Evaluation of customer satisfaction for PSS design

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Abstract

Purpose – Combined offerings of products and services, that is, a product-service system (PSS), have been attracting much attention. Consequently, a good design methodology of services as well as that of manufacturing products is needed. The purpose of this paper, is to propose a method for estimating customer satisfaction that enables designers to compare design solutions in the conceptual stage.

Design/methodology/approach – In the proposed method, first, the models that represent PSS features with relation to a customer’s state is adopted. Then, the authors propose the estimation procedure that utilises a non-linear value function called the satisfaction-attribute (S-A) function to quantify customer satisfaction.

Findings – The proposed method centres on the estimation of customer satisfaction. It enables the designers to evaluate design candidates in the conceptual stage where little information is available, and therefore supports iterative improvements without the designer needing to hesitate under the weight of market analysis.

Research limitations/implications – In this paper, the estimation is limited to a single transaction with a customer, rather than cumulative satisfaction that represents a customer’s imprints about the provider accumulated by repeating purchases. In future, therefore, the authors need to integrate the concept of effects over time such as loyalty and defection into the proposed framework.

Practical implications – In the application, the proposed method is statistically proven to effectively illustrate customer satisfaction.

Originality/value – This paper proposes the estimation method of customer satisfaction for PSS design. The proposed method allows designers to choose a design solution from the customer viewpoints.

Keywords Customer satisfaction, Services, Design for quality

Paper type Research paper

1. Introduction

The offering of products in combination with services by manufacturers as a strategy for retaining their competitiveness has been receiving much attention (Shostack, 1977). Recently, manufacturers must contend with severe market circumstances, namely, diversified customer needs, overheated low-cost competition, and social demand for sustainable development. The product-service system (PSS) is a concept whereby services are additionally offered with products to increase their value (Mont, 2000; Tukker and Tischner, 2006). Services are produced rather flexibly and independently.
from materials compared to products. Therefore, PSS is expected to afford opportunities for manufacturers to differentiate their products by meeting diversely segmented customer needs in a sustainable manner.

The design should involve integrated procedures that can deal with service and products seamlessly. Service and product designs place importance on different points. Service is designed in chains of activities (Teboul, 2006; Shostack, 1984) or policies (Fisk et al., 2004) for employees, whereas products are designed to satisfy consumers by their features (Akao, 1990; Suh, 2001; Kano et al., 1984). We therefore need an integrated methodology for designing PSS to make the combination effective.

The conceptual stage plays an important role in the entire PSS procedure. Implementation of PSS is complicated, because solutions have wider possibilities and services are dynamic and intangible. The conceptual design works as a compass in the implementation. It consists of customer values and features of the offering. Designers make decisions as to how to provide the features according to the conceptual design. Therefore, the conceptual stage defines almost all of the value provided to customers.

For the conceptual design, designers need an evaluation that compares different candidates of the solution. In this stage, the solution should be chosen using the same method customers use, which is according to customer satisfaction. Designers carry out the evaluation depending on their own experience and knowledge, because little information about the customers is available. This conceptual design that depends on the designer rarely creates ideas that are consistent among designers or satisfying for customers. Therefore, designers desire procedures that can analyse customer satisfaction as a consequence of the features, thus enabling quantitative estimation of satisfaction by the candidate solution.

Hence, in this paper we propose a method for estimating customer satisfaction that enables designers to compare design solutions in the conceptual stage. To do so, first, the models that introduce the customer’s viewpoint are adopted. Then, we propose the estimation procedure that utilises a value function called the satisfaction-attribute (S-A) function to quantify customer satisfaction. The proposed procedure is verified through its application to domestic in-flight service.

In Section 2, we review the literature regarding PSSs, service engineering, service marketing and management and product design, and in Section 3, we propose an estimation procedure. We verify the estimation by application to a case study in Section 4. In Section 5, we present our conclusion of the findings and outline a direction for future research.

2. Evaluation of PSS design
2.1 Product-service system
The motivation for developing PSS can be explained from three viewpoints: manufacturer problems, service company productivity and social issues. From the viewpoint of manufacturers, competition circumstances are drastically changing. Periods for product development have shortened recently, so even the latest products have become commodities soon after being produced. In addition, customer needs and preferences have become widely diverse; conversely, demands for a certain product have decreased. From the perspective of manufacturing cost, as a result of low-labour cost in emerging countries, product prices have decreased. Therefore, manufacturers presently crave ways to strengthen their products differentiations.
One approach to developing competitive products is to customise products along individual preferences. Thus, some research studies (Pine, 1993; Hart, 1995; Silveira et al., 2001; Fogliatto and Silveira, 2008) focus on mass customisation of products; however, this method still has problems in terms of production lead-times and cost (Bullinger and Schweizer, 2006). On the other hand, services are produced from the moment they are consumed and materials therefore are flexibly customised to meet customer demand.

