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Product-Service Systems across Life Cycle

Improving PSS Costing based on Customer Integration

[a]Wolfgang Seiringer*, [b]Wolfgang Bauer

[a,b] *Institute of Software Technology and Interactive Systems, Vienna University of Technology, Austria*

* Corresponding author. Tel.: +43-676-7074400 ; *E-mail address:* wolfgang.seiringer@gmail.com

Abstract

A company's economic survivability depends on the trust customers have into the company and its offered solutions. Consequently a company tries to act as a trustworthiness business partner. A difficult task, when customers cannot check the outcome and quality of an offered solution. Especially for Product Service Systems (PSS), the service part represents such an intangible performance, which cannot be used and verified by customers before consumption. Consequently, customers must trust a company's promised performance quality before they can experience the service. Service production always involves the customer into the service provision process, as the value is co-created. That is why, the service provider's performance and thus its service production costs rely trusting a customer's input. As trust plays such an important role we integrate it into service costing. In our work we present and evaluate a risk-based costing approach for PSS. The benefit of our cost model is to include risk factors associated with the trustworthiness of customer input. Our contribution to service science is the computation of service costs by the extension of standard Time-Driven Activity-Based Costing (TDABC) including the expected loss due to customer input. In our work we demonstrate the successful inclusion of trust-based risk factors into service costing to improve service cost management in the context of PSS.

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Keywords: PSS cost model, customer integration, trust, risk-based costing

1. Introduction

Research in Product Service Systems (PSS) grows out as one specialism of service science. One reason therefore is the globalization of markets, which forced companies to add service offerings to their product portfolio. Companies needed to protect their market positions and to differentiate their product portfolios from competitors. A further reason for the need to combine products with services is the increased demand to offer customized consumer solutions, rather than only standardized mass products. Moreover, increased service orientation is caused by the corporative trend to concentrate on core competencies and thus by the outsourcing of activities. So, the combination of products with services gains importance and research in product-service-systems was the consequence [1], [2]. The term PSS is mainly used in B2C context. Industrial Product Service Systems (IPSS) can be seen as a specialism of PSS for all research activities in the context of products and services in the B2B environment. Research is carried out in the fields of innovation and design, production, distribution & sales or even costing and controlling of IPSS [3]. Since the industrial revolution, the research focus has been mainly upon the manufacturing of goods, rather than on the provision of services which lead to a lack of research due to the essential differences of services compared to goods [4].

Considering the service part of a PSS, each company is forced to integrate the customer into service production. Depending on the integration characteristics like e.g. duration, depth or frequency, the customer influences service production and is a main source for uncertainty concerning service performance and service costs. Inexperienced, not motivated and unqualified customers are such risk factors for service performance and the associated service costs. Some motives which influence the quality of customers' participation in a service production process are: personal interaction, information exchange, affective commitment, unique experience, self-serving bias, encouragement of

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creative participation, self-efficacy or interaction fairness. The importance of these factors can vary for each customer. Personal interaction and information exchange have the "… *highest relation with customer participation* …" [5]. Based on the study presented in [5], it can be argued that personal interaction is one essential characteristic of services and indicates the integrative nature of a service during its joint production. A customer must always cooperate, which leads to an information exchange between the provider and customer. The joint service production can help provider and customer to improve existing skills and to develop new capabilities [6].

We observe risk by the possible loss due to bad customer involvement. Such problems occur when customers cannot provide the promised experience, human resources, technology, infrastructure capabilities or information. The concept of operational risks can be used to describe these customer associated risks on service performance. The Basel Committee on Banking Supervision defines operational risks as "… *the risk of direct or indirect loss resulting from inadequate or failed internal processes, people and systems or from external events* ..." [5]. which is an appropriate framework to conceptualize the risk of the external event of customer integration.

For service costing the problem area of customer integration, more precisely, the risks of customer integration and the trust on customer input could need a rethink and extension of existing concepts for service costing. Our paper focuses on the service part of the PSS. We investigate the risk of mandatory customer integration during service production. As a solution to the risk introduced by the customer we present our risked-based service costing approach. Our approach computes the activity time for a service including the potential loss due to customer integration. The computed loss is integrated into the well-known Time-Driven Activity-Based Costing (TDABC) [7].

