# Service Evaluation Method for Managing Uncertainty

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**Abstract.** A service is mainly produced by human capabilities and their interaction, and therefore, the process for the service production includes a lot of uncertainties caused by human factors. In order for service organizations to cope with these uncertainties, in this study, the concept of the modular architecture is applied to the service organization. Especially, this study proposes a method to determine teams consisting of human resources based on the concept of the modular service organization. The effectiveness of this method is demonstrated by the application to a hotel service.

**Keywords:** Service Engineering, Uncertainty, Design Structure Marix.

## 1 Introduction

Service is nowadays regarded as a way to achieve the “sustainability” of businesses in manufacturing companies. Long-term and strong relationship with customers can be realized by providing services in combination with a product throughout its lifecycle. In addition, recently, a rapid rise has occurred in expectations that engineering and scientific approaches will bring dramatic improvements in the design and production of services [1]. Indeed, now that the service industry accounts for some 70% of the workforce and Gross Domestic Product (GDP) in Japan [2], it is obvious that the service industry must see dramatic improvement in productivity. According to this background, there is a critical need to establish a method to design and evaluate services from scientific and engineering viewpoints.

On the other hand, the authors of this paper have conducted conceptual research on design services from the viewpoint of engineering. This series of research is called Service Engineering [3-5]. Its objective is to provide a fundamental understanding of services as well as concrete engineering methodologies that can be used to design and evaluate services. The goal of this study is to develop a way of achieving customer satisfaction as a change in the state of the customer of the service. More specifically, procedures for modeling and analyzing human activities and human behaviors are

S. Yamamoto (Ed.): HIMI/HCII 2013, Part III, LNCS 8018, pp. 569–578, 2013.

formed and a computer-aided design (service CAD) software system [5] using those procedures is developed.

A service is mainly produced by human capabilities and their interaction. In order to implement a service designed by the service CAD, therefore, it is important for the service organization to manage uncertainties caused by human factors. To solve this problem, this study aims to propose a method to determine a service organization in consideration of uncertainties. In the proposed method, the concept of the modular architecture is applied to the service organization. The effectiveness of this method is demonstrated by the application to a hotel service.

## 2 Scope of This Study

### 2.1 Definition of a Service

Service Engineering is a new engineering discipline with the objective of providing a fundamental understanding of services as well as concrete engineering methodologies to design and evaluate services. In Service Engineering, service is defined as an activity between a service provider and a service receiver to change the state of the receiver [3-5]. 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.

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) [3-5]. 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.

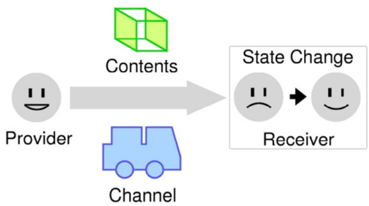


**Fig. 1.** Definition of a service [3-5]

### 2.2 Definition of an Uncertainty

Since a service is mainly produced by human capabilities and their interaction, the production process includes a lot of uncertainties. These uncertainties influence on the service quality and efficiency, and therefore, many researches have been conducted in order to manage them. In the ergonomics, for example, some studies classify uncertainties from the viewpoint of human errors (for example [6]), and then, propose methods to prevent them. While these studies mainly focus on provider's human activities, Frei proposed the five types of variability introduced by customers [7].

An uncertainty is represented as uncontrolled stochastic variations with the mathematics of probability, and therefore, is distinct from imprecision [8]. For example, in a service process, uncertainties include human capability variations, customer preference variations and so on. In order to cope with these uncertainties, it is crucial to assess the expected size of variations and determine target range. On the other hand, imprecision is used for the state where a certain variable may potentially assume any value with in a possible rang; the final value will emerge from a process. For example, some customer requirements are ambiguous before offering a service; the service provider make these requirements more detail through the service process.

According to this concept, in this study, uncertainty is defined as uncontrolled stochastic variations. Especially, this study focuses on variations of functional inputs and/or outputs among human resources.

