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A SERVICE EVALUATION METHOD FOR SERVICE/PRODUCT ENGINEERING

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ABSTRACT
As a result of changes in the way consumers understand and determine value, the high value once placed on typical mass-produced products has diminished. Consequently, a new paradigm must be created to revitalize the global economy. New concepts have emerged which offer partial solutions: Service/Product Engineering (SPE) (formerly called Service Engineering), Product/Service Systems (PSS), Functional Products, and Functional Sales. In this report, a method for evaluating service solutions is proposed. Here, service evaluation is defined as an evaluation conducted by a provider during the design process in order to generate the largest value for all the concerned agents. First, a fundamental definition of service and elements for modeling a service are given. Quality Function Deployment (QFD), used widely in product design, and other mathematical methodologies are then employed. Finally, the proposed service evaluation method is used to evaluate a clothes-washing service in order to demonstrate the effectiveness of the method. In addition, a service evaluation tool based on the proposed method is described. The effectiveness of the proposed method is demonstrated, as is the usefulness of the tool as a structural element of a service CAD system for service design support.

Key words: Service Modeling, Service CAD, Quality Function Deployment, Analytic Hierarchy Process, Dematel Method

1 INTRODUCTION
Manufacturing, an important aspect of the economy in developed countries, is currently in crisis. One reason is that social awareness of environmental friendliness is rapidly increasing, and the manufacturing industry, a major contributor to environmental problems, is facing continuous and growing social pressure to reduce pollution. Another reason for this difficult situation is related to changing customer values [1]. As a result of changes in the way consumers understand and determine value, the high value that was once placed on typical mass-produced products has diminished, which has had a negative influence on social systems built on the paradigm of mass-production, mass-consumption, and mass-disposal, generated by the manufacturing industry over a long period of time. A new social paradigm must be created in order to revitalize the global economy [2]. At the same time, a new role for engineering, traditionally regarded as the systematized study of mass-production technology, is required.
New concepts have emerged which offer partial solutions: Service/Product Engineering (SPE) (formerly called Service Engineering) [3, 4], Product/Service Systems (PSS) [5], Functional Products [6], and Functional Sales [7]. The objective of Service/Product Engineering has expanded to include an engineering method embracing services that create value not only by providing material goods but also by increasing the value of products generated by the manufacturing industry, thereby heightening the social value of the products and achieving a kind of dematerialization. Service/Product Engineering, through its various methodological approaches, can help the manufacturing industry provide value to society by offering low-cost products with high functionality and performance as well as by offering value in a much broader sense through acts of service. By planning the manufacture of optimized products and services, the negative effects of mass-production and mass-consumption can be eliminated.

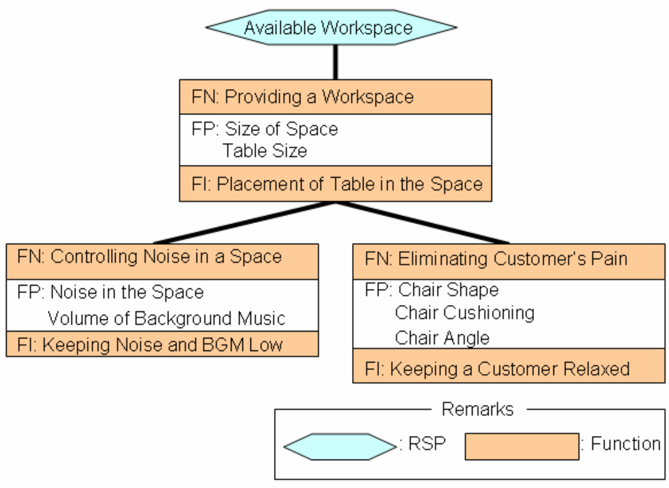

Figure 1. A view model [2]

In a significant achievement for Service/Product Engineering, the authors have succeeded in developing a prototype for service CAD, a computer service design support system which uses a computer to represent service, thus enabling service to be handled as a design object [8]. A fundamental definition of service and a method for modeling service were developed [3]. In this paper, based on the results obtained thus far, a method is proposed which makes it possible to evaluate the computer-constructed service design solutions. In order to conduct service design support through service CAD, the formalization of a service design method and the evaluation of service design solutions, including intermediate solutions, are essential.