What service companies provide are actually PSSs. Some products such as terminals or portable radios are used in the background of their services. Others such as auto teller machines and trains are used during contact points with customers (Tukker, 2004). If PSS research studies can provide ways of communicating with manufacturers, service companies can integrate products effectively and thus, improve productivity.

PSSs are also significant in the context of social issues. In the twentieth century, mass production made people being in easy circumstances through the sale of materialised products. At the same time, however, industrialised countries were confronted with crucial problems such as environmental disruptions, trade frictions caused by decreasing absorptive capacity, and increased resource and energy consumptions. Therefore, a weight shift among industries to produce fewer materials but to add value is required for sustainable advance in the future (Tomiyama, 1997). Services create value without abandoning materials, and continuously create value throughout the entire life cycle. PSSs, therefore, can be an approach to dematerialise products without losing value (Manzini et al., 2001).

As mentioned above, it is well-known that PSSs are inherently superior to the product itself, although few studies have demonstrated their effectiveness (Bartolomeo et al., 2003). One of the reasons for this is that the design methodologies and engineering tools for PSSs have not yet been firmly established (Shostack, 1982; Aurich et al., 2004; Tomiyama et al., 2004). This further implies that there is no systematic method to evaluate a PSS in the design stage.

2.2 Service engineering

Combining services and products is a strategy for competitive product development in a sustainable manner; thus, methodologies for designing PSSs are desirable. We previously proposed service engineering as a discipline for developing design methodologies for PSS (Arai and Shimomura, 2004; Shimomura and Tomiyama, 2005; Sundin et al., 2005; Lindahl et al., 2006; Sakao and Shimomura, 2007). The methodologies consist of models for describing services, design procedures, and a computer-aided design tool.

In service engineering, service is defined as an activity between a service provider and a service receiver to change the state of the receiver (Arai and Shimomura, 2004; Shimomura and Tomiyama, 2005; Sakao and Shimomura, 2007). Note that the term “service” is used in a broad sense, and, thus, the design target includes not only intangible human activities but also tangible products in a similar manner to that of PSS.

According to the definition, a receiver is satisfied when his/her state changes to a new desirable state. Since the value of a service is determined by the receiver, service design should be based on the state change of the receiver. For design purposes, it is necessary to find a method to express the state changes of the receiver. The target receiver’s state in service design is represented as a set of parameters called receiver
state parameters (RSPs) (Arai and Shimomura, 2004; Shimomura and Tomiyama, 2005; Sakao and Shimomura, 2007). RSPs correspond to target parameters in the service design. Any receiver’s state can be defined as an RSP; however, for meaningful design to be realised, RSPs must be observable and related to the concrete requirements of a service receiver. The adequate representation of a service receiver’s requirements with RSPs is one of the most important processes in this service design process.

RSPs are changed by “service contents” and “service channels,” as shown in Figure 1. Service contents are materials, energy, or information that directly changes the receiver’s state. Service channels transfer, amplify and control the service contents. The parameters expressing service contents, which influence RSPs directly, are called content parameters (CoPs). In the same way, the parameters of service channels are called channel parameters (ChPs), and they influence RSP indirectly.

Since PSS has intangible service parts and is more complicated than solely offered services or solely offered products, the conceptual design has a significant role in the entire design of the system, where designers define values the PSS delivers. In addition, the conceptual design needs a model to share ideas within people involved in the offering, since the values should be consistent at all customer contact points.

In service engineering, the models are proposed for conceptual design.

2.2.1 Persona model. The state change of service receivers that is the design target in service engineering should be evaluated from the viewpoint of the receivers. Therefore, service designers need to have a clear understanding of the customers who receive the service. In service engineering, the concept called person (Cooper, 1999) is adopted to describe a representative customer in the form of personal information.

The concept of persona is frequently used in the practical design of software interfaces. The persona is a tool to give a simplified description of a customer and works as a compass in a design process.

2.2.2 View model. A view model is described in terms of the functional relationships among RSPs, CoPs and ChPs. In service engineering, it is assumed that service contents and service channels are comprised of various functions. These functions are expressed by function names as lexical expressions and function parameters (FPs) as target parameters of the functions. Thus, FPs that are directly related to RSPs are identified as CoPs, and those indirectly influencing RSPs are ChPs.