# 3 Service Evaluation Method for Managing Uncertainty

## 3.1 Overview

Since a service production process includes a lot of uncertainties caused by human capabilities, the service organization needs to have the adaptability for flexible changes in managing these uncertainties. However, addressing the changes requires much more complex interactions among relevant human resources; these types of interactions involve tremendous coordination efforts. To solve this problem, in this study, the concept of the modular architecture is applied to the service organization. Especially, this study proposes a method to determine teams consisting of human resources based on the concept of the modular service organization. In the modular product, each component can be changed independently without influences on the other components. Since teams within a modular service organization can be regarded as the components in a modular product, it is assumed that changes in managing the uncertainties could be addressed within a relevant team. As a result, it could be possible to reduce coordination efforts for managing uncertainties.

In the proposed method, first, the degree of the uncertainties is evaluated from the viewpoint of the information content proposed in the axiomatic design. According to the information content, subsequently, teams within the service organization are specified in order to reduce coordination efforts for managing uncertainties. For the specification of teams, this study adopts the Design Structure Matrix. The remainder of this section introduces the relevant works: Axiomatic Design and Design Structure Matrix.

**Axiomatic Design.** Axiomatic design proposes fundamental design principles. It is a methodology about how to use fundamental principles during the mapping process among the domains of the design world [9]. The principle defines the elements that have respective domains: customer needs (CNs), functional requirements (FRs), design parameters (DPs), and process variables (PVs) (see Figure 2).

In the design process, CNs in the customer domain are converted into FRs in the functional domain. FRs are a minimum set of independent requirements that completely characterize the functional needs of the design solution. FRs are embodied into DPs in the physical domain, and then DPs determine PVs in the process domain to produce and/or control the DPs.

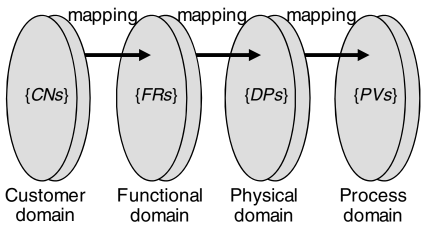


**Fig. 2.** Four domains of the design world [9]

In axiomatic design, this mapping process is evaluated according to an axiom called the Information Axiom [9], which is stated formally as:

*Minimize the information content.*

Information is defined in terms of the information content I that is related to the probability of satisfying a given FR. In the Axiomatic Design, the information content is determined by the two ranges: the system range and design range. Figure 3 illustrates these two ranges graphically.

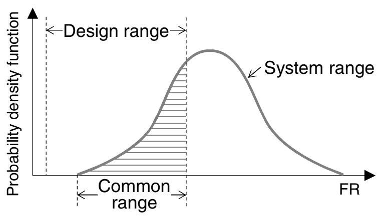


**Fig. 3.** Relationships among design range, system range, and common range

The system range is plotted as a probability density function versus the specified FR. The design range, on the other hand, represents a target range of the FR. The overlap between the design range and system range is called the common range, and therefore this is the only region where the design requirements are satisfied. Consequently, the area under the common range divided by the area under the system range is equal to the probability of achieving the design objective. As a result, the information content $I$ is expressed as the following equation.

$$I = log\ (A_{sr}/A_{cr}) \tag{1}$$

where
$A_{sr}$ denotes the area under the system range
$A_{cr}$ is the area of the common range

**Design Structure Matrix.** The design structure matrix (DSM) (e.g. [10]) is becoming a popular representation and analysis tool for system modelling. A DSM displays the relationships between elements of a system. As shown in Figure 4, a DSM is a square matrix with identical row and column labels. An off-diagonal mark represents an element's dependence on another. Reading across a row reveals what other elements are provided by the element in that row. Scanning down a column reveals what other elements the element in that column depends on. For example, in Figure 3, element B provides input to elements A, C, D, F, H, and I, and it depends on outputs from elements C, D, F, and H.

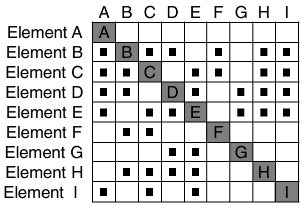


**Fig. 4.** Example of Design Structure Matrix [10]

DSMs are classified into two main categories: static DSMs and time-based DSMs. Static DSMs represent system elements, such as components of a product architecture or groups in an organization. Static DSMs are usually analyzed with clustering algorithms. In time-based DSMs, on the other hand, the order of the rows and columns indicates a flow through time. Therefore, time-based DSMs represent characteristics of a process sequence, such as feedforward and feedback. Time-based DSMs are typically analyzed using sequencing algorithms.