In this paper, Service/Product Engineering and the proposed service modeling method are reviewed; additionally, a method is presented by which specific service evaluations can be carried out through the Quality Function Deployment (QFD) [9] method, with some modifications, which is widely used in product design. A service evaluation tool, constructed according to the proposed method, is introduced and shown to be a useful structural element of the service CAD system for service design support.

2 THE SERVICE MODELING METHOD

In Service/Product Engineering, service is defined as the actions that the supplier (provider) performs with the objective of satisfying some, if not all, of the situational changes demanded by the beneficiary (receiver) [3]. This definition assumes that the provision of a service and the change resulting from the service can be expressed by combining the parameters of which the service is composed. The parameters can be classified into those that express the state of the receiver and those that directly or indirectly influence the situational change of the receiver. The parameters that represent the receiver state are called Receiver State Parameters (RSPs). In Service/Product Engineering, a change in the receiver state is represented by a change in an RSP. Furthermore, parameters that are directly involved in the receiver's situational changes through the supply of services are called Contents Parameters (CoPs). Parameters in which the CoPs are used to indirectly influence the RSP are called Channel Parameters (ChPs) [3].

Service/Product Engineering uses a service modeling method consisting of three models, i.e., flow, scope, and view, to represent the various views concerning the service upon which receivers and providers subjectively depend [3]. In particular, the view model takes a single RSP which is targeted by the service being observed and then line up the functions that can facilitate change. A graph is then constructed to describe the connection between the RSP and the functions. The view model takes the receiver's situational change, contents, and channel relationship, which are the structural elements of service, and then describes the functional relationships of the three parameters of RSP, ChP, and CoP. Figure 1 is an example of a view model. In Figure 1, the functions of channels or contents are represented by their lexical expression and the Function Parameters (FPs) as the main target parameters, as well as the Function Influences (FIs) as the main effects on the Function Parameters. Connections are then established which represent the relationship of individual functions to either another function's FP or RSP; in other words, the FP that has a direct relationship with the RSP is the CoP, and the FP that has an indirect link to the RSP through another FP is the ChP.

3 SERVICE EVALUATION USING THE QFD METHOD

In this section, a method is proposed for evaluating service solutions using Quality Function Deployment (QFD) [9], which corresponds to the service modeling method described in Section 2. The proposed method makes it possible to obtain an indicator used in service design by realizing the evaluation of the effect of the service on the receiver through QFD. The view model, which is represented by the graph structure, is converted into a matrix expression. QFD was created to appropriately reflect the Engineering Metrics (EM) of a product, i.e., a product's quality characteristics, to meet the customer's needs, or the Voice of the Customer (VOC). The proposed service evaluation method consists of five steps:

(1) Set the receiver importance
(2) Create a service quality table
(3) Structure the RSP and obtain importance
(4) Derive FP importance
(5) Integrate service quality tables

3.1 Setting the Importance for the Receiver

Generally speaking, service is supplied through a multistage structure involving numerous agents; therefore, when conducting service design, it is necessary also to consider the sufficiency of RSP changes of the different agents. First, all receivers and agents are extracted from the appropriate scope model for the target service in the flow model. Next, with regard to the extracted individual receivers, the Analytic Hierarchy Process (AHP) method [10] is used to establish the importance of the receiver from the provider's perspective. The AHP method is an Operation Research (OR) method used in the course of decision-making based on criteria that are difficult to express numerically. The method is used to determine the relative importance of individual elements on a subjective scale which is converted into a value in order to perform quantitative decision-making.

3.2 Creation of a Service Quality Table

Next, a service quality table is created. The RSP showing the receiver state as a service evaluation component corresponding to the VOC and EM in the existing QFD is placed on the y-axis. The FP showing the manifestation rate of the functions related to the RSP is placed on the x-axis. Distinguishing features are affixed to the observed service by pairing the RSP and the corresponding FP. The RSP and FP can then be extracted using the given description of the view model.

