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APPLICATION OF FAULT TREE ANALYSIS TO THE SERVICE PROCESS: SERVICE TREE ANALYSIS APPROACH

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ABSTRACT

Responding to recent transformations in the service industry, the service system is getting bigger and its structure is more complicated and more diverse. The most remarkable thing about service processes is that service processes can not take place without customers. Customer participation is essential in service processes, and customers continuously decide and assess each service component in the service system. But few studies have focused on visualizing and analyzing the service process from the customer participation point of view. And it is hard to deduce the proper corporate strategy from service processes using previous service process analysis. To address the limitations of previous research, this study proposes a novel approach based on fault tree analysis to reflect the customer participation point of view and to deduce the strategically useful information from the service process analysis.

The objective of this paper is to propose the service tree analysis which is translated from fault tree analysis, and to propose how to analyze the service process qualitatively and quantitatively using the proposed service tree analysis. In this proposed approach, a service tree is structured with Boolean logic according to whether the service component is always selected by customers or not. With this proposed approach, strategically useful information can be derived through both qualitative and quantitative analysis.

The implications of the proposed approach are threefold. First, this approach helps to analyze the service process in a constitutive way from the customer participation point of view. Second, it helps to identify core services and optional services by visualizing the service process. Finally, it enables the service process to be analyzed in a quantitative way, elaborating on how each service component influences the total service process. To illustrate these implications of the proposed approach, a case study on the hospital service is presented.

Field: *Service Operations Management*

1. INTRODUCTION

Based upon rapid industry changes throughout the service industry, it is clear that the importance of research into the service industry is increasing. Increases in the service industry include increases in the complexity of service processes, as well as increases in service quantity.

Service processes are getting more complicated and more diverse, and relationships between service components are also getting more complex according to the growth of service industry. To deal with this situation, it is clear that the analysis method of complex service process is needed to improve the service system.

There are some methods to analyze service processes such as Fishbone diagram (Ishkawa, 1943), service blueprint (Shostack, 1982), process flowchart (Bohl, 1971), and process simulation (Law and Kelton, 1991). But these methods have limitations. First, previous methods lack the viewpoint of customer's evaluation and choice for each service component. The most important thing in service processes is the customer participation (Chase, 1978; Lovelock and Young, 1979; Zeithaml and Bitner, 2000). The evaluation and selection of service components are simultaneously done by customers (Ettenson and Turner, 1997). So, there is a need to analyze the complex service process from a customer participation point of view, especially the selection of each service component by customers. Second, a strategic point of view to derive useful information from these methods is not considered in previous methods. Previous methods for service process analysis are focused on intuitional way without the systematic approach because of the characteristics of the service process. It is evident that services have distinct characteristics such as intangibility, perishability, inseparability of production and consumption (Judd,1964; Sasser *et al.*,1978; Shostack, 1977), so service process analysis has been faced with some difficulties to deduce the tangible strategic information.

To address these two limitations, this paper proposes a new method for analyzing service process which is translated from fault tree analysis (FTA). FTA is the method which can identify the faults and their influences on the total system using Boolean logic tree illustrating the relationships between elements. With FTA, the critical events which significantly affect the occurrence of the top event can be identified easily, and the sensitivity of the probability of failure can be examined.

This paper aims to propose a novel approach named service tree analysis (STA), which is translated by taking advantage of FTA, and to propose how to analyze the service process using STA with both qualitative and quantitative ways. From the qualitative analysis, core services and optional services can be derived easily. From the quantitative analysis, customer satisfaction of higher level event can be calculated, estimating the influences of each service component on whole service process. Through these qualitative and quantitative analyses, strategic useful information can be derived, providing basic knowledge for improving the service process. The remainder of this paper is organized as follows. In section 2, background knowledge on both theoretical and methodological backgrounds will be presented. The section on theoretical background will cover previous research on service processes and their limitations, and the section on methodological background will cover the definition and analysis method of FTA which is the basis of this paper. Section 3 deals with the proposed approach, representing the construction method and its qualitative and quantitative analysis. A case study for hospital services will be presented to illustrate the proposed approach in section 4. The paper will end with conclusions in Section 5.