This study adopts the clustering algorithms in static DSMs. These algorithms are generally clustering along the diagonal marks by reordering the rows and columns of the DSM. Clustering requires several considerations. The foremost objective is to maximize interactions between elements within clusters while minimizing interactions between clusters.

## 3.2 Procedure of the Proposed Evaluation Method

**Step 1: Extraction of customer requirements.** Since value in a service is always determined by customers, this method begins with the extraction of customer requirements. For the extraction of customer requirements, in this step, a persona is described. The persona is a tool to give a simplified description of a customer and works as a compass in a design process [11]. According to this persona, subsequently, a scenario is developed to clarify the context in which the service is received. The scenario is described in the form of a state transition graph, since the purpose of receiving a service is to change the customer's state into a more desirable one. The customer's state is represented as a set of parameters called state parameters (SPs) [3-5]. SPs represent the internal/external state of a customer and have a causal relationship. From the SPs, RSPs, which correspond to target requirements in the service design [3-5], are extracted.

**Step 2: Development of a realization structure for each customer requirement.** In this step, the designers determine a realization structure for each customer requirement, which is represented as an RSP. In this method, we adopt the view model [3-5] as the modeling method for describing the realization structure.

A view model is described in terms of the functional relationships among RSPs, functions and entities. It is assumed that contents that realize customer requirements in a service are comprised of various functions [3-5]. These functions are expressed by function names (FNs) as lexical expressions and function parameters (FPs) as target parameters of the functions. In addition, the realization structure is associated with entities and their attributes that actualize the functions in the view model. Entities in the view model include human resource within a service organization.

As shown in Figure 5, the view model works as a bridge from an RSP to entities and thus allows designers to clarify the roles of the entities in consideration of the RSP.

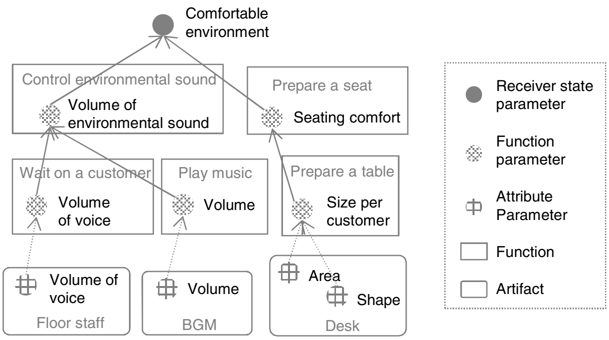


**Fig. 5.** Example of the view model (a restaurant service) [3-5]

**Step 3: Evaluation of uncertainties among human resources.** This method focuses on uncertainties with regard to functional inputs and/or outputs among human resources. Therefore, first, the designers develop a functional input-output model based on the view models described in Step 2. In the functional input-output model, FPs correspond to the inputs and/or outputs; FNs are represented as lexical expressions of functions that convert the inputs into the outputs. In addition, entities in the view models are decomposed into human resources so that each human resource can take responsibility for a single function. Next, the designers estimate uncertainties of the inputs and/or outputs represented as FPs. In this method, an uncertainty of an FP is evaluated from the viewpoint of the information content that is defined in the Axiomatic Design [9]. Namely, the information content is evaluated by the system range and design range of corresponding FPs, and then is replaced by a number, for example 5 (large), 3 (normal), 1 (small).

**Step 4: Specification of teams within a service organization.** Next, the designers specify teams that consist of human resources. For the specification, a DSM is developed according to the inputs and/or outputs developed in the previous step. The DSM in which elements correspond to human resources is described using the numbers that represent the information content of the FP. According to the numbers in the matrix, a clustering of off-diagonal elements is conducted. In this method, the clustering for specifying teams is carried out on the basis of the following assumptions.

1. The difficulty of managing uncertainties is proportional to the amount of the information content. Managing the large amount of the information content requires more attention and/or more time between relevant human resources.
2. It is easier for teams to manage uncertainties within the same team rather than across different teams. In order to manage uncertainties, human resources need to have sufficient communication to share the information content. Human resources belonging in the same team easily communicate with each other rather than ones belonging in the different teams.
3. It is easier for teams to manage uncertainties in smaller human resources rather than large ones. The fewer human resources take part in a team, the easier the team will facilitate managing uncertainties.

