

PSS, industry transformation for sustainability and business. Proceedings of the 7th CIRP Conference on Industrial Product-Service Systems

Business Transformation in the manufacturing industry - How information acquisition, analysis, usage and distribution affects the success of Lifecycle-Product-Service-Systems

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Abstract

Companies in the manufacturing industry are shifting towards a more service-oriented business model. One major challenge of this transformation is the information exchange between the different stages of the product-service-lifecycle. We extend the existing body of knowledge by conducting an empirical study in the German manufacturing industry, addressing the cause-effect relationship between 1) information gathering over the product-service-lifecycle, 2) data analytics 3) interpretation and use of new information and 4) distribution of new product related information and the impact of these four aspects on performance. The analysis reveals five different success factors with a significant impact on innovation and operation excellence. The implications from our research can help to develop new and more practical oriented Lifecycle-Product-Service-System approaches on the one hand. On the other hand it enables companies to focus on activities leading to higher service efficiency. Creating new stimuli will transform their existing business model to a more service-oriented one.

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Peer-review under responsibility of the International Scientific Committee of the 7th Industrial Product-Service Systems Conference - PSS, industry transformation for sustainability and business

"Keywords: Business Transformation; Servitization; Service Lifecycle Management; Success Factors"

1. Introduction

For today's manufacturing industry, the materialized product is losing its former prominence. Tailor-made and business-specific services complementing the product are gaining continuously more relevance [1; 2; 3]. However service is more than another way for manufacturers to achieve additional revenues or a higher market reach. Providing business-related services offers the chance to solve a customers' problem and deliver an individualized solution. This means to substitute a customer internal process or function rather than just to deliver a single service in a single transaction [4]. „Customers do not look for goods or services per se; they look for solutions that serve their own value-

generating processes" [5]. According to Grönroos, this statement very well reflects the need for change towards a solution-centered organization. Differentiating between products and services within companies becomes obsolete, and therefore subsequently needs to become integrated within the specific functions and structures.

Thus, producing companies increasingly link products, parts, after sales services and valued added services such as training, business consulting and engineering services into an integrated solution system to successfully set themselves above competitors.

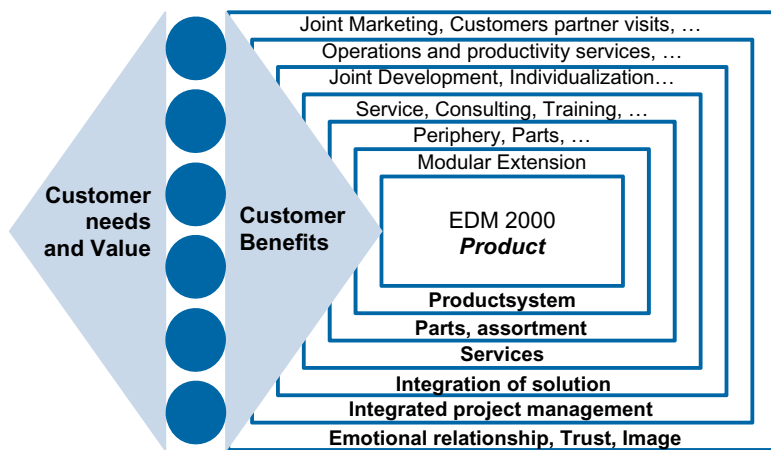


Fig. 1: Solution systems to deliver value to the customer (based on [4])

The underlying strategy in industrial markets is to substitute the subsequent and single offerings by integrated value adding solutions which lead to lasting relationships to closely link providers and customers. The corresponding concept is illustrated in Figure 1.

Additionally the dynamic development of information and communication technology offers new potentials to transfer data from the front-end of the service technician to the early steps of the product development process and vice-versa. This development is boosted by sensors and actuators becoming intelligent and fully integrated in industrial goods. Numerous types of data on an unprecedented quantitative and qualitative level is transmitted and can be used to gain new insights into customer demands and to derive new products and associated service products.