2. BACKGROUND

2.1 Theoretical Background

A service process includes the steps, tasks, and mechanisms that are necessary for service delivery to occur (Booms and Bitner, 1981). The result of this service process is a customer outcome; that is, a customer is either satisfied or dissatisfied with the service delivery experience (Mayer *et al.*, 2003). Customers continuously participate in the service process, selecting each service component and evaluating the selected service before finally judging the result of service process through expressing their satisfaction or dissatisfaction. Therefore, it is evident that customer participation is an essential factor in service process (Chase, 1978; Lovelock and Young, 1979; Zeithaml and Bitner, 2000). It is thus clear that service process analysis, which focuses on customer participation and customer selection behaviors, is essential toward understanding and improving the service process.

Some attempts to analyze the service process with systematic method have been tried in various ways. *Fishbone diagram* (Ishkawa, 1943), *service blueprint* (Shostack, 1982), *process flowchart* (Bohl, 1971), and *process simulation* (Law and Kelton, 1991) are representative methods for analyzing the service process. *Fishbone diagram* is a tool that classifies the cause of a target problem. This is considered as one of the basic tools of quality management. Classification of causes in the Fishbone diagram is normally based on the 4ms – man, machine, method, and material. This tool is known as a useful method for tracking the dissatisfaction factor of customers. But this method is not an analysis method of service process, but a method to track the customer's dissatisfaction. So it might be useful for tracking the fault, but not for analyzing the service process itself. *Service blueprint* was developed by Shostack in 1982 to visualize, analyze, and design service processes. It depicts the roles of consumers, service providers, and supporting services in a two-dimensional plane. The horizontal axis represents the chronology of actions performed by customer and service providers, and the vertical axis divides the different service area. These areas of action can be divided by lines. The service blueprint is known as a useful tool to plan and diagnose the service process, and is used for understanding the flow according to the service area. But it lacks the quantitative depth because it only depends on qualitative ways of displaying the process in a two-dimensional plane. So the quantitative analysis between the service components is not supportive. *Process flowchart* is another tool that helps to track service flow by representing the service in a single flowchart. It is also used to describe the process of communication. But it lacks a quantitative dimension just like the service blueprint. *Process simulation* helps to develop and execute practical model experiments using computers. But this simulation method is costly and takes a long time to implement and maintain. These analysis methods for service processes are organized in Table 1.

But these methods have two limitations. First, there are a lack of standpoints that consider the customer's evaluation and choice for each service component. Second, it is hard to derive the strategic useful information from the analysis of each method. In order to overcome these problems, this paper proposes a novel approach which is translated from FTA which is useful to describe the causes of system failure using the Boolean logic tree. Using FTA, we can overcome these two limitations of previous methods. How FTA works in the proposed approach will be described in the next section.

Table 1
Methods for service process analysis

Type	*Definition*	*Effects*
Fishbone diagram (Ishkawa, 1943)	A tool to classify the cause of a target problem with a shape of fishbone	- Tracking causes of service dissatisfaction - Improving the service process
Service blueprint (Shostack, 1982)	A tool to describe the service delivery process and its tasks as a flow, dividing the service behavior areas according to the chronology and service area	- Identifying the flow according to the service behavior area
Process flowchart (Bohl, 1971)	A tool to track the service flow, describing the tasks of each step.	- Identifying service flow - Describing thecommunication
Process simulation (Law and Kelton, 1991)	A tool to develop and execute the practical modelexperiments using computer	- Enabling the multiple execution and multiple scenario selection, making it possible for practical model experiments

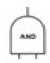
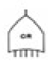
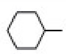
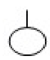
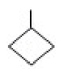
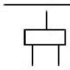
2.2 Methodological Background

FTA is a method for determining combinations of component failures which result in the occurrence of top event using formulations of the Boolean logic tree structure. It enables easy identification of the key element and key composition of the top event occurrence. FTA is designed by Watson (1962) in Bell laboratory, and developed by Haasl (1965) in Boeing, making it useful in the practical world. FTA is generally used for reliability tests in manufacturing fields such as the electronics and nuclear industry. Recently, with the development of the IT industry, FTA has been used for software design and software testing (Dehlinger and Lutz, 2004; Knight and Nakano, 1997; Liu and McDermid, 1996).