3.3 Structuring the RSP and Obtaining Importance

When evaluating a target service solution, RSP weighting is carried out using the AHP method in order to decide which RSP is to be counted. In RSP weighting, if there are different abstract RSP levels within the target service solution, restructuring must be carried out in order to arrange the abstract levels. Once that is done, RSPs with abstract levels on an equal level of hierarchy are compared and their weights allocated.

3.4 Deriving FP Importance

The next step is to establish the relationship of the RSP and the FP. Since the existence of a relationship between RSP and FP parameters is a given, the main purpose of this step is to describe the Relational Strength (RS) on a quality table. By taking the data of the RSP weight and the RS between the RSP and FP, the importance of each FP is obtained using the formula defined by QFD.

3.5 Integrating Service Quality Tables

The next step is performed after individually creating service tables for each receiver using steps (2) through (4). Based on the importance previously set for each receiver, the individual quality tables are integrated in order to determine which FP should have the most importance within the service contained in the scope model.

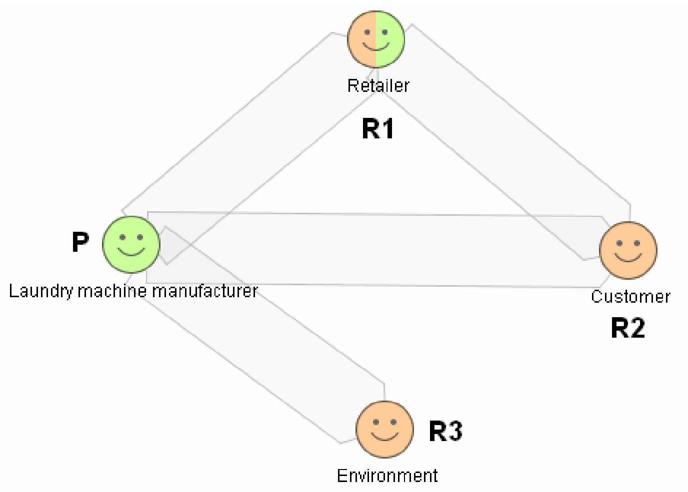

Figure 2. Flow model for the clothes-washing service

3.6 Example

Based on the evaluation method described above, an evaluation example is shown for the clothes-washing service (providing clothes-washing functions through the supply of laundry machines). A laundry machine manufacturer, a retail store, a customer who uses a laundry machine, and the global environment were set as the agents related to this service. The flow model and scope that these agents are composed of were also set. The global environment was included as an imaginary agent in order to express the evaluation of the environmental aspect of the service. In relation to the above flow model, four scopes were set with the laundry machine maker as a provider (Figure 2). For each part, receiver and RSP weighting was performed, and an evaluation model was constructed. The results are shown in Table 1 and Figure 3. Each FP is listed in the left-hand column of Table 1. The numerical symbols that start with "R" represent the agents related to the appropriate FP. In the same manner, on the right-hand side of Table 1, the importance of each FP is listed. As shown in Table 1, by using the proposed method and taking the emphasized receiver and the RSP as input, it is possible to derive the importance of each FP included within the service-realizing structure. In this example, the results of which are shown in Table 1, the customer was set at the highest priority level. We confirmed that it is possible to take in evaluation data for multiple receivers of the service through the flow model and scope settings of the proposed method.

Table 1. Results of clothes-washing service evaluation (FP importance)