In addition, the realisation structure comprised of CoPs and ChPs is associated with artifacts that actualise the functions in the view model. Artifacts in the view model represent not only physical products but also facilities, employees and information systems.

![Figure 1. The definition of service](image-url)
As shown in Figure 2, the view model works as a bridge from an RSP to artifacts and thus allows service designers to clarify the roles of the artifacts in consideration of the RSP. In these models, customer satisfaction can be considered as the overall evaluation of the service receiver’s preferred state changes, and the states are described by the effects for each feature. Utilising these models, designers can concentrate on features related to customer satisfaction. After choosing the features the service delivers, the designers determine the target quality of the features. In this procedure, the designers must contend with many constraints, including cost, physical interference, service position in the market and provider feasibility. In addition, features differently affect customer satisfaction. For example, a television that has better quality on the very basic features such as safety or low-failure rate hardly satisfies consumers even if its quality exceeds that of other products, while some unnecessary features such as a remote control with superior touch satisfies them (Kano et al., 1984). In this way, the designers come up with ideas for design solutions. We propose here an evaluation that quantifies customer satisfaction based on quality, considering the effects of feature differences on satisfaction.

2.3 Service marketing/management
The service management literature has little discussed the design for services, but rather has discussed methodologies for the analysis of service. Some research has classified services from the standpoint of extent of goods/services or extent of relationship (Lovelock, 1983) and these classifications are helpful for understanding the positions of services in the market. Other research has proposed models for service operations, for example, the service blueprint (Shostack, 1982, 1984, 1987). In this section, we review the relevant literature and discuss it in relation to service design.

Figure 2.
View model of a restaurant service
The service literature includes examination of the structure of customer satisfaction and related elements (Zeithaml, 1988; Bolton and Drew, 1991; Taylor and Claxton, 1994; Wirtz and Lee, 2003). Parasuraman et al. (1988) proposed an evaluation for service organisations utilising customer expectation as the comparison standard. Zeithaml et al. (1995) investigated how service quality and subsequent behavioural intentions influenced customer intentions, such as “pay premium price” and “bring in new customers”. Since services are intangible (Vargo and Lusch, 2004), service attributes are perceived in a different way from what is actually provided. Burton et al. (2003) revealed failures uncontrollable by the provider would little effect customer perception, while Mittal et al. (1999) observed that a change of service or product would affect customer intentions toward the manufacturer or service provider over time.

These approaches analyse covariance structures of attributes, satisfaction, and intentions using consumer questionnaires on specific services. The researchers investigated consumer cumulative satisfaction of repetitive transactions. Evaluation of cumulative satisfaction is helpful for managing service operation and organisation. For design, however, the information derived from the evaluation is too abstractive. Rather, the evaluation for a transaction of service is needed from the service designers.

A service blueprint (Shostack, 1984) describes the stakeholder sequences of activities and interactions in a service transaction. Designers can construct a sequence of activities using the blueprint. However, for creating a complex service or a PSS, the designers need a principle to maintain consistency, and the principle should stand on the customer side. The conceptual design that service engineering provides could be a model for representing the principle.

Models and classifications can reveal what specific services do and where the strengths and weaknesses are in comparison with other services in the market. However, they cannot be used to create or improve services because they are incapable of describing what the sources of value are and how they are implemented. Our evaluation should be consistent with the implications in the service marketing literature, while still describing customer value in a service transaction.

2.4 Product development

In the engineering literature, many theories, procedures, and evaluations for design have been proposed. These methodologies are also demanded for PSS design. PSSs are more complex and dynamic than solely provided products or solely provided services. In addition, designers need to integrate their products and services. A framework for PSS design is therefore required, and it should be one that combines services and products seamlessly. Some engineering methods are considered useful for PSS design, although they should be enhanced for application to services.

Axiomatic design (Suh, 2001) propose design principles needed in conceptual design; it is a methodology about how to think and use fundamental principles during synthesis or mapping between the domains of the design world (Suh, 1995). The principle defined the elements that have respective domains: function requirements (FRs), design parameters (DPs), and process variables (PVs). FRs are a minimum set of independent requirements that completely characterise the functional needs of the design solution. DPs are the elements of the design solution in the physical domain that are chosen to satisfy the specified FRs. In axiomatic design, the designers iterate a process that decomposes FRs and synthesise corresponding DPs, until the design
gathers enough information to be implemented. After the determination of DPs, the process methods to satisfy the DPs are defined as PVs. In product development, after the functions required in the market (FRs) are determined, the next task is to design the physical structure (DPs) to realise the functions, and then find humans and facilities (PVs) to staff and manufacture the products.