Based on these assumptions, the equation proposed by Fernandez [12] is adopted as the evaluation formula of the clustering. This formula aims to minimize the coordination cost among teams in a product development project. In this method, the formula is applied to the service design in order to find teams that minimize coordination cost.

The formula first calculates a coordination cost for each human resource in the DSM, and then the sum of the coordination costs for each resource provides a total coordination cost. Equations 2-3 show the coordination cost for a human resource *i*.

<u>If both human resource *i* and *j* are in any cluster *k*;</u>

$$\text{Coordination Cost}(\text{human resource}_i) = \sum_{j=1}^{size}\big(\text{DSM}(i,j) + \text{DSM}(j,i)\big) * \sum_{k=1}^{Cl} \text{cl\_size}(k)^{pow\_cc} \quad (2)$$

<u>If no *k* cluster contains both human resource *i* and *j*;</u>

$$\text{Coordination Cost}(\text{human resource}_i) = \sum_{j=1}^{size}\big(\text{DSM}(i,j) + \text{DSM}(j,i)\big) * size^{pow\_cc} \quad (3)$$

where;

| | |
|---|---|
| *size* | is the size of the DSM: the number of human resources in the DSM |
| DSM (*i*, *j*) | is the number of the information content between human resource *i* and *j*. Note that when $i = j$, DSM($i$, $j$) = 0, DSM($j$, $i$) = 0 |
| *Cl* | is the maximum number of clusters (set to the number of human resources in this analysis) |

*cl_size* is the number of human resources contained in cluster *k*
*pow_cc* is a parameter that controls the type of penalty assigned to the size of the cluster in the coordination cost (set to 2 in this analysis)

The total coordination is expressed as Equation 4. This objective function is the expression that the algorithm attempts to minimize.

$$\text{Total Coordination Cost} = \sum_{i=1}^{size} \text{Coordination Cost}(\text{human resource}_i) \quad (4)$$

According to the result of the DSM, finally, teams in the service organization can be specified based on clusters in the DSM. Each team is not necessarily corresponding to an actual department or division in the organization, but corresponding to a unit to conduct the management of uncertainties.

# 4 Application

In this chapter, the proposed method is demonstrated in an application to a hotel service. The purpose of this application is to determine teams in the organization of the hotel service providers.

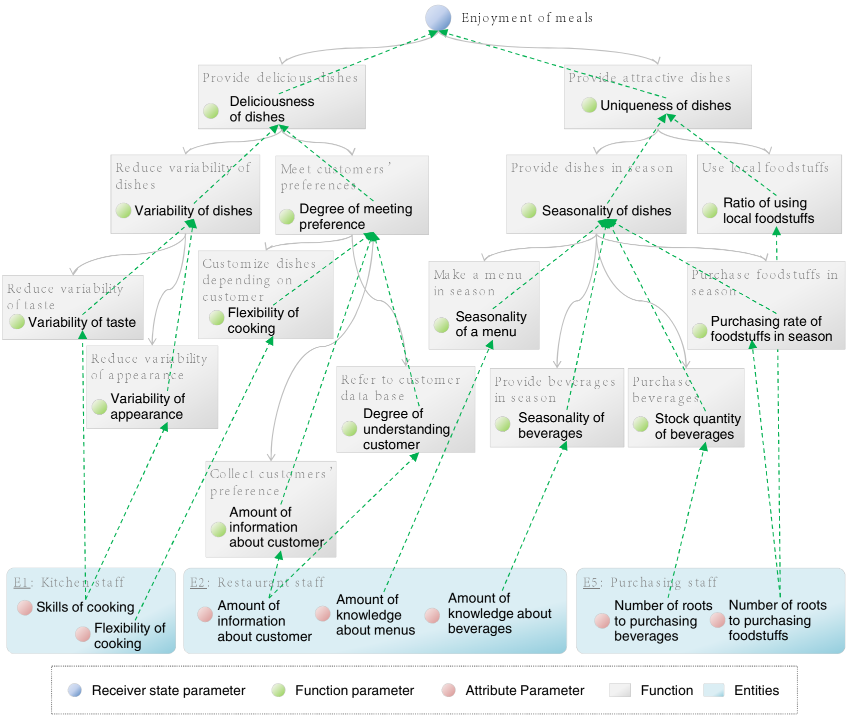


**Fig. 6.** The view model for "Enjoyment of meals"

In this application, first, RSPs, which correspond to target customer requirements in this service, were defined. As a result, “Enjoyment of meals”, “Atmosphere of guest rooms”, “comfort of services” and “Flexibility of services” were determined as RSPs. Next, realization structures were developed for these RSPs. Figure 6 shows an example of the view model for “Enjoyment of meals”. Functions that realize “Enjoyment of meals” were decomposed into detailed functions, for example “Provide delicious dishes” and “Provide attractive dishes”, and then entities, for example “Kitchen staff” and “restaurant staff”, were associated with these functions.