We claim that the inclusion of customer integration risks will increase the controllability of service costing and provides additional information for service performance measurement. In our paper we show one possibility to include the risk of customer integration into service costing. Including customer related information into a costing method supports companies to react on possible service performance problems and it will help to get more stability into service costs management. Increased accuracy in service costing provides advantages for both customer and provider. Good performing customers' will receive appropriate price discounts. On the other hand, the loss of providers due to bad customer performance will be minimized by the adaption of sales prices. This accuracy should motivate customers in long-term to improve performance, thus increased accuracy in service costing could lead to an overall performance improvement in service industry, which also applies for all PSS.

This paper starts with the relevant literature background to services in general, the perceived risk in customer integration and to trust. We conceptualize customer risk categories based on factors that are useable to assess customer's input. Subsequently, we describe our costing approach and present our evaluation results. Finally we conclude and give an outlook on our further research activities.

2. State of the Art

2.1. Service Science

The definition of services has its roots in service marketing, when scholars identified characteristics that try to distinguish services from goods. To distinguish services from goods the IHIP (intangibility, heterogeneity, inseparability, perishability) characteristics can be used [8]. In general services tend to have IHIP aspects, but do not necessarily need to comply with them completely. In this context we share the opinion of "… *we should not generalize the characteristics of services, but use them when they are relevant and in situations when they are useful and fruitful. We need to understand the conditions under which they apply* ..." [9]. We considered services as a process that transforms input of the provider and particularly input of the customer to the demanded output. An import concept, also in the context of PSS, is Service-Dominant Logic (S-D) proposed by the authors Vargo and Lusch [10]. The worldview of service-dominant logic stands in contrast to the worldview of the goods-dominant logic of the past, as it holds service - the application of competencies for the benefit of others -, rather than goods to be the fundamental basis of economic exchange. One fundamental premises of this approach is that a service is the process of doing something - for and with another party. This concept of "value co-creation" moves the view from being a 'producer' to a collaborative process. Value is co-created with the customer in the service provision process. This argumentation is also applicable regarding the PSS lifecycle, where provider and customer interaction is required.

2.2. Risk Of Customer Integration

Customer integration during service production imposes uncertainties in the service production process. The required input of the customer influences the service performance and the provider's service costs. In general service providers have to manage business processes which additional risks due to customer integration and their consequences on service performance and service costs. In the context of customer integration the concept of perceived risk which was introduced by Bauer in 1960 is important. Bauer argues that a person will experience risk if his/her behavior will produce unanticipated and unpleasant consequences [11]. This concept was further developed by Cunningham (1967). Cunningham described perceived risk with the six dimensions: performance, financial, opportunity/time, safety, social, and psychological loss [12]. Further perceived risks were identified in the literature e.g.: personal or privacy risks. Lim (2003) introduced sources of perceived risk and classified them to "technology, vendor, consumer and product" sources [13].Service providers have to manage risks related to a customer's impact on service production. This type of risk can be classified as operational risks. In the financial sector operational risks are an important aspect, which is also represented by its important role within Basel II [4], [14]

A service provider must integrate customer input and must trust that this is from the expected quantity and quality. Customer input consists of all the tangible and intangible objects, which are necessary during service production and can change over time. For example, a customer ordered a repair service for one device, but in fact three devices arrived at the warehouse. Consensus is present within the literature that trust is required whenever risk, uncertainty, or interdependence exists [15], [16]. The more risk service stakeholders perceive, the more trust they need to agree to a service production. The trust in a customer could be used as indication to the probability that certain risks occur. In the next chapter we explore factors that are used to evaluate the trust in a customer, so that we can consider the risk to trust customer input more profoundly.