The ongoing “servitization” of the manufacturing industry [6] combined with the increasing information feedback from service applications via smart structures and vice-versa enables new ways to improve the performance of Lifecycle-Product-Service-Systems (LPS²). However, there is still a gap in research according to the design of an adequate information architecture. In particular the exchange of information between customer field services and the product and service development on supplier side is not examined in detail. Thus, the aim of this study is to analyze the cause-effect relationship between 1) information gathering over the product-service lifecycle, 2) data analytics, 3) interpretation and use of new information and 4) distribution of a new product related information and its impact of these four aspects on firm performance.

2. Theoretical Foundations

2.1. Product Service Systems

The term Product-Service-System (PS²) has been discussed in the scientific community for over a decade now [7]. Various definitions are currently existing. A widely accepted

approach [6; 8] was formulated by Goedkoop et al. [9]. They give a first insight of a PS² by first clarifying the meaning of its basic elements:

- A *Product* is a tangible commodity, manufactured to be sold.
- A *Service* is an activity (work), often done on a commercial basis and for others with an economic value.
- A *System* is a combination of elements including their relations.

A literature review conducted by Baines et al. [6] defines PS² as “... an integrated product and service offering that delivers value in use”. The

dematerialization of solution offerings are one of the fundamental ideas of a PS² [11]. An often used approach to develop a PS² is to take the physical product as a starting point [10] and further to start at the early stages of the development phase. This added lifecycle perspective enlarges the concept of a PS² by adding specific life-time stages, reflecting typical characteristics of a product or service. Stark [11] offers a classification of five significant phases a product or service can achieve over its lifecycle. The first phase *imagine* reflects the beginning of the lifecycle and appears just as an idea in people’s heads. The *definition* phase highlights the conversion of the idea into a detailed description. The *realization* phase shows the appearance of a product, service or PS², ready to use by its customers. The *Use and support* phase classifies products or services in their utilization phase. The *retiring or dispose* phase reflects a period when the product or service is no longer requested by the customer.

2.2. Information linkage in PS²

A relevant question is how to optimize the interaction between the different lifecycle phases and in particular, how information from different phases of the product lifecycle affects each other. Important in this context is the information exchange between service technicians in field service operations and their interaction with research and development departments.

A constant exchange of information in both ways fosters the feedback from the field to the origin of the product or service creation process and vice versa [12]. The contacts of service technicians with customers are offering unique ways to gather information and data. Both sites benefit from that exchange. The service technicians are able to access highly exclusive and relevant customer information. Feedback loops between service providers and customers are offering new innovation impulses to develop new product and service offerings [13]. The specific knowledge about individual customers helps to establish unique service offerings, tailored to individual demands.

2.3. Organizational Ambidexterity

A primary target of a successful PS² is to guarantee a high organizational performance. In this paper, we define organizational performance as "... the economic outcomes resulting from the interplay among an organization's attributes, actions, and environment'" [14]. A theoretic foundation of what affects organizational performance can be found in the concept of organizational ambidexterity. The term was first mentioned by Duncan [15] and is nowadays a set expression, describing the ability of a firm to simultaneously exploit existing competencies while exploring new business opportunities [16].

The ability to balance the efforts between efficiency and innovation is elementary to the survival and performance of a company [17]. A view on several studies searching for empirical evidence on the phenomenon validates the correlation between ambidextrous organizations and different subjective levels of performance, e.g. financial or innovation performance [18; 19].

3. Research Model

Based on the given theoretical foundations, we developed a research framework in order to figure out the cause-effect relationship between 1) Information gathering over the product service lifecycle, 2) data analytics, 3) interpretation and use of new information and finally 4) distribution of new product related information and the impact of these four aspects on performance.

In our research approach, we first adapted the performance axis of exploration and exploitation to the service context. Thus we define performance as the ability of a company to be service efficient (exploitive perspective) and to develop new innovative business opportunities in the service sector (explorative perspective) at the same time. A high performance level exists when an organization is able to achieve a high efficiency level, further called service excellence, combined with the ability to explore new business ideas, hereinafter called innovation capability.

In this context, we adapted a typology, based on the work of Sutcliffe et al. [20], that segments the matrix of service excellence and innovation capability into five areas. In our approach, we modified the matrix by using four areas to avoid logical overlapping or misunderstanding in our adapted typology. The applied following four segments characterize specific organizational orientations. Figure 2 visualizes the relationship of the four different areas.