In axiomatic design, the design is evaluated according to the two axioms as follows:

1. **The independence axiom.** Under the independence axiom, the design should maintain the independence of FRs. To satisfy a FR with a DP that has effects on several FRs may cause a negative effect on the other FRs. Therefore, designers should associate FRs with DPs so that a DP has an effect on a single FR.

2. **The information axiom.** Under the information axiom, the design should have minimum and efficient information. The output of design contains much information for the production; the information determines the complexity of the post-process, production cost and so-forth. Therefore, in axiomatic design, ideally, the design should maintain the independence of FRs and keep the amount of DPs the same as that of FRs.

Axiomatic design provides a logical and systematic method for creating and evaluating PSS design. In addition, the elements correspond to those defined in the view model of service engineering. Therefore, the principles are applicable to evaluate the logical consistency and the informational efficiency of PSS designs written in the view model. However, the principles are still insufficient to decide the quality of the DPs to suitably satisfy the FRs.

In the context of quality, design for quality (DfQ) is a well-known concept (Hubka, 1992). Research in the DfQ literature is interested in achieving a target quality that is the designer's supposed level of quality, and such research is considered appropriate for delivering a constant quality in services as well. However, the designers still need a methodology to support the process of deciding the target quality, in which they have depended on their knowledge and experience.

Quality function deployment (QFD) (Akao, 1990) is a methodology that enables designers to systematically convert voices of customers (VoC) into engineering characteristics. VoC represents verbalised customer needs, which are synthesised from actual interviews with customers, whereas engineering characteristics correspond to the DPs in axiomatic design. QFD also supports the designer in deciding the specification of the engineering characteristics by making a comparison with competitors' similar products. It utilises a matrix called the “house of qualities” to convert VoC into engineering characteristics.

The approach provides a systematic conversion of consumer analysis into the DPs and therefore reduces the subjective decision making of the designers. However, there is a disadvantage in its application to PSS design; the engineering characteristics are less flexible and prevent the designer from considering alternative ways to satisfy customer needs. This disadvantage comes from the expression of the engineering characteristics, namely their description as physical specifications of the product, instead of functions the product provides. The view model introduces functions to describe the PSS elements and is therefore in some way able to address this disadvantage.

In addition, QFD has a weakness in its principle of planning quality, namely, “the better the quality is, the more the product satisfies the customer”. QFD implicitly
assumes a linear relationship between quality of the engineering characteristic and satisfaction. However, we need to assume a non-linear relationship between quality and satisfaction. Kano et al. (1984) insist that satisfaction a quality level delivers has different inclinations by quality element. Prospect theory (Kahneman and Tversky, 1979) in behavioural economics also insists that cognitive benefit in human decision making is inconsistent with actual benefit. Therefore, the procedure proposed here introduces a non-linear function model that accurately captures the relationship between quality and satisfaction in the customer’s actual perception of a PSS.

3. Estimation of customer satisfaction

3.1 Approach

The evaluation aims to support PSS designers in comparing solution candidates in conceptual design. As a measure for comparing the candidates, we chose customer satisfaction. According to a study that summarised the antecedents and consequences of customer satisfaction (Szymanski and Henard, 2001), customer satisfaction is an integrated indicator of performance, expectation, equity, affect and disconfirmation. In other words, customer satisfaction is considered to be the best indicator for comparing services created or improved by the designers.

Among a sequence of design procedures (Pahl and Beitz, 1988), conceptual design is the stage where an evaluation is supposed to be used. This stage determines the quality criterion, which in turn specifies performance, the best correlated antecedent of customer satisfaction (Szymanski and Henard, 2001). Therefore, the evaluation in the conceptual design stage is a significant procedure in the whole design for delivering improved satisfaction.

The proposed procedure estimates customer satisfaction in a single transaction, rather than cumulative satisfaction. A single transaction is a sequence starting with a customer’s decision to purchase the PSS and ending with the completion of the provider’s commitment. On the other hand, cumulative satisfaction represents a customer’s imprints about the provider accumulated by repeating purchases. Although in the service marketing literature cumulative satisfaction is rather a popular indicator in the evaluation, the evaluation of transaction is more convenient for the purpose of design. The other phenomena not covered in our estimation, such as change in a customer’s comparison standard, are topics for future study.