2.3. Trust On Customer Input

Important contribution on trust research comes from sociology, (social) psychology, and philosophy [17]. The definition given by Morton Deutsch in 1962 is more widely accepted than many others, which states that "... *trusting behaviour occurs when an individual perceives an ambiguous path, the result of which could be good or bad, and the occurrence of the good or bad result is contingent on the actions of another person ...*" [18].

A customers' service performance is experienced during the service provision process, so it is not known at the time of service costing. Only the customer knows, if he/she is capable or even willing to provide the promised service input. The provider has to trust the consumer. This circumstance leads us to the literature of the "principal agent theory". It says that principal and agent have different goals and it assumes that the information asymmetry between service provider and consumer causes opportunistic behaviour [19]. A recent study [20] concluded, that the most efficient way to overcome the problem of information asymmetry is, to force the service stakeholders to provide the appropriate performance level by legal binding liability clauses.

The marketing mix concept of 4Ps developed by McCarthy's (1964) is one of the core concepts of marketing theory [21], which was developed for manufacturing industries [22]. Booms and Bittner (1981) extended this model for services with further 3Ps': process, physical evidence and participants, which gain widespread acceptance until now [23]. Service marketing argues, that service quality can only be as good as its people, the participants. A service is a performance and it is usually difficult to separate the performance from the people. If the people don't meet expectations, then neither does the services [24]. Consequently, information about customers' people can be used to evaluate customer's trustiness in regard to its promised service input.

Physical evidence plays an important role in service marketing, due to the intangible characteristic of services, tangible clues of the service like facilities, communication material, objects or employees are used to evaluate the trustworthiness of the offered performance. Managing evidence is integral to the service marketing mix [25]. Physical evidences of the customer can be used as indication for customer's trustiness.

The provision of customized solution, as service are, require a lot of customer interaction and are more relationship oriented than business cases with standardised products [26]. We use the relationship to the customer as another determination for customer integration risks, assuming that an experienced bad performance increases the probability for inaccurate future performance.

The exploration to appropriate categories that describe customers' trustiness leads us to the SERVQUAL model [28]. SERVQUAL uses 10 service quality determinants to evaluate, if the perceived service conforms to the expected service quality. One mentioned quality determinant we consider as important, to evaluate customer's trustiness, is the reliability for the security and confidentiality of sensible data and information. The RATER model is a simplification of the SERVQUAL model, which introduced five main categories to evaluate the service quality: Reliability, Assurance, Tangibles, Empathy and Responsiveness. Some parts of these categories are already mentioned, as for example: competences and skills of the involved participants or the importance to describe tangibles. However, the description of the RATER categories served us especially, with the adoption of the evaluation of the empathy of the customer and its responsiveness. Trust is subjective and perceived differently from person to person and even more differently from culture to culture [29]. We assume that the location and culture of the customer are also relevant factors for the determination of perceived trust in the customer.

2.4. Customer Risk Categories

On the basis of our literature review and after analyzing two services of two companies (a software company and a medical manufacturer), we have identified four main categories which we call Customer Risk Categories (CRC). These categories help us to evaluate the customer input a service provider has to trust. We suppose a relationship between trust and the probability of a certain loss occurs, due to a bad performance of the customer. The higher the trust in a customer is, the lower the probability that customer integration causes performance damages. In other words, the higher the trust in the customer, the lower the risk. Customer input is extreme heterogenic and often difficult to identify. Customers provide input in form of tangible and intangible objects, which are required for service production. A tangible customer input is for example, the personal presence during a project meeting or a defect car with a flat tire, which needs a repair service in a garage. Intangible input is experience or information. Independent of the customer input the service provider is forced to integrate it into service production. The risk event we observe is the trustiness of the provided customer input. We have identified following CRC categories: Co-Production, Technology/Resources, Experience and Information. They are always present in a service scenario, while the importance of them can vary between services. For example, customer's provided speed of the internet connection is less important for a repair service than for a remote maintenance tasks a software provider performs. Otherwise, a technological input is very important for a repair service or software engineering, but for consulting or training technology has not such a high impact on service performance. The CRC are important for our cost model as they support the systematic selection of customer input and to compute the associated risk. In Table 1 the CRC are described and we raise some trust related questions to clarify their meaning. The driving question for all four categories is: “Can a service provider trust a customer and its input?”