A low efficiency and innovation level is given when an organization moves in a strong *reactive* manner. New business opportunities for service offerings are evaluated on the basis of a defensive and follower-oriented strategy. Concerning the efficiency level, a reactive behavior is characterized by an inhibited and reduced organizational will to create and continuously increase customer value.

The opposite is determined by a *dual* organization. These organizations are able to manage the balancing act of efficiency and innovation efforts in an appropriate manner. A constant search of new business opportunities out of service

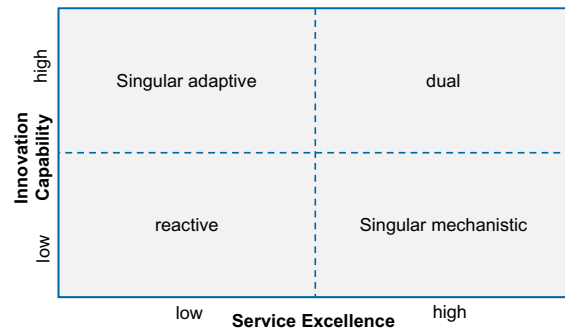


Fig. 2: Efficiency and innovation impact on performance (based on [20])

information feedback combined with a strong impetus to reach a high level of service excellence are characteristics of a dual organization.

Another segment identified is a *singular adaptive* organization that reflects the opposed orientation of the last type, a *singular mechanistic* organization. A singular adaptive service orientation is given when innovation is seen as a key driver for performance but the capability to reach service excellence is not a dominating organizational characteristic. A singular mechanistic organization reflects the contrary perspective.

On the basis of the introduced typology, we postulate ten different success dimensions which describe distinctive characteristics or capabilities of a firm offering PS², that may lead to a higher performance level and that should be typical characteristics of a dual service organization. The success dimensions are formulated as hypothetical statements and declared as followed. The corresponding research model is shown in Fig. 3.

Service efficiency and innovation capability are positively influenced by ...

1. ... the ability to generate product information on the basis of engineering efforts.
2. ...the integration of product and service information for training and qualification issues.
3. ... the acquisition of information from service.
4. ... an integrated central product and service history.
5. ... the extend of information quality.
6. ... the ability to distribute information from service.
7. ... the analysis of changes in service requirements.
8. ... the analysis of changes in product requirements.
9. ... the implementation of changes in service requirements.
10. ... the implementation of changes in product requirements.

The ability to generate product information (1) on the basis of engineering efforts is the foundation for a close interaction between internal engineering and service departments. The integrated interaction between both ends of the value chain helps to create product information that suits individual

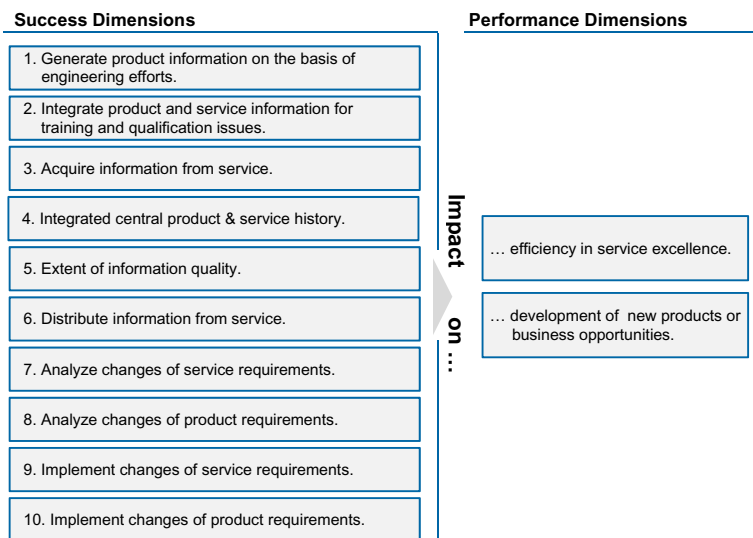


Fig. 3: Research model

customer demands and reduces the often criticized lack of knowledge between both entities.

The capability to integrate product and service information for training and qualification efforts (2) helps to establish a comprehensive knowledge of information insights for both, engineers and service technicians.