FP	Importance	FP	Importance
R2: Variety of washing functions	11.3	R2: Detergent action	3.0
R2, R3: Water consumption	10.0	R2: Number of buttons	2.5
R1: Manufacturing cost of laundry machine	8.3	R2: Deterioration on fabrics being washed	2.4
R2: Washing method	6.5	R2: Rinsing time	2.0
R2, R3: Electricity consumption	6.0	R2: Spin-drying time	2.0
R1: Selling price of laundry machine	5.0	R3: Parts-recycling rate	1.9
R2: Variety of clothes that can be washed	4.8	R1: Delivery cost of laundry machine	1.7
R1: Size of laundry machine	4.2	R2: Operating steps	1.5
R2, R3: Detergent consumption	3.5	R2: Deterioration on fabrics during spin-drying	1.4
R2: Washing time	3.3	R2: Degree of agitation	1.4
R3: Consumption of resources during manufacturing	3.1	R2: Stain-resistant washing drum	1.0
R2: Easiness of detergent dissolving	3.0	R2: Easiness of detergent supplying	1.0
R2: Cleanness of laundry machine	3.0	R1: Height of laundry machine	0.8

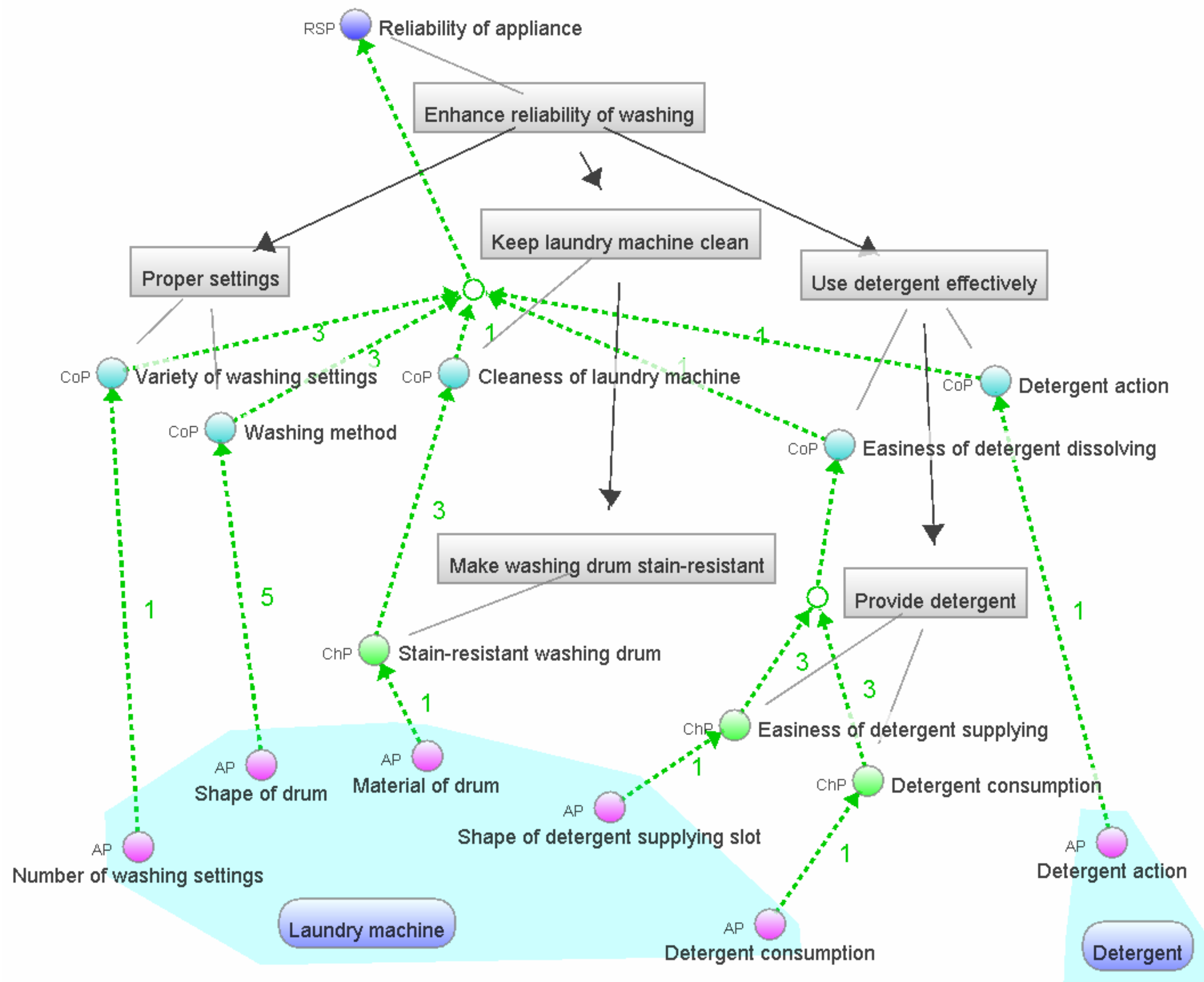

Figure 3. Part of the realization structure for the clothes-washing service

4 INTRODUCTION OF A MATHEMATICAL STRUCTURING METHOD

Based on the service modeling method described in the previous sections, a fundamental method has been presented that makes possible the evaluation of service solutions. In this section, a method is proposed for obtaining evaluation results even more intuitively. This method is achieved by adding a mathematical modeling method to the above service evaluation method. The resulting evaluation information and the method for using that information with an index for service design are discussed. The Dematel (Decision-Making Trial and Evaluation Laboratory) method [11] is used to structure the service model. As described previously, by using the service modeling method in Service/Product Engineering, the service-realizing structure can be expressed through the connections of the RSP and the related functions. Based on the result, a model combining the RSP, the FP, and the relationship between them can be extracted, and the correspondence of their functions and parameters to the physical entity through which they are related can be made. The FPs, the target parameters for the effect of the functions, are classified as CoPs or ChPs, depending on whether they directly affect the RSP. In other words, it is possible to classify the relationships of the parameters by the interactions between the CoP and RSP, between the ChP and CoP, or among the FPs. In this method, quantitative analysis is made possible by structuring the interactions using a mathematical method.

4.1 Service Evaluation Model based on the Dematel Method