Table 1.Customer Risk Categories

Co-Production(covers risk concerning frequency, intensity and duration): • Does the customer deliver the committed resources in time and quality? • Is unexpected behavior known from past co-productions?
Resources and Technologies(Covers risks about the capability of resources and technologies): • Are the qualifications of the responsible persons at the customer sufficient to perform the required tasks? • Does a customer has the required quality and educational certifications required to perform specific tasks (e.g. ISO16449 in automotive)? • Does the customer has machines required to fulfill specified tasks?
Experience (Covers risks about a provider’s past experience with customers): • Was the last service co-production profitable? • Is bad experience with a customer known from other business partners?
Information (Covers risks concerning information granularity and information externalization): • How high is the dependency on external information? • Is the provided information detailed enough to solve the service tasks? • Is the required information provided machine readable? • Did the customer provide prompt answers to questions? • Has the customer a problem keeping data confident?

3. A Model for Trust-Based Service Costing

Following section describes our model to compute service costs including the risk of customer integration. The model is based on our hypothesis, that the customer trust level indicates how uncertain customer input is. A customer with a high trust level represents a lower economic risks for service provider compared to a customer with a low trust level. This means, a service provider can be more confident about the forecasted service costs, when he can trust the customer to get the committed customer input. Based on these assumptions, in our model, a customer with a low trust level gets a higher surcharge during cost computation compared to a customer with a high trust level, compare also to Formula 1.

Our model consists of the steps (1) service process modelling, (2) customer interaction point identification, (3) customer input identification and metric selection, (4) regression analysis, (5) risk computation and (6) cost calculation. During the PSS lifecycle these steps will be repeated to adapt them to the actual situation. Adaption can be necessary when the underlying PSS changes, customer performance is not as expected or the correlation between costs and customer input is no longer significant.

For service cost computation we rely on the concept of Time-Driven Activity-Based Costing (TDABC). TDABC is a further development of standard Activity-Based Costing (ABC). In TDABC, time equations are used to calculate the activity time required to perform a service activity e.g. for a repair service this means the documentation of customer complaints, unpacking and cleaning a defective device and repair and maintenance of a returned device. Time is regarded as the main cost driver to measure the effort for service production. A TDABC costing model is easier to update and maintain compared to standard ABC [7], [30].

In this paper we focus on steps 3 to 6. During step 3, the reliability of customer input must be identified to get the basis for risk computation. These customer input should correlate with the service costs. The correlation is important to explain their systematic interdependency and to have meaningful input for the subsequent risk computation. The relevant customer input is selected by the use of the described CRC. Customer input selection is a difficult task as this depends on the analysed service and the relation between customer and provider. We suggest to define for each CRC relevant questions in order to define metrics, which are required as input for a correlation analysis. The fourth steps is used to perform a correlation analysis. Regression analysis is used and necessary to identify the customer input with a statistically relevant correlation to the activity time. We suggest the usage of a linear regression analysis to identify statistically relevant customer input, so that we can compute the risk of a loss by given customer input in step 5. Service costs represented by activity time are computed in step 6.

For our approach we have extended TDABC with the customer integration risk factor $CRFAi$, which is computed per activity. The $CRFAi$ represents the probability to get the required level of customer input and is calculated by dividing the number of positive service production by the total number of service productions at this time. The positive classified service productions are those which fall within a defined forecast error. After $CRFAi$ is computed it is multiplied by the associated loss category. The associated loss category is determined according to Formula 1. For example, a $CRFA1=0.35$ belongs to the severity level “minor”, so the activity time is multiplied by 1.4.