The ability to acquire information from service (3) in a structured way and in particular to its full extent is a fundamental competence and therefore mandatory for an intensive information exchange between the different lifecycle phases. Thus, information gathering at the service front-end is the starting point of a successful information loop that fosters service excellence and innovation capabilities in service organizations.

The involvement of an integrated central service and product history (4), we highlighted as a third success factor. A consistent service and product history continuously enlarges the data basis for analytics and helps to reveal possible coherencies and interdependencies.

We also postulate that information quality (5) has a strong impact on the regarded success dimensions. A high intrinsic, contextual, representational and accessible level of specific information characterizes an outstanding information quality [21]. It guarantees a solid information foundation further decisions and actions are based on.

The ability to distribute information from service (6) reflects the ability of the service organization to transmit data under use of a suitable infrastructure and devices to other relevant entities for further analysis.

The analysis of changes in service (7) and product (8) requirements helps to react promptly to upcoming alterations on customer requirements or innovations that are based on technical or market trends. An early analysis of these changes helps to recognize incremental or disruptive drivers that may require an appropriate reaction.

Finally, we hypothesize that beside the analysis, it is also

essential to implement changes in service (9) and product (10) requirements. The ability to realize required actions based on previous analysis efforts is the final step to react to requirement changes in the PS².

We hypothesize that these ten success dimensions are leading to a higher performance level of PS² and the organization itself. We think that these dimensions are reflecting the cornerstones of an intensive information exchange between the service front end and the early stages of a PS² development. By our research model, we analyze the impact of these ten success dimensions on company performance and in particular on the organizations ability to reach a new level of service excellence in combination with the competence to develop new product ideas or business opportunities.

The target is to approve or reject possible interdependencies between the success dimensions and performance dimensions.

4. Empirical study

4.1. Study design

Based on the given research framework, we conducted an empirical study to validate the formulated hypotheses. The underlying data were gathered using a questionnaire. The questionnaires were conveyed to informants from the service department of companies from the German manufacturing industry. The final survey was initially pre-tested to secure the clarity of the given questions. The questionnaire was structured enquiring general information and industry orientation as well as specific dimensions of the service business, in particular the underlying service business model and its underlying success factors. Possible answers were based on four different and disjoint response categories to enhance the reliability of the underlying multidimensional questionnaire [22].

72 surveys were received reflecting a response rate of 3.27%. 25% of the surveys were filled by chief service managers. The amount of 23% was represented by general managers or company owners. 11% of survey participants were group or regional service managers. The rest of 41% accompany other positions. The participating companies have a broad spread in terms of turnover and amount of employees. Most of the sample companies are from the manufacturing industry (74%), followed by the automotive industry with 9%. Other sectors are reflecting 17%. After Europe and North America, most of the companies are operating representative service offices in areas of exceptional growth like PR China or India.

4.2. Statistical approach

The evaluation follows the development and verification of

hypothetic constructs and the use of a linear multiple regression analysis. The applied scales were approved using an explorative factor analysis. Hypotheses were formulated and tested regarding their influence on both performance dimensions, service excellence and innovation capability by use of a linear regression analysis.

5. Findings

Considering the influence on service excellence, we could confirm three out of ten success factors that have a high significant impact.

First, the extent of information quality has a strong significant influence ($\beta=.481, T=4.515, \sigma=.000$) on service efficiency. The same insight could be confirmed for success factor no. 1, the ability to generate product information for service offerings on the basis of engineering efforts ($\beta=.234, T=2.103, \sigma=.039$). The third success factor with a strong impact on service excellence is the ability to acquire information from service ($\beta=-.236, T=-2.080, \sigma=.041$). Other hypotheses concerning service excellence could not be confirmed due to missing significance. Table 1 shows the statistical results of confirmed positive coherencies.

Reflecting the impact on the second performance dimension, innovation capability, we were able to confirm three significant success factors. In relation to the impact on new business opportunities, the involvement of an integrated central product and service history is fostering the innovation capability of a service organization ($\beta=.263, T=2.271, \sigma=.026$). The second confirmed factor we identified is the ability to acquire information from service ($\beta=.222, T=1.898, \sigma=.062$). The third element is the ability to integrate product and service information for training & qualification issues ($\beta=.211, T=1.947, \sigma=.056$). Other former stated hypotheses related to organizational innovation capability, e.g. analyze changes in product requirements could not be confirmed. Table 2 highlights the results.