We utilise a model proposed in service engineering where satisfaction is represented as a change of the service receiver’s state. In the model, the receiver’s state and features of the service are described. The hypothesis that the features change the receiver’s state is consistent with the definition of customer satisfaction, which according to Oliver’s (1997) synthesis of the definitions in the marketing literature is as follows:

Satisfaction is the consumer’s fulfillment response. It is a judgment that a product or service feature, or the product or service itself, provided (or is providing) a pleasurable level of consumption-related fulfillment, including levels of under- or over fulfillment.

The estimation procedure presented here utilises a value function called a S-A function. The S-A function estimates customer satisfaction from a receiver’s state according to the quality of a feature. The function is formulated as an exponential function that is determined as a result of regression analysis on a set of questionnaire data. The expression and details of the procedure now follow.
3.2 Estimation procedure

This section presents our proposed estimation procedure. Figure 3 shows all of the procedural steps in the IDEF0 model (IEEE, 1998), which is a process mapping technique where a square box is an activity and arrows around its four sides show conditions. An arrow approaching a box from the left side represents input information and an arrow moving away to the right side means output. Constraints that control the activity enter from the top side and mechanisms that are means to carry out the activity exit at the bottom side. Details of each activity involved in the procedure are now explained.

3.2.1 Modelling customer. The designers determine a model customer called a persona (Cooper, 1999) in order to clarify for whom the service is designed. The persona contains personality information about the customer, such as his/her objectives of receiving the product/service, the context in which the product/service will be used, and the type of the customer.

For the persona to be effective, it should have detailed and consistent information as if it were a description of a real person. Though the persona is prepared by designers, they can ensure the objectivity of the persona by determining the information for the persona from demographic statistics, qualitative and quantitative data from marketing and so-forth. The information is not necessarily collected exhaustively to represent the persona; the designers need to focus on the information related to the PSS under consideration. The kinds of information about the persona also include strategies of the

![Figure 3. The IDEF0 model of the proposed procedure](image)
provider such as targeting a customer segment in the market and positioning in the
provider’s product or service portfolio.

The designers need to discuss the details and involve people relevant to the
development considering consumer behaviour. This process helps the designers to
determine and share the image of the customer within the design group and with other
parties such as those in sales or marketing. The designers can maintain consistency
during the following procedure by sharing the persona.

Through the following procedural steps, the designers make decisions on the basis of the
persona. If a PSS should be customised to two or more different customer segments, different
personae that fit the segment are needed, and the service model mentioned in the following
section should be prepared separately by the different personae. The important point in
using the persona in the design is to make sure the design is consistent for the persona.

3.2.2 Modelling requirement-features relationship. The service is described in the
view model (Figure 2), which represents the receiver’s state and service features
(Shimomura and Tomiyama, 2005; Arai and Shimomura, 2004). The model clarifies
what to do and how to satisfy the customer. According to the definition of customer
satisfaction (Oliver, 1997), it is a consequence of the quality of the features. It implies
that the view model is suitable for estimating satisfaction by evaluating the features.
The single view model describes a single state, and multiple view models describe a
service. A service is therefore evaluated on multiple scales.

The model has a network structure that represents causal relations between a RSP
and FPs as the features affecting the RSP. In order to describe the model, designers start
by enumerating RSPs. The designers collect VoC in the same segment as the persona.
The voices are classified into groups that are independent and represent the receiver’s
internal state. The groups are labelled and the labels are regarded as the RSPs.

For each RSP, the designers enumerate features that are significant in the relation
with the RSP. RSPs are written in the form of abstract concepts, since they are written
from the viewpoint of the receiver who has little knowledge of the procedures
undertaken in the backstage of service delivers. Therefore, some abstract features
might be raised by the designers. These features are represented as FPs, and then are
decomposed into concrete FPs at the level understandable by the people actually
implementing them into the products or services, in the same manner as conventional
product development (Pahl and Beitz, 1988; Suh, 2001).

The designer needs to prepare the view model for all RSPs in order to evaluate the
whole service. Although view models are descriptions of relationships between
customer satisfaction and antecedent features, the quality of each feature remains to be
represented. The S-A function introduced next expresses the quality.