The activity time in hours for a service Si is calculated according to Formula 1, please note that a service can consist of several activities. The $ActivtyTimeAi$ indicates the service activity time in hours, which is part of $ActivityTimeSi$ for service Si. The monetary costs are derived by the multiplication of the $ActivityTimeSi$ by an hourly rate. This hourly rate can be the costs per hour of an employee. In Formula 1, the expected loss is represented by the values 0.2 to 1, which conforms to severity levels (insignificant, minor, significant, major and severe). These severity levels represent the impact of the loss and needs to be adapted to the analyzed service. The usage of risk probability categories (almost certain, likely, moderate, unlikely and rare) and to associate it with its loss using severity levels is a known method from risk management. If a service consists of more than one activity the computed activity times including $RiskCRFAi$are added up.

$$ActivityTimeSi= \quad ActivtyTimeAi*1+RiskCRFAi0.2 insignifi. \quad if \; 0>CRFAi\le 20.4 minor if \quad 2>CRFAi\le 40.6 signifi. \quad if \; 4>CRFAi\le 60.8 major\ if\ 6>CRFAi\le 81 severe\ if\ 8>CRFAi\le 10$$

Formula 1: Risk-based service activity time computation

4. Model Evaluation: Repair Service Scenario

In the following, we describe the evaluation of our risk-based service costing approach. First, we describe the analyzed service case of a medical manufacturer. Afterwards, we present the selected customer input, which is subsequently used as basis to test the quality of our risk-based costing approach.

We have investigated the repair service from a manufacturer producing medical devices for blood analysis. It is an appropriate example for a PSS, as the medical device is first produced and afterwards the after sales repair service can be consumed. If a defect occurs, or also when maintenance is required, the customers can request this repair service. If an active service-level agreement (SLA) exists, or if the customer accepts the repair costs, the repair is carried out at the provider's production site. The costs must be calculated independently from the decision who has to bear them. The defective device is shipped to the manufacturer and the repair is carried out by following process steps: stock receipt, quality assurance, production order, planning materials, commissioning, production (device repair), quality assurance and, shipment of the repaired device to the customer.

During a repair, the customer is involved with the defective device and the problem description. The customer's input is the experience of past repairs, employees with their experiences and competencies. Input data for the subsequent regression analysis was acquired in open expert interviews and through data from the used manufacturing system. In total, 685 finished repair services were selected from the repair database. The selection criteria were: repair service finished, actual costs already calculated and the working costs greater than zero. A repair without working costs can occur, if only spare parts are exchanged and sent to the customer by post.

4.1. Application of Risk-Based Service Costing

The first step, which complies to step 3 of our model, was to identify customer input, which statistically significant correlates with the activity time. This was done by using a linear regression analysis, step 4. We could identify and obtain data for customer input for each CRC. Four statistically significant customer input factors were determined which are: integration duration (CRC co-production), quality of problem description (CRC information), product complexity (CRC resources and technology) and number of finished repairs (CRC experience). Based on our data only these customer inputs are statistically significant related with the actual service costs.

Integration duration: Indicates the length of contact to the customer required during the repair process, the time period from the beginning to the end of the repair process and how long specific resources are tied up in a repair process.

Quality of problem description: Measures the quality of the provided problem description. It is assumed, that the more detailed a problem description is, the higher the quality level is.

Product complexity: Indicates how technically complex the repaired product is. An increasing product complexity also increases the time to repair it.

Number of finished repairs: Indicates the number of completed repair services per customer. The more repairs have been completed with a customer, the more experienced the relationship between customer and provider is.

The statistical significance was tested using six test assumptions. These are independence of observations to get a sound regression model, linearity for the linear relationship between the dependent variable and each independent variable, homoscedasticity, multicollinearity, outlier, leverage point and influential point detection and the presence of normal distribution. The SPSS linear regression output was used to examine the values for R, R^2 and adjusted R^2. R can be between 0 and 1, a value of 0.731 indicates a good prediction level. The R^2 value of 0.535 explains 53.5% of the variability of the dependent variable. More importantly, the adjusted R^2 value of 0.53 means, that the regression model explains 53% of the proportion of variance, which indicates a medium effect size. The effect size, which is explained by Cohen's classification, could be better, but based on the available data it was not possible to find a better model. The final regression equation is:

$$Ac\ iv\ ityTime = -124.453 + 4.201 * problem\_description + 0.054 * integration\_duration - (0.091 * num\_repairs) + (0.088 * product\_complexity)$$

Formula 2: Regression equation.