Table 2 shows the components that construct the fault tree. With these components, the fault tree is constructed according to the following steps. First, you should locate the fault or failure as the top event. Then you should identify potential first-level contributors. After identifying them, these potential first-level contributors are linked to fault by logic gates. Then, these steps will be repeated until the basic events cannot separate further.

There are two ways to analyze the system using FTA. One is qualitative analysis using the concept of minimal cut set, and the other is quantitative analysis using the concept of probability relationship. A representative way of qualitative analysis is to find minimal cut sets. Minimal cut sets are compositions of basic events which are essential for occurrence of the top event. In other words, by finding minimal cut set, the smallest group resulting in the top event can be identified. Therefore, the basic events which are included in the minimal cut set should be managed carefully, as they are critical elements for the system failure. A representative way of quantitative analysis is to estimate the probability of occurrence of higher level events and finally the top event, analyzing the relationship between basic events and the whole system. The AND gate is used where all input events must occur for the output event to occur, and the OR gate determines that only one of the occurrences of the input events can result in occurrence of the output event. This is reflected in the following equations for AND and OR gates respectively

Table 2
Basic Components that Construct the Fault Tree

Symbol	Name	Definition
	AND	Failure happens when the N subordinate event are happened simultaneously.
	OR	Failure happens when at least one of subordinate events is happened.
	Condition	Condition is represented
	Basic event	Basic events that cannot be decomposed
	Undeveloped event	No further consideration is needed
	Intermediate event	Intermediate events

$$Q = \prod_{i=1}^{n} q_i \quad \text{[Eq. 1]}$$

$$Q = 1 - \prod_{i=1}^{n} (1 - q_i) \quad \text{[Eq. 2]}$$

where q_i denotes the probability that event i occurs and Q denotes the probability or failure rate of the relevant gate.

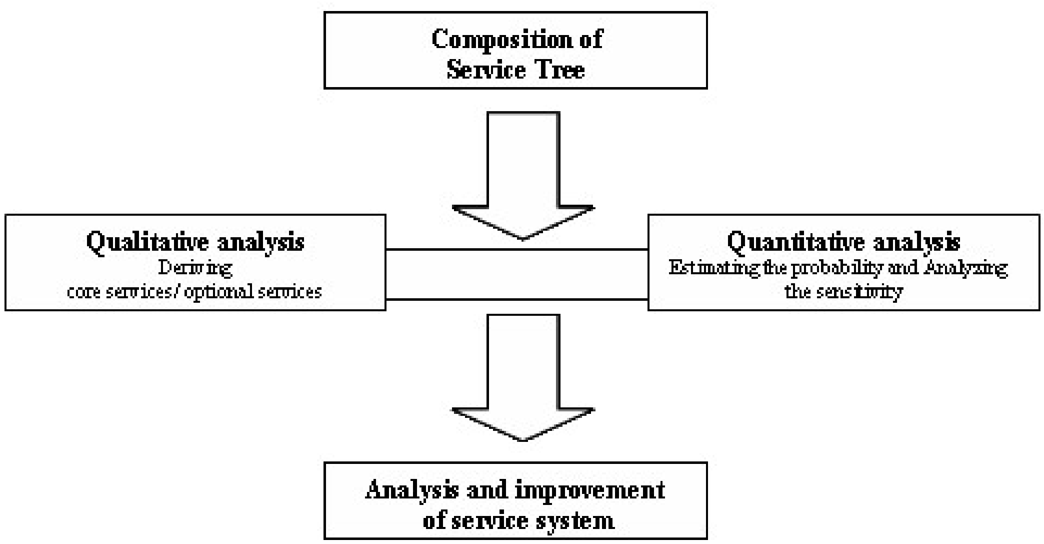
As described above, FTA is useful to describe the causes of system failure using the Boolean logic tree of the relationships. And also, it can easily identify the smallest collection of causes which result the failure, and it can measure the reliability of the system using probability calculation. Due to these characteristics of fault tree, it can be applied to service field for the following reasons. First, AND/OR gate is useful in service field because these Boolean logic gates can support the concept of customer’s Boolean selection of a service component in a target process. Second, FTA supports the qualitative and quantitative analysis methods which are also needed for service process analysis. By applying the FTA toward a novel approach, we can analyze the service process with a systematic way.