3.2.3 Obtaining satisfaction-attribute functions. The S-A function \( S_r \) is a value
function, which quantifies the customer satisfaction with an FP \( S_{FP} \) by the quality of an
FP (equation (1)). The designers determine a S-A function for each FP that is directly
related to an RSP. The input value of the S-A function is the quality of an FP supposed by
the designers, and the output is customer satisfaction with the affected RSP. The designer
can suppose a quality and evaluate it using the S-A function. Since designers determine
the quality for each FP under constraints through trial and error, the estimation needs the
function model to be suitable for iterations of suppositions and evaluations:

\[
S_{FP} = S_r(FP \text{ Quality}).
\]
The receiver’s expectations are used as a comparison standard in the estimation. In the service marketing literature, it is accepted that the quality difference from the expectation is perceived as the quality (Anderson, 1973; Tse and Wilton, 1988; Teas, 1994; Parasuraman et al., 1988). The estimation regards that the receiver to be satisfied with a quality level exceeding the expectation, and dissatisfied with a quality level inferior to it. Therefore, the expression of an S-A function is divided into “satisfied” and “dissatisfied” by the expectation.

The required information to determine the actual expression is obtained by questionnaire survey of the receiver candidates. The candidates would be former customers or users of similar services. In both cases, they should have a personality like that of the persona.

Three kinds of information for each FP are necessary to determine an S-A function:

1. **Expectation.** A quality level that the respondent expects at the next transaction. The questionnaire shows the respondents the definition as the quality it would actually be, rather than what it is desired to be.

2. **Quality.** A quality level that the respondent perceived at the last transaction, represented as the same options as the questionnaire for the expectation.

3. **Satisfaction.** A seven-point scale ranging from “dissatisfied” to “satisfied”.

The quality levels are represented as quantitative values if possible. For example, the temperature of a room is expressed in degrees. The respondents are asked to make a choice from options the designer prepared. In cases where it is difficult to express quality by concrete values, the designer must look for another way. For example, the designer could present options that illustrate states of the features and the respondents choose several states that indicates the actual state, such as “polite”, “friendly” or “constructive” as the quality of the FP “staff’s good attitude”. In this case, the number of options the respondent chooses can be utilised as the quantified quality.

The expression is determined by regression analysis for each side of the function. After the questionnaires are completed, the designers have data sets of customer expectation, quality and satisfaction. The expectation data is averaged to obtain a quality value where satisfaction is assumed at zero. The satisfaction data is quantified into $-1$ – dissatisfied to $1$ – satisfied, then pairs of the satisfaction and the quality data are regressed into an exponential function (Figure 4; equation (2)). The obtained expressions are the S-A functions:

$$S_r = a \left[ 1 - \exp \left\{ \frac{-b(v - c)}{a} \right\} \right]$$

**Figure 4.** Regression function of the S-A function
where, \( v \), FP quality; \( a \), this defines max. or min; \( S_r \), value, set 1 in “satisfied” or \(-1\) in “dissatisfied”; \( b \), this parameter is decided by regression analysis; \( c \), this indicates the expectation.

3.2.4 Deciding target quality. Finally, the designers decide several sets of FPs target quality, considering budgets, physical limitations, other constraints and the provider’s strategy. Once the sets of qualities are determined, the S-A functions return the customer satisfaction with the FPs, and total customer satisfaction with the RSP is calculated by the weighted sum of the estimated satisfactions (equation (3)). Here, the weights data \((w_{FP})\) is obtained by another set of questionnaires that ask relative importance of each FP in a seven point scale ratings. Thus, the designer chooses the best idea that maximises satisfaction, minimises cost, passes all constraints and meets the strategy:

\[
\sum S_{RSP} = \sum w_{FP} S_{FP}.
\] (3)

4. Application to domestic in-flight services
The proposed method was applied to domestic in-flight services for verification. In-flight services are typical PSS where a customer evaluates intangible factors as represented, for example, by the flight attendants’ attitude, as well as tangible assets, such as amenities or seats. The purpose of the application is to prove the estimation’s capability to quantify customer satisfaction with both tangible and intangible features.

At first, the persona was decided as a person who usually uses domestic flights for the purpose of business trips, and all questionnaires introduced below were designed with this in mind. Although the requirements on business trips vary depending on his/her gender, age, condition on the flight and so forth, in this application, we limited the questionnaire items to the receiver’s state and the service features that are commonly important for a business person. As a result, the receiver’s state “feel comfortable while seated” was chosen as the target of evaluation. Although, we discuss about only the state “feel comfortable while seated” in this application, the designers should evaluate all the states in the actual development.

We enumerated 25 FPs that affect the receiver’s state and then chosen five significant FPs according to the results of a preliminary questionnaire completed by 25 business people who usually travel on domestic flights. The questionnaire asked the respondents to choose five of the most important FPs from among the original 25 we enumerated. The following five features were selected according to the preliminary questionnaire results:

1. leg space;
2. seat to sit in;
3. personal space to be apart from others;
4. cabin crew’s attentiveness; and
5. silence of space.