As reported earlier, the Dematel method is used to obtain the importance of an FP as an indicator of service design by making connections between the RSP (represented by the VOC) and the FP (represented by the quality characteristics or EM) and by developing quality using the QFD quality table. However, in methods previously reported, the FP has been used uniformly, with no classification as CoP or ChP; therefore, the evaluation of service contents and channels has not been achieved. In some cases, the FP importance has not matched up intuitively. As a solution, the

		CoP-1		CoP-2		CoP-3	
		+	-	+	-	+	-
RSP-1	20.0	◎		△			
RSP-2	10.0			○			
RSP-3	5.0		○			○	
RSP-4	2.5						△
		16.0	2.5	14.0	0	2.5	2.5

Figure 4. Quality table

difference between CoP and ChP can be structured through the Dematel method, making quality development more detailed and relevant to function development. The structure development of QFD can be added, making it possible to obtain evaluation information which is easier to handle as a design indicator.

A service evaluation process based on the proposed evaluation model is constructed using the following procedures, expanded from those described above.

(1) Set receiver importance
(2) Create a service quality table
(3) Structure the RSP and obtain importance
(4) Obtain CoP importance
(5) Structure the FP using the Dematel method
(6) Obtain ChP importance
(7) Deploy QFD functions/structures

Steps (1) through (3) are explained above. In this section, a procedure is proposed that assumes that the importance of an individual RSP has already been obtained. Steps (4) through (7) are described below.

4.2 Obtaining CoP Importance

After obtaining RSP importance, a binary table for the degree of association is used, and the RSP importance is converted into FP importance. According to the definition of the service model [3] in Service/Product Engineering, the FP that has a direct effect on the RSP is the CoP. In other words, only FPs that are also CoPs can have their degree of importance defined and their importance deployed by the binary table. On the other hand, under the definition of the service model, an effect that is a functional manifestation of the FP is defined as a Function Influence (FI). In this method, an evaluation model is adopted by simplifying the FI as the change direction (positive or negative) of the FP (Figure 4). Using this process, the CoP Importance vector, wco, can be obtained. However, this importance vector is defined in relation to the entire FP, and the corresponding elements of a FP that do not have a CoP are set to 0 (Equation (1)):

$$w_{co} = \left(w_{co1}^{\ +} \quad \cdots \quad w_{con}^{\ +} \quad w_{co1}^{\ -} \quad \cdots \quad w_{con}^{\ -} \right) \tag{1}$$