3. PROPOSED APPROACH

3.1 Overview of Proposed Approach

The procedure of analyzing service process using STA is described in Figure 1. First, the service tree which includes a Boolean logic tree should be structured. In this step, the composition of the service tree according to the customer's participation is considered. Each basic event in traditional FTA is replaced by service component in STA. If the subordinate events are always taken by the customer, it should be linked with an AND gate. If the events are taken by the customer optionally, it should be linked with an OR gate. Using this Boolean logic, a service process is disassembled to its components and restructured according to the behavior of the customer. Second, a qualitative analysis is followed according to the described service tree. It includes the definition of core services and optional services by defining minimal service cut set, which is translated from tradition minimal cut set. Third, a quantitative analysis is executed. It includes the sensitivity analysis of each service component, finding the effects of whole service process when the basic service component is changed. The indicator in quantitative analysis is service satisfaction of each element. With these results, finally, service process should be analyzed and improved.

Figure 1: Overview of Proposed Approach



3.2 Composition of Service Tree

The composition of service tree is basically same as FTA, but there are some differences when the events meet the Boolean logic. Boolean logic in service tree depends on how the elements are taken by the customer. If the subordinate events are always taken by the customer, it should be linked with an AND gate. If the events are taken by the customer optionally, it should be linked with an OR gate. Suppose there are two service elements, A and B. When the customer always takes the element A and B whenever he enters the system, then A and B are linked with an AND gate. If not, they are linked with an OR gate. Some differences in drawing the trees between FTA and STA are described in Table 3.

Table 3
Differences in Composition of Tree between Fault Tree and Service Tree

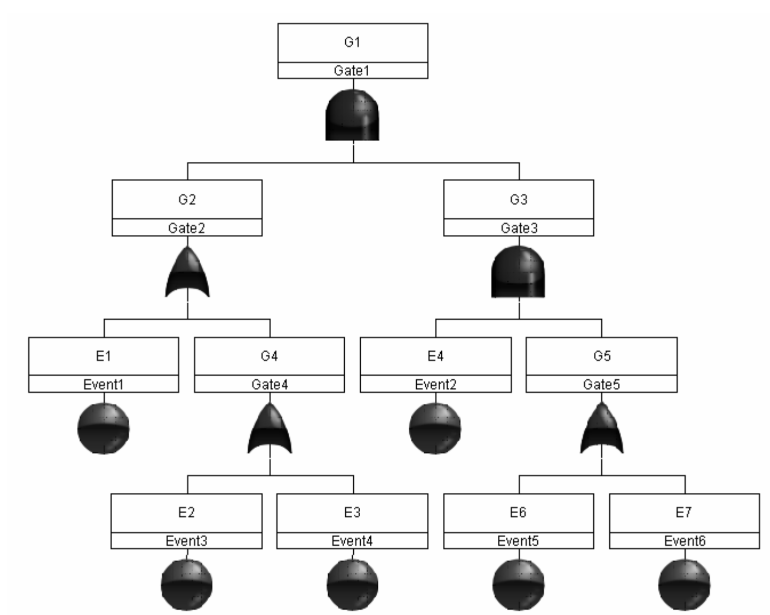
	Fault Tree	*Service Tree*
Top Event	Failure of the system	System itself
Tree Structure	Collection of the basic events which causes the system failure	Structural analysis of target service system
AND/OR Gate	AND gate: System failure happens if the two elements happen simultaneously.OR gate: System failure happens if at least one element happens.	AND gate: If the customer requisitely choose the subordinate service components OR gate: If the customer optionally choose the subordinate service component with their own choice

Based on Table 3, the composition procedure of service tree is as follows.