Based on the receiver’s state and five features corresponding to the original abstract FPs, we described the view model. Figure 5 shows a small part of the developed model.

Next, we collected the responses of 554 people through an internet research service. The respondents were limited to business people who used domestic flights at least one
time within a year according to the persona. The questionnaire was carried out to obtain the information required for determining the S-A functions and the importance of each FP. The questionnaire comprised four items. Q1 asked the perceived quality of each FP and the corresponding level of satisfaction was revealed by Q2. The expectation of quality was obtained by Q3. Q4 concerned the importance of each FP that is used as weight to calculate satisfaction with the RSP. In Q1 and Q3, quality was represented by a single choice of numeric quality: “cm” for “leg space” and “personal space to be apart from others” and “dB” for “silence of space”. For “seat to fit in” and “cabin crew’s attentiveness”, we prepared options where the respondents could choose multiple options: for example, “hardness of a seat”, “position of arm rests”, “ease to recline” for “seat to fit in”. Quality was represented by difference between the number of chosen comfortable items and chosen uncomfortable items. However, since the impact of each item is not fully equivalent, we regarded the number to represent the degree of goodness in order to quantify quality. In Q2 and Q4, the respondents rated the importance of each feature on a seven-point scale, from 1 – dissatisfied/not important to 7 – satisfied/important.

Table I and Figure 6 show the S-A functions, which were determined for the five features from the obtained data. The functions are divided into “satisfied” and “dissatisfied” by the expectations as explained previously. In Table I, the expectations are determined by averaging the answers from all respondents. “Satisfied” indicates the functions of quality that exceed the expectation, and “dissatisfied” of quality inferior to the expectation. These functions are obtained by regression analysis on pairs of quality and satisfaction data. Here, the satisfaction values obtained by the questionnaires are normalised from – 1 to 1 before being regressed. All the functions are statistically significant. In Figure 6, dots indicate respondents’ answers and lines
<table>
<thead>
<tr>
<th>Function parameter</th>
<th>Expectation</th>
<th>Satisfied side</th>
<th>Regressed equation</th>
<th>Dissatisfied side</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Leg space</td>
<td>18.22</td>
<td>$S = 1 - \exp(-0.03556(v - 18.22))$*</td>
<td>$S = -1 + \exp(-0.0643(18.22 - v))$*</td>
<td></td>
</tr>
<tr>
<td>(B) Seat to sit in</td>
<td>0.8790</td>
<td>$S = 1 - \exp(-0.01418(v - 0.8790))$**</td>
<td>$S = -1 + \exp(-0.1312(0.8790 - v))$*</td>
<td></td>
</tr>
<tr>
<td>(C) Personal space to be apart from others</td>
<td>10.50</td>
<td>$S = 1 - \exp(-0.01187(v - 10.50))$***</td>
<td>$S = -1 + \exp(-0.09445(10.50 - v))$*</td>
<td></td>
</tr>
<tr>
<td>(D) Cabin crew’s attentiveness</td>
<td>1.568</td>
<td>$S = 1 - \exp(-0.5579(v - 1.568))$*</td>
<td>$S = -1 + \exp(-0.03608(1.568 - v))$**</td>
<td></td>
</tr>
<tr>
<td>(E) Silence of space</td>
<td>44.35</td>
<td>$S = 1 - \exp(-0.008366(44.35 - v))$**</td>
<td>$S = -1 + \exp(-0.01290(v - 44.35))$*</td>
<td></td>
</tr>
</tbody>
</table>

Notes: *$p < 0.001$, **$p < 0.01$, ***$p < 0.05$; $v$ is reversed in regression function for FP “silence of space”, since the larger $v$, which indicates noise, leads to dissatisfaction; $N = 554$
Figure 6.
Determined S-A functions
surrounding the dots indicate the number of overlapping data. Solid curves represent satisfaction with the S-A functions and dashed curves represent dissatisfaction.

Figure 6 shows that the non-linear function is necessary to estimate satisfaction. In Figure 6(a)-(e), curves show continuity as well as linear functions. However, Figure 6(c) reduces the incline at the expectation toward satisfied, Figure 6(d) increases the incline toward satisfied. This implies the designer needs different strategy to decide quality considering shapes of the S-A function. For example, different trends between “Leg space” and “personal space to be apart from others” lead to different strategies. Namely, the leg space should be widen as much as possible, meanwhile satisfaction will be little increased if the designer widens the distance from next person.