The above described step of customer factor selection was necessary to obtain meaningful values to test the accuracy of our risk-based costing approach. For each of our 685 records we used the regression equation from Formula 2, output of step 4, to forecast activity time and computed the loss from the difference between the forecasted and the actual activity time. This loss is the basis to obtain our customer risk factor in step 5. Step 6 was the service costing by forecasting activity time including the risk factor.

To verify the quality of our model we split up the input data into two parts. The first 50 records we have used to compute start values, which we have subsequently used to forecast activity time for the remaining 635 values. Accordingly to Formula 1 we have defined service scenario specific values for the loss categories based on our actual data. We have used 2, 4, 6, 8 and 10: 2 means insignificant with a loss between 0 to 20 %, 4 means minor with a loss between 21 and 40 %, 6 means significant with loss between 41 and 60 %, 8 means major with a loss between 61 and 80 % and 10 means severe with a loss between 81 and 100 %. We decided to use 20 % as the limit for a positive service production. The main reason is the high loss we had to deal with. In only 8% of the first 50 records the loss (absolute difference between forecasted and actual activity time) was smaller than 20%. The average loss was 1053 hours and the average loss category was 6.

The final step was to compare the forecast error between the versions without and including the risk factor. This was done for the remaining 635 records. Without the risk factor only 28 (4.45%) service productions have a forecast error smaller than 20%, with an average loss of 321 hours and an average loss category of 7.36. For our risk-based approach we achieved 247 (39.14%) service production with a forecast error smaller than 20 %, the average loss is 145 hours and the average loss category is 4.91. From these results we can conclude an improvement and an increasing accuracy of service costing of 34.69 %.

5. Conclusions

Trust is one core attribute for a sustainable relationship between a company and a service customer. We developed and successfully evaluated a risk-based service costing approach. We have motivated our research by mandatory customer integration and the necessity to trust a customer's input.

Compared to other service costing approaches our costing approach also includes the customer domain. This is done by considering the customer's impact on service production. Consequently our approach is based on the origin of the costs, the customer's performance. The service costing approaches of Time-Driven Activity-Based Costing (TDABC) provides a profound base from the provider's point of view. With our approach we can extend this costing approaches with information related to a customer's performance and behaviour.

In the context of PSS costing our approach is conceptualized to cover the service aspect, with the possibility to integrate it into a complete PSS costing model for a complete PSS lifecycle. When entering the PSS lifecycle a customer provides input and influences the PSS performance. Our costing approach is capable to compute a provider's costs for the changing customer integration all the time a customer is part of the provided PSS. Customer input and participation can change during PSS lifecycle e.g. during the design phase other skilled employees and physical input are required compared to the usage phase. During the usage phase the customer support time will change when a customer involves higher qualified employees. Such a change can increase or decrease the provider's costs. Our approach will detect these changes due to an increasing or decreasing customer risk factor and enables the PSS provider to react on such changes. Over the time a PSS provider will get individual customer integration profiles, which indicate the overall customer performance. These profiles can be used to monitor customers and can also be used for benchmarks between customers.

Based on our evaluation results, we can conclude an increasing controllability of service costs. The evaluation results show the high potential of our risk-based approach. An increasing forecast accuracy of 35 % supports our claim.

Benefits for the service provider are the ability to judge how trustful customer input is, which customer input influences service performance, which quantity and quality of customer input is required or how intensive customer interaction is. All these information can be used to improve human resource and production capacity management - with a direct link to a customer. Customers will benefit from the more accurate cost computations by more realistic prices. A customer getting information about the own service performance can use it to improve the own business processes and to lower the own costs and also for the whole PSS. Customer relationship management gets additional data for complaint management and can communicate why and when problems occur. The next step of our research will be the application of our model to other types of PSS models to confirm our results.

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