Taking the results into account, we could emphasize one exposed success factor that in terms of service excellence ($\sigma=.041$) and innovation capability ($\sigma=.062$) has a strong significant impact. The ability to acquire information from service seems to be highly relevant to reach and outstanding service performance level.

Based on the given data base, the impact on service excellence and innovation capability of other success factors, e.g. the analysis or implementation of changes in production and service requirements or the ability to distribute information from service could not be confirmed. Combining the results with the introduced typology of efficiency and in-

Tab.1: Results of linear regression analysis for service excellence

Significant influence on service excellence (Efficiency)	Non Standardized Coefficients		Standardized Coefficients		
	Regression Coefficient	Standard Error	Beta	T	Sigma
(Constant)	1.123E-016	.103		.000	1.000
Extent of information quality	.478	.106	.481	4.515	.000
Product information based on engineering efforts	.234	.111	.234	2.103	.039
Acquire information from service	-.236	.114	-.236	-2.080	.041

Tab.2: Results of linear regression analysis for innovation capability

Significant influence on business opportunities (Innovation)	Non Standardized Coefficients		Standardized Coefficients		
	Regression Coefficient	Standard Error	Beta	T	Sigma
(Constant)	2.049E-16	.106		.000	1.000
Integrated central product and service history	.263	.116	.263	2.271	.026
Acquire information from service	.222	.117	.222	1.898	0.62
Product and service information for training and qualification issues.	.211	.108	.211	1.947	.056

-novation impact on performance, the conducted study reveals five insights for key characteristics of dual, singular mechanistic and singular adaptive organizations. A dual organization is not only able to acquire information from service, but also to reach a high quality level. Also the ability to generate product information on the basis of engineering efforts is a relevant attribute of such an entity. Using acquired data for training and qualification issues can be seen as another important success factor of a dual organization by establishing a comprehensive knowledge for service technicians and field engineers. Finally, an integrated central product and service history continuously enlarges the data basis and supports further analytic approaches. Comparing a dual with singular adaptive or mechanistic organizations, the study revealed that these types only combine certain success factors. The final results are highlighted in Fig. 4.

6. Conclusion

In summary, the exchange of information between the service front-end and the early stages of the development of PS² and vice versa is not known very well. We contributed to that fact by formulating hypotheses that can be used as management guidelines and further as the basis to develop an appropriate information architecture for PS².

We tested these hypotheses in order to identify the variables that have a significant impact on performance in terms of information acquisition, analysis, use and distribution. Based on a questionnaire in the German manufacturing industry, we were able to identify five success factors that have a positive impact either on innovation capability, service excellence, or on both dimensions.

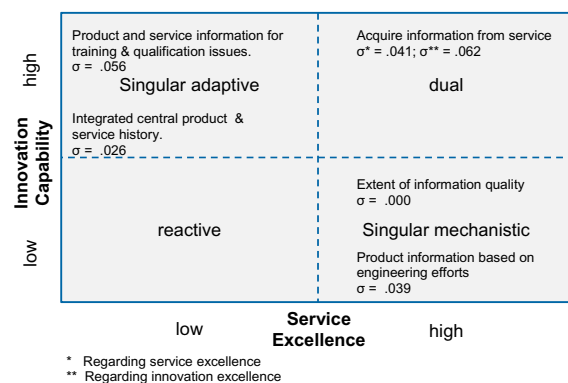


Fig. 4: Study results

Regarding service excellence, we were able to identify the ability to generate product information on the bases of engineering efforts and the extent of information quality as relevant factors.

With reference to the innovation capability, a relevant dimensions is the ability to generate product and service information for training and qualification issues.

Beside that aspect, we identified the ability to establish an integrated product and service history as pertinent to establish explorative organizational skills. Finally, the ability to acquire information from service influences both performance dimensions.

For further research, we suggest that our approach should be adopted to other industries in order to validate our results in terms of robustness and transferability. It may reveal a deeper understanding how information exchange over the lifecycle affects the performance of PS² respective the companies offering PS² and what are the essential and relevant elements of an adequate information architecture.

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