4.3 Considering Indirect interactions Using the Dematel Method

In the service-realizing structure, there are direct and indirect interactions between FPs. It is possible to conduct quantitative weighting of the state of the interactions, and the Direct Influence Matrix X* that describes the direct influence of these FPs can be obtained (Equation (2)). In Equation (2), xlm represents the strength of the interaction from xm to xl. When considering the interaction of the FPs, it is important also to consider the FI. In other words, the influence of FPa on FPb is considered a positive or negative change. Thus, FPa influences FPb in four ways (Figure 5), all of which are represented in the matrix. If the symbols are the same for the active FI, the active FI is considered to have a complementary relationship with both FPs; however, if the symbols are different, the active FI is considered to have an interfering relationship. From the Direct Influence Matrix of the defined FP's, the Dematel method [3] is used to obtain the Entire Influence Matrix A (Equations (2) to (4)). In this process, it is necessary to set the constant s, the measuring factor representing the strength of the indirect influence, in the Direct Influence Matrix (Equation (3)). The measuring factor is a deciding

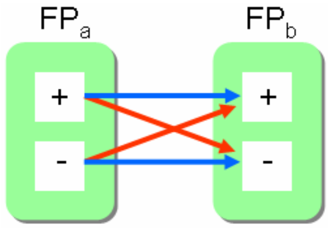

Figure 5. Effect of the FP

factor in this experimental model-construction process. The Entire Influence Matrix A, obtained through the above steps, represents the strength of the influence of the FPs on the RSP considering all the direct and indirect interactions among the FPs.

$$X^* = \begin{pmatrix} x^{++}{}_{11} & \cdots & x^{++}{}_{1n} & x^{+-}{}_{11} & \cdots & x^{+-}{}_{1n} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ x^{++}{}_{n1} & \cdots & x^{++}{}_{nn} & x^{+-}{}_{n1} & \cdots & x^{+-}{}_{nn} \\ x^{-+}{}_{11} & \cdots & x^{-+}{}_{1n} & x^{--}{}_{11} & \cdots & x^{--}{}_{1n} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ x^{-+}{}_{n1} & \cdots & x^{-+}{}_{nn} & x^{--}{}_{n1} & \cdots & x^{--}{}_{nn} \end{pmatrix} \tag{2}$$

$$X = sX^* \tag{3}$$

$$A = X + X^2 + X^3 + \ldots = X(I - X)^{-1} \tag{4}$$

4.4 Obtaining ChP Importance

Using the process outlined in the previous paragraph to obtain the Entire Influence Matrix of the FP and FIs, it can be determined that the ChP, which strongly influences the CoP, is most important. Following this thought, the ChP importance is obtained. Using this method, the equation below provides the ChP importance vector wch (Equation (5)). The individual CoP and ChP importance vectors are obtained using Equation (5). By combining the equations, we can obtain the importance vector for the entire FP (Equation (6)):

$$w_{ch} = \begin{pmatrix} w_{ch1}{}^{+} & \cdots & w_{chn}{}^{+} & w_{ch1}{}^{-} & \cdots & w_{chn}{}^{-} \end{pmatrix} = w_{co} A \tag{5}$$

and

$$w = \begin{pmatrix} w^{+} & \cdots & w^{+} & w^{-} & \cdots & w^{-} \end{pmatrix} = w_{co} + w_{ch} \tag{6}$$

4.5 Functional/Structural Deployment

Using the QFD method, it is possible to obtain a detailed design indicator by taking the importance of the quality elements obtained through quality deployment and then deploying their functions, or structural importance. In QFD, a functional deployment or structural deployment process is performed to extract the functions and mechanics of the quality elements in order to obtain a design indicator for a product. In the proposed service modeling method, the relationships among the FPs (equivalent to the quality element), the functions, and the entity are described using a view model. A degree of association is then quantitatively given to the relationships between the FP and the functions and between the function and the entity. It is then possible to create a deployment table or structural deployment table, and a two-way chart allowing for the conversion of FP importance into either functions or entity importance can be constructed. As a result, the following information can be obtained as service design indicators:

(1) FP Importance

Using this method, we are able to obtain importance by considering the concept of service channels/contents corresponding to the importance of quality elements in traditional product design.

