service provision. Vice versa, a targeted maintenance strategy could be used to design the product accordingly. First steps in this direction are currently made in the field of product-service systems [78].

It is apparent that information systems play a central role for offering mass customized services. But in contrast to product offerings, the information system is not only a co-design tool but a central coordination platform for design and operation of the service portfolio. In practical implementation, this means e.g. that the digital customer portal should be in continuous exchange with the service configuration and the configured assistance system in order to operationalize the potential of agile service configuration even outside isolated application areas.

This work is not free from limitations. The services focussed here are technical services from after-sales that have a certain complexity, usually incorporate operational resources and the involvement of human beings in service execution. E.g. financial services are set in a completely different environment and thus will lead to other design tools and support systems.

Furthermore, the main point of interest for the service system was drawn on service execution. Regarding liability and e.g. transparency of accounting, such systems offer potentials as well. With smart glasses, service execution may be recorded or monitored externally. This may be taken as a basis in case of warranty claims etc. Hereby, legal aspects like surveillance of personal must be kept in mind.

From a scientific point of view, the consideration of service engineering is rather not complete. A following extensive literature review might lead to other building blocks for the implementation framework. This is particularly true for the integration of the research area of smart service systems which are understood as assembly of smart products and digital services that represent holistic solutions which are not limited to fulfill a predefined set of customer needs but to adapt to changing requirements over time [79].

Fokussing back on mechanical and plant engineering, the expansion of after-sales services as a differentiation strategy and revenue stream is already being actively pursued in many industries. The role of the customer is shifting from the buyer of a product to the recipient of a service offering tailored to their individual needs. While the adaptation to these needs has already become established in the product area, the customer-specific development and provision of services still poses challenges for companies, so that often only predefined services can be chosen from.

As a design guideline for the implementation of a mass customizable after-sales service portfolio, the implemented framework met the expectations during the project and serves as starting point for the discussion about mass customizing (technical) services.

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