1. Locate the target service system as the top event.
2. Separate the service system to some basic components and link them with AND/OR gates. If the subordinate services are essential in customer's point of view and every customer chooses them, those services are linked with an AND gate. If they are optionally chosen, those services are linked with an OR gate.
3. Repeat these procedures until the basic element cannot separate to any other element.

The proposed service tree can be made up by Boolean logic tree, reflecting the standpoint of customer participation and customer selection behaviors. It also helps to estimate the importance of each service component. An example of service tree is described in Figure 2, and qualitative and quantitative analysis of the service tree will be followed.

Figure 2: Composed Service Tree



3.2.1. Qualitative Analysis

When composing service tree, one should analyze the target service process from a structural point of view. When each element of the target system is identified during this structural analysis, the service tree is reconstructed according to the characteristics of subordinate service elements. So, the service tree helps to judge which the core service is and which is not using Boolean logic composition.

According to the definition of service tree, if the subordinate services are linked with an AND gate, they are essentially taken by customers when customers enter the service process. But, if they are linked with an OR gate, they are optionally chosen by customers. With this point of view, core services and optional services can be determined. An estimation of core services and optional services is as follows.

1. Deduct the minimal cut set from the composed service tree using the traditional method of FTA.
2. Define the *Minimal Service Cut Set (MSCS)* as common elements in the minimal cut set. MSCS is the set of essential elements of the target service process which are always taken from the customers. And with these elements only, the service process can be functionally organized.
3. Define *core services* as each element of MSCS.
4. Define other service elements as *optional service*. If the optional service is adheres to the core service, define it as the *primary optional service.* If not, define it as the *secondary optional service*.

Table 4 Describes the Difference between the Fault Tree and the Service Tree with a Point of Qualitative Analysis

Table 4
FTA vs STA with a Point of Qualitative Analysis

	Fault Tree	*Service Tree*
Minimal (Service) Cut Set	Collection of essential basic events which cause the occurrence of the top event	Collection of the service elements which are essentially taken by the customers
Relationship	If the event is linked with only OR gate, it is an element of minimal cut set.	If the event is linked with only AND gate, it is an element of MSCS.
Meaning of element	Each element of minimal cut set is the essential elements that cause the system failure.	Each element of MSCS is essential elements that can make the basic functional service process.

Let us take an example for qualitative analysis using the proposed service tree in Figure 2. In this figure, minimal cut sets are (E1, E4, E6), (E1, E4, E7), (E2, E4, E6), (E2, E4, E7), (E3, E4, E6), (E3, E4, E7). According to the definition of MSCS, the common element of minimal cut set becomes *MSCS*. So E4 is determined as MSCS. E4 is also the *core service* because it is an element of MSCS. Other elements are turned out *optional services*. Among these, E6 and E7 which connect directly with E5 become *primary optional services*, and the remaining E1, E2, and E3 are classified as *secondary optional services*.

As a result of qualitative analysis, one can classify the service elements and determine which elements should be improved according to the strategies of each service firm. If the firm focuses on the improvement of basic essential service itself, the resulting core service should be carefully managed. On the other hand, if the firm focuses on differentiation, resulting secondary optional service should be taken care of. Therefore, useful strategic information can be derived from qualitative analysis.

3.2.2. Quantitative Analysis

Quantitative analysis of service tree means the measurement of the influence of each element on the total service process by calculating the probability rate according to the gates.

This consists of two steps. The first step is to set the weight for each service component using the customer satisfaction coefficient, and the second step is to analyze quantitatively using probability calculation. The reason for setting the weight for each service component is that it is widely believed that increases of satisfaction of each service don't guarantee the linear increase of satisfaction of the total system in service fields. Following is a detailed guideline for the two-step procedure of quantitative analysis.

Step 1: Weight Setting for each Service Component

As described above, it is not guaranteed that customer satisfaction linearly grows according to the satisfaction growth of each service component. Service components have different influences on the total system according to their characteristics. Therefore, it is important to assign a different weight to each component.