Finally, we estimated overall satisfaction of each respondent by weighted sum of the estimated satisfaction for each FP. The importance obtained by Q4 was averaged across the respondents, and then normalised within the FPs. Table II shows the weights of the FPs. The respondents answered that they were satisfied with overall services in Q3. Figure 7 is the scatter diagram showing correlations between the stated satisfaction with overall services and the estimated satisfaction. Calculation of Spearman's correlation coefficient revealed that the estimated satisfaction and the overall satisfaction were correlated ($R = 0.66695, p < 0.001$). This implies that the estimated satisfaction has a similar trend to the customers' stated satisfaction, and thus the estimation is applicable to making a comparison of design candidates.

5. Discussion

The evaluation centres on the estimation of customer satisfaction to allow the designer to choose a design solution from the customer viewpoints. For this purpose, we introduced two fundamental models: the view model and the S-A function. The view model illustrates features with relation to a customer’s state change. This principle of the model is effective to let the designer stand in the customers’ shoes. In addition, the description of features, instead of physical specifications, allows designers to seek another way to satisfy customers. The second model, S-A function, provides designers with a systematic method with which to estimate customer satisfaction. It introduces a non-linear model that utilises customer expectation as a comparison standard. It enables the designer to evaluate design candidates in the conceptual stage where little information is available, and therefore supports iterative improvements without the designer needing to hesitate under the weight of market analysis. In addition, the proposed procedure estimates customer satisfaction in a single transaction. It can offer concrete information for design, as opposed to cumulative satisfaction, which is a popular indicator in the service marketing literature.

The estimation was statistically proved to effectively illustrate customer satisfaction through application to an actual case with a sufficient size of data sample. Table III shows

<table>
<thead>
<tr>
<th>Function parameter</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Leg space</td>
<td>0.2113</td>
</tr>
<tr>
<td>(B) Seat to sit in</td>
<td>0.2030</td>
</tr>
<tr>
<td>(C) Personal space to be apart from others</td>
<td>0.2127</td>
</tr>
<tr>
<td>(D) Cabin crew’s attentiveness</td>
<td>0.1911</td>
</tr>
<tr>
<td>(E) Silence of space</td>
<td>0.1817</td>
</tr>
</tbody>
</table>

Table II. Weights of FPs
the comparison between non-liner function and liner function obtained from linear regression analysis. It revealed that the satisfaction of the customer is not necessarily proportional to quality. This implies that non-liner function is suitable for the estimation of customer satisfaction, as opposed to liner function, which is assumed in conventional product development. However, in some FPs, liner function was suitable for estimating customer satisfaction. Therefore, designers need to select either function type depending on the type of FP. With regard to total customer satisfaction of the RSP, the application revealed that the estimated satisfaction was correlated with the satisfaction obtained from the questionnaire. This means that designers can use the proposed estimation procedure in decision making without the need for surveys each time they change the design. Thus, the estimation procedure presented here appears to be applicable to and effective for improving the design of PSSs.

<table>
<thead>
<tr>
<th>Function parameter</th>
<th>Spearmans correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Leg space</td>
<td>0.5593</td>
</tr>
<tr>
<td>(B) Seat to sit in</td>
<td>0.6936</td>
</tr>
<tr>
<td>(C) Personal space to be apart from others</td>
<td>0.4533</td>
</tr>
<tr>
<td>(D) Cabin crews attentiveness</td>
<td>0.5267</td>
</tr>
<tr>
<td>(E) Silence of space</td>
<td>0.3765</td>
</tr>
</tbody>
</table>

Note: $N = 554$
6. Conclusion
The tough circumstances in which businesses are currently operating can be addressed by PSSs. Consequently, as a matter of course, a PSS design is needed that will meet the diversified demands of customers. The design should be applicable to multidisciplinary fields, including engineering, service marketing and psychology. In this paper, we proposed an evaluative method developed by integrating concepts and methodologies scattered across the literature. The evaluation includes the following characteristics:

- evaluates a transaction of a PSS;
- introduces customer satisfaction as the criterion to choose the design solution;
- assumes that PSS designers use the evaluation in the conceptual design stage;
- represents the PSS within a structure of customer state change and features; and
- uses a non-linear value function model to estimate customer satisfaction from features.

In this paper, we limited the estimation to a single transaction. However, for companies producing PSSs, it is necessary to consider the relationship with customers over time. Since customers easily switch to other companies and their preferences show increasing liquidity, companies need to predict and advance their products and services beyond these customer changes. Therefore, in future, we need to integrate the concept of effects over time such as loyalty and defection into the proposed framework, thus allowing the designer to manage customer satisfaction through entire service experience. Other future works include implementation on a software tool to design PSS by using the proposed method more efficiently.

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