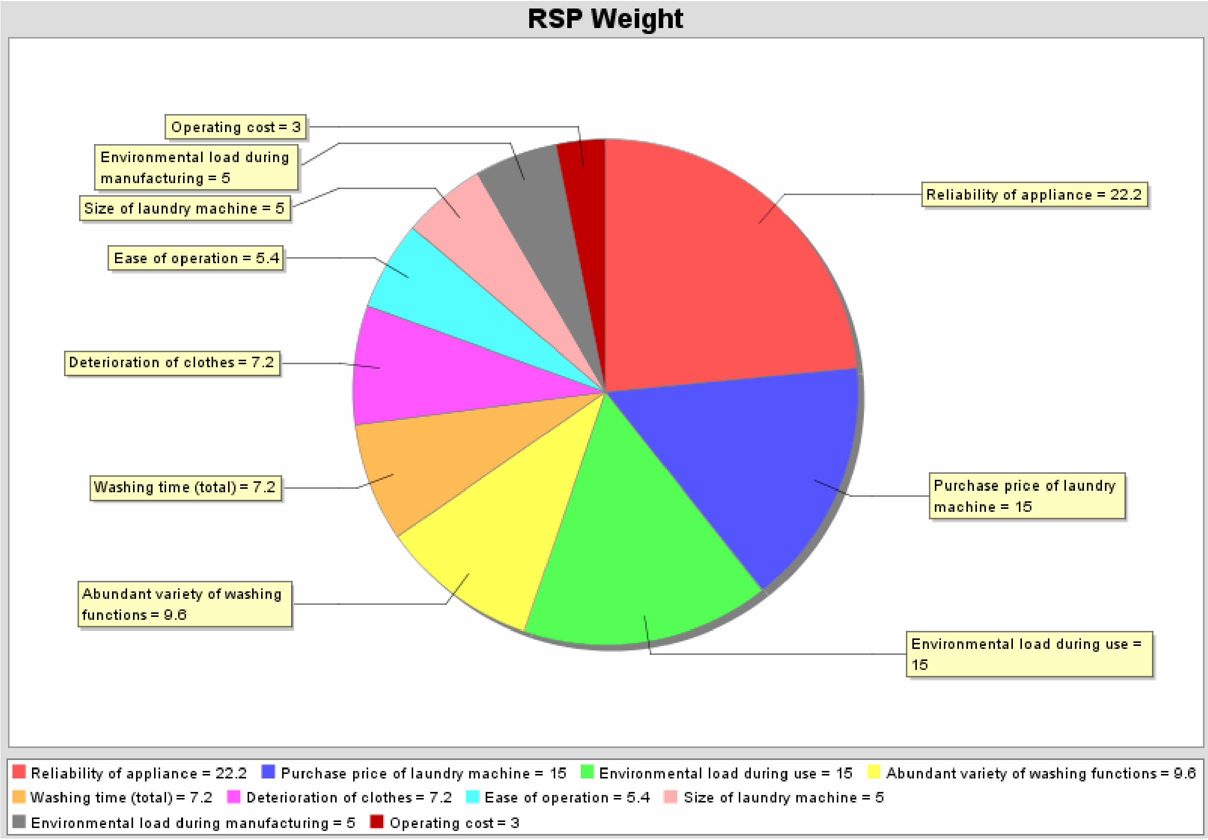

Figure 6. Screen dump of the service evaluation module (RSP weight)

(2) FP Reciprocal Influence Matrix

Regarding the realization structure of the observed service, we are able to gain an overview of the interactions among the FPs. By representing any complementary or interfering relationships and the RS in a matrix, it is possible not only to design but also to realize the synergy expected of an FP relationship as well as trade-offs from interfering relationships among the FPs.