In this paper, the Kano model will be used for setting the weight for each service component. The Kano model illustrates the relationship between customer satisfaction and the performance of a product or a service. This relationship differs from attractive to one-dimensional and to must-be attributes. (Kano *et al.*, 1984) It has been used for weight setting of customer's requirement in various ways (Berger *et al.*, 1993; Islam and Liu, 1995; Matzler and Hinterhuber, 1988; Robertshaw, 1995; Tan and Shen, 2000; Tan and Pawitra, 2001) Tan and Pawitra (2000) categorized the attribute based on the Kano model. After determining the appropriate Kano category for each attribute, multiplier values of 4,2,1 are assigned to the attractive, one-dimensional, and must-be categories respectively. Matzler and Hinterhuber (1988) proposed the customer satisfaction (CS) coefficient which consists of the extent of satisfaction and the extent of dissatisfaction. The extent of satisfaction and the extent of dissatisfaction are defined as $\frac{A+O}{A+O+M+I}, \frac{O+M}{(A+O+M+I)*(-1)}$, respectively, where A denotes "attractive", O for "one-dimensional", M for "must-be", and I for "indifferent" attributes in the Kano analysis. The CS coefficient indicates how strongly a product feature may influence satisfaction or, in the case of its non-fulfillment, customer dissatisfaction.

According to the firm's strategy, the choice for setting weight might be different. In this paper, we will use the method of Matzler and Hinterhuber's CS coefficient, especially the extent of satisfaction. So, the Kano analysis is executed for each service component, and each component will be categorized as attractive, one-dimensional, must-be, or indifferent. And extent of satisfaction is calculated as $\frac{A+O}{A+O+M+I}$..

Step 2. Quantitative Analysis of STA using Weight Setting

After finishing setting the weight of the service component, quantitative analysis is executed. The indicator of quantitative analysis is defined as service satisfaction rate for each service component. Each service component is supposed to be independent.

In revised STA, each weight is multiplied to each rate. This is reflected in the following equations for AND and OR gates, respectively

$$Q = \prod_{i=1}^{n} a_i \times q_i \qquad \text{[Eq. 3]}$$

$$Q = 1 - \prod_{i=1}^{n} (1 - a_i \times q_i) \qquad \text{[Eq. 4]}$$

where q_i denotes the satisfaction rate of service component i , a_i denotes the weight for the service component i, and Q denotes the satisfaction rate of the relevant gate.

Through this method, quantitative analysis can be executed, analyzing the total satisfaction rate in the given situation, and estimating the influence of each service component on the whole system satisfaction according to the satisfaction change of each service component.

4. CASE STUDY

A case study was conducted to illustrate the proposed service tree. The target service process is hospital services. The procedure for executing the case example is explained as follows.