These view models were subsequently converted into functional input-output models, and then, entities in the view models were decomposed into human resources so that each human resource took responsibility for a single function. With regard to the inputs and/or outputs among human resources, uncertainties were estimated from the viewpoint of the information content. In this application, the subjective assessment was carried out in order to evaluate the information content, and then, the information contents were rated on a three-point scale, from 1 (small) to 5 (large).

Next, for the specification of teams, a DSM was developed according to the functional input-output models; the DSM was described using the numbers that represent the information content. According to the numbers in the DSM, the clustering of off-diagonal elements was conducted. As a result, eight clusters of human resources were specified as shown in Figures 7 (a)-(h). Each cluster corresponds to a team in the service organization. For example, team (a) includes four kind of human resources that take responsibility for functions, such as “F26: Purchasing foodstuffs” and “F8: Planning beverages”. These human resources originally belonged to the entities “Purchasing staff” and “Restaurant staff” respectively.

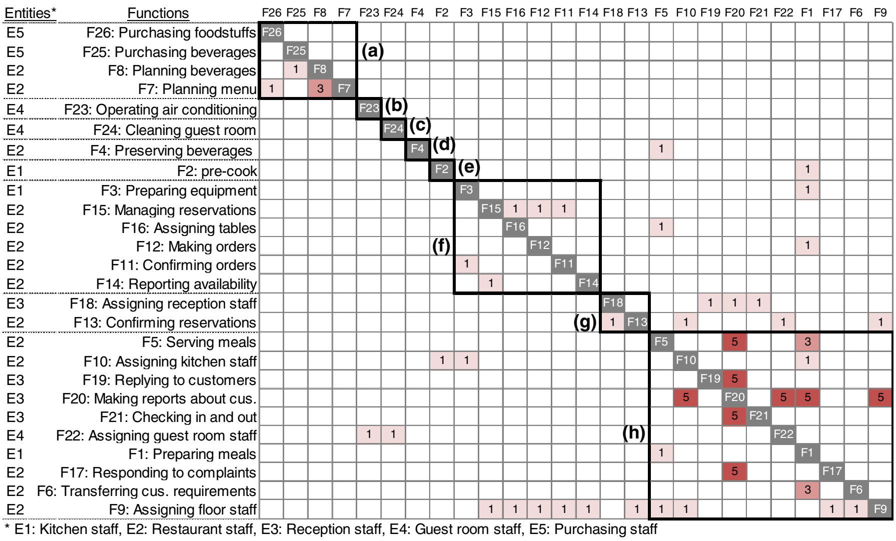


**Fig. 7.** DSM clustering result of the hotel service

## 5 Summary

This study proposed a method to determine teams consisting of human resources based on the concept of the modular service organization. In the application, the proposed method is applied to a hotel service, and then, the eight teams, as shown in Figures 7 (a)-(h), were specified. For example, team (h) includes ten kinds of human resources that take responsibilities for functions, such as “F5: Serving meals”, “F19: Replying to customers”, and “F20: Making reports about customers”. Since the information contents of outputs from these functions relatively large, i.e. 3 or 5, managing uncertainties regarding these functions will impose high coordination costs on relevant human resources. Therefore, it is effective for the human resources to manage the uncertainties within the same team rather than across different teams. In addition, since the information contents of inputs and/or outputs among the eight teams are relatively small, i.e. 1, it is enable for each team to carry out the management of uncertainties independently. Therefore, the proposed method is useful for determining teams in consideration of coordination efforts for managing uncertainties. In this application, however, uncertainties were estimated by the subjective assessment. Future works therefore include further applications about evaluation of the information content. In addition, feasibilities of teams result from the proposed method need to be validated.

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