(3) Function and Entity Importance

Because we are able to obtain the importance of the functions and entity involved in the target service-realizing structure, we can use the information to perform design operations, such as the addition, replacement, and deletion of the functions and entity.

5 IMPLEMENTATION RESULT

A prototype service CAD tool, called Service Explorer, was developed for service design. Designers can describe services and register them in a Service Explorer database. Designers can utilize the service in the following ways:

- To express a service following the definition in Service/Product Engineering.
- To edit the models by, for example, rerouting arcs among function units or changing attributes of function units.
- To evaluate the total service by assigning the value of each component.
- To search suitable service models, such as analogous and related services, in the database.

The current version of Service Explorer was developed using Java (Java SDK version 1.4.1) and XML version 1.0 in the Microsoft Windows XP environment. The MVC model [12], which has been used widely in general GUI applications, was adopted as the basic architecture of Service Explorer. Through the application of the MVC model, Service Explorer has high flexibility and reusability, and the service model data are robust. Furthermore, a service evaluation module was implemented based on the proposed method and applied to this function using the example described in Section 3 to verify the effectiveness of the proposed method. Figure 6 and Table 2 show each parameter in which the designers can define relative weight.

- The influence weights of RSPs are computed numerically by the AHP method according to bilateral comparisons between parameters.

- The importance weight of a function parameter is determined by considering the weights of the RSPs previously obtained, i.e., which function parameter is most important for satisfying the receiver's RSPs.

Table 2. Results from the service evaluation module (FP importance)

FP	Importance	FP	Importance
R2: Variety of washing functions	13.7	R2: Easiness of detergent dissolving	2.5
R2, R3: Water consumption	10.0	R2: Detergent action	2.5
R2: Washing method	8.5	R2: Cleanness of laundry machine	2.5
R1: Manufacturing cost of laundry machine	8.3	R2: Number of buttons	2.5
R2, R3: Electricity consumption	6.0	R2: Degree of agitation	2.3
R1: Selling price of laundry machine	5.0	R2: Spin-drying time	2.0
R2: Variety of clothes that can be washed	4.8	R2: Rinsing time	2.0
R2: Deterioration on fabrics being washed	4.5	R3: Parts-recycling rate	1.9
R1: Size of laundry machine	4.2	R1: Delivery cost of laundry machine	1.7
R2, R3 :Detergent consumption	3.7	R2: Operating steps	1.5
R2: Washing time	3.3	R2: Stain-resistant washing drum	1.2
R3: Consumption of resources during manufacturing	3.1	R2: Easiness of detergent supplying	1.2
R2: Deterioration on fabrics during spin-drying	2.7	R1: Height of laundry machine	0.8

These weights are given as numerical values by combining the Dematel and the QFD methods. In the service evaluation model described in Section 3, during the process of converting importance from RSP to FP, it was necessary to make decisions uniformly based on the subjectivity of the strength of the direct and indirect influences. However, in this method, it is necessary only to show the strength of the direct influence of the relationship, making it easier to obtain FP importance. Values for function and entity importance in the content and channel categories are also obtained. Using this information, a service designer can gain an understanding of the structural elements of a service and easily confirm which elements are most important in realizing such a service.

6 CONCLUSION AND OUTLOOK

In this paper, a method is proposed in which detailed service evaluation can be performed by applying the QFD method to the service modeling method in Service/Product Engineering. Next, in regard to the realization of the service described above, a method is proposed for clearly defining the relationships among individual parameters and quantitatively evaluating their interactions through the Dematel method, a mathematical modeling method. Additionally, by reapplying the QFD procedure to the obtained information, it is possible to obtain function and entity importance, which is the structural element of service, considering the contents and channels as the fundamental concepts of services. Additionally, while examining the effectiveness of the proposed methods using a service evaluation tool based on the proposed methodology, the authors show that using this method as a compositional factor in a service CAD system can enable useful service design support.

In the future, while clarifying the service design process, we will conduct a detailed examination of the positioning of service evaluation tools as one part of the process. Our future work also includes the reinforcement of the service evaluation method and the validation of the proposed techniques by means of continuous tool development.

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