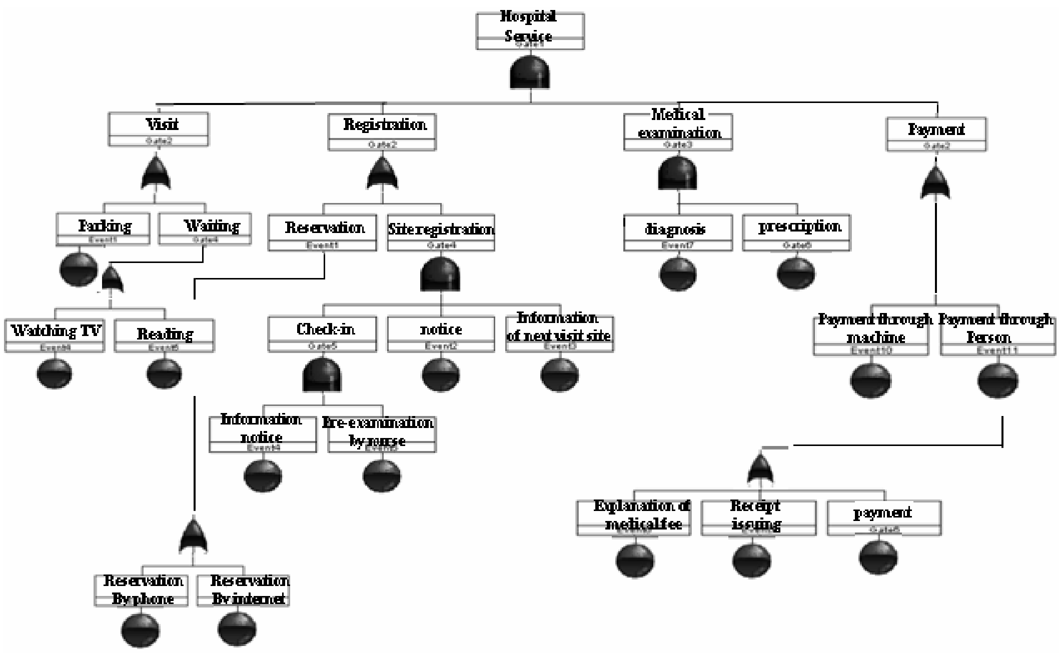
4.1 Composition of Service Tree

In this stage, the structure of hospital service is restructured according to Boolean logic to determine whether one service is always taken by the customer or not. First, hospital service is located as the top event. Then, hospital services are broken down into “Visit”, “Registration”, “Medical examination”, and “Payment”. These components are always happened when customers enter the target service system. So they are linked with an AND gate. Likewise, second level contributors are also broken down according to the first level contributors. For example, there are two subordinate services under the payment service. These are “payment through machine” and “payment through person”. These are not always taken by customers, so they are linked with an OR gate. The tree structure for the case example is described in Figure 3.

4.2 Qualitative Analysis

Qualitative analysis is executed in the same way mentioned. *MSCS* was found to (diagnosis, prescription), so the components of MSCS–diagnosis, and prescription–are turned out as *core*

Figure 3: Service Tree of the Hospital Service



services of hospital services while the remaining services are turned out as *optional services*. Optional services can be categorized as *primary optional services* and *secondary optional services*. Services which are directly connected with core services are turned out as *primary optional services*. These services should be managed along with the management of core services. *Secondary optional services* are turned out as remaining services, which are not directly connected with core services, such as parking, reservation, and payment.

The proposed case example is analyzed by the general hospital service structure. Therefore when it is to be used in a practical context, it might be analyzed more profoundly if the scope is narrower. For example, among the hospital services, payment service or reservation service can be analyzed with detailed element. This makes it easier to understand the whole service process without setting an excessive hierarchy structure.

4.3 Quantitative Analysis

Quantitative analysis is executed to this case example also by using the indicator as the satisfaction rate and weight setting method as Kano analysis. We will use the CS coefficient by Matzler and Hinterhuber (1998) as the weight setting for each component in this case example, as it indicates how strongly the total service process can be influenced by each service component, with a high weight for attractive services. The result of Kano analysis and the derived weigh of each service element are described in Table 5.

Table 5
Result of Kano Analysis and Derived Weight According to Kano Analysis

Service Component	*Kano Result* *M*	*O*	*A*	*I*	*Extent of Satisfaction*
Parking service	0	12	41	0	1
Supporting TV service	6	24	11	12	0.66
Supporting reading material	5	21	19	8	0.75
Reservation by the phone	0	16	31	6	0.89
Reservation by the internet	0	11	40	2	0.96
Information notice	8	18	6	21	0.45
Pre-examination by nurse	12	17	9	15	0.49
Notice	10	8	11	24	0.36
Informing of next visit site	2	23	21	7	0.83
diagnosis	49	3	0	1	0.06
prescription	49	4	0	0	0.08
Payment through the machine	0	8	39	6	0.89
Explanation of medical fee	7	24	19	3	0.81
Receipt issuing	24	18	9	2	0.51
Payment	47	4	0	2	0.08

Through this table, the extent of the influence to total service in case of improvement can be identified. To analyze the influence of each service, we try to change the probability of each service component. Suppose that initial satisfaction rates of all services are 0.6, and they will be changed to 0.8, respectively.

Table 6 shows the results, comparing the results according to the adjustment of the component satisfaction weight according to [Eq. 3] and [Eq. 4]. In this way, the influence of each service component can be estimated. Core services such as diagnosis and prescription show an improvement of 33.67%, whereas the optional services show about 0~10%. This

Table 6
Rate of Change in Improvement of Satisfaction when the Weight is Adjusted

Changing Target	*Extent of satisfaction*	*Overall service satisfaction* *P = 0.6*	*P = 0.8*	*Rate of change in improvement of satisfaction*
Parking Service	1	0.00101	0.00109	7.92%
Supporting TV service	0.66	0.00101	0.00105	3.96%
Supporting reading material	0.75	0.00101	0.00106	4.95%
Reservation by Phone	0.89	0.00101	0.00111	9.9%
Reservation by Internet	0.96	0.00101	0.00113	11.88%
Information notice	0.45	0.00101	0.00101	0%
Pre-examination by nurse	0.49	0.00101	0.00101	0%
Notice	0.36	0.00101	0.00101	0%
Informing of next visit site	0.83	0.00101	0.00101	0%
Diagnosis	0.06	0.00101	0.00135	33.67%
Prescription	0.08	0.00101	0.00135	33.67%
Payment through machine	0.89	0.00101	0.00109	7.92%
Explanation of medical fee	0.81	0.00101	0.00107	5.94%
Receipt issuing	0.51	0.00101	0.00104	2.97%
Payment	0.08	0.00101	0.00102	0.99%

means that improvement of core services is sensitive to total satisfaction. Among the optional services, 'reservation by phone' and 'reservation by internet', 'parking service' and 'payment through machine' are turned out to be influential to the total satisfaction. So if these services are improved, the total satisfaction will be highly improved over other optional services.

5. CONCLUSIONS

This paper proposes a novel approach named STA, translated from FTA. STA is based on the idea that customers always make choices for each service component whenever they enter the service process. The service process needs to be analyzed through the points of view of customer participation and selection behaviors. In STA, the subordinate service components which are always taken by customer are linked with an AND gate, whereas the components which are optionally taken by customers are linked with an OR gate. This tree has the concept of Boolean logic tree, reflecting the customers' selection of the service components they meet and overcoming the limitations of previous studies that haven't consider the component selection of target service process.

The analysis of service tree is conducted in two ways, qualitative analysis and quantitative analysis. From these analyses, strategic useful information can be derived. Qualitative analysis is executed using the concept of MSCS. Through the concept of MSCS, core services and optional services can be easily derived, and these elements can be managed according to firm's strategic purposes. If the firm aims to develop the basic core service, derived core services should be managed carefully, whereas derived optional services should be managed when the purpose of the firm is differentiation. Quantitative analysis can show the influence of each service component on the total system, as well as the sensitivity of each service component by estimating the probability of occurrence of higher level event. Because it is widely believed that increases of satisfaction of each service don't guarantee the linear increase of satisfaction of total system in service fields, weight for each component is derived by Kano analysis before being used for probability calculation.

Therefore, we can summarize that the implication of this study is threefold. First, the service process can be structurally analyzed and visualized from a customer's point of view. Second, the proposed approach can help to classify the core services and optional services, providing the strategically useful information. Finally, service process can be analyzed in quantitative way, measuring the influence of each service component on whole service process.

However, this paper also has limitations. The most important thing is that constitution of service tree is subjective to some extent. Further research should cover the subjective aspects of tree construction. The second limitation is a matter of weight setting. As service itself is intangible and hard to be analyzed quantitatively, it is also hard to analyze quantitatively how the satisfaction of each service component affects the whole service process. To overcome this, a weight setting method should be considered according to the situation of firms. In this paper, we used the CS coefficient as the weight setting method, but there might be better way to set the weight for each component. So, the objective and effective way to set the weight should be considered in future research. Finally, XOR gate will be considered in future research. Currently, AND and OR gates are only considered to constitute the service tree, but XOR condition is basic and important condition in the process analysis. Therefore, consideration of XOR gate will help to analyze the service process elaborately and practically.

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