

# Introduction to service engineering

## — A framework for theoretical study of the service engineering —

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This paper proposes a framework for a theoretical and systematic study of service engineering. In this framework, primitive service is defined as a person (donor) donates a service to another person (receptor), and the service effect occurs when the receptor receives the service donated by the donor. The conventional service is amplified primitive service through some medium. The service industry is a complex system composed of those conventional services, in which primitive services are amplified and organized by diverse tools and various social mechanisms.

**Keywords :** Service science, theoretical framework, function, amplification, service industry

### 1 Introduction

This paper describes a system necessary to discuss service from an engineering perspective. The system is synthesized as a “product” that is to be usefully utilized for improving real services, and the synthetic process of the system is clarified as explicitly as possible within this paper. The system must clarify objectives, range, and related disciplines of service engineering, as well as extract concepts that are necessary to address the service theoretically and to clarify relationships among concepts. Also, the service engineering must promote reconsideration of society and industry from a perspective of service, creation of new service and its industrialization, extraction of elemental technologies for service and their improvement, and improvement of service productivity in the current industry *etc.*

The basic stance of this paper for considering service is stated here. Although the following points have been discussed earlier by the Author *et al*<sup>[1]-[3]</sup>, they will be summarized to set a starting point of the paper.

- (1) Human possesses an ability to manifest function<sup>[1]</sup>.
- (2) All things have functions<sup>[1]</sup>.
- (3) A function is recognized as being meaningful or valuable to human<sup>[1]</sup>.
- (4) Both natural and artificial things have functions, but the function of artifact contains the intent of the manufacturer<sup>[1]</sup>.
- (5) A value of thing is not in the object itself, but is in its function<sup>[2]</sup>.
- (6) A function is latent and becomes manifest through an action or a use. However, a different function is manifested depending on the mode of the action or the use<sup>[1]</sup>.
- (7) A service is manifest function<sup>[3]</sup>.

- (8) A service is unique to human, had existed before the establishment of industry, and was the major motivation for human to form a society<sup>[3]</sup>.
- (9) Because, as an artifact, industrial product manufactured is a carrier of an intended function, manufacturing industry and service industry are not separated but are mutually and complexly related<sup>[2]</sup>.
- (10) Because the purpose of products made by manufacturing industry is to strengthen or amplify services, service industry ideologically includes the manufacturing industry<sup>[3]</sup>.

Here, service is identified by its meaning or value to human, and therefore it cannot be discussed in terms of physics, and must be discussed in terms of function study. However, there is no study of function that compares the consistency of physics, and since function study is an emerging discipline<sup>[4][5]</sup>, service engineering must evolve side by side with the basic function study or contribute to its advancement. This is a difficult issue revealed in this paper. However, if this issue is encountered frequently, it may mean service research has a great potential to contribute to the advancement of function study.

In the service engineering, functions and values are discussed separately. The function is thought not dependent on personal subjectivity. On the other hand, the value lies within a person because it is dependent on human values, and thus the value cannot be discussed without considering the fact that people seek different values in a certain object. Human value is an issue that transcends service engineering, and this issue will not be addressed here, although it must be inevitably addressed when discussing specific service. However, when the word “value” is used to mean some agreement within the society, it will be specified in this paper as “a social value.”

Currently, the perspective of nature providing services to

human is drawing an attention, as exemplified by ecosystem service<sup>[6]</sup> and the value of nature<sup>[7]</sup>. Although this is an important perspective, in the stance of this paper, it will be discussed elsewhere and later as an issue of function. The basic premise here is that service is donated “by a person to another person.”

Any strict definition of service will not be given here, and it is simply stated as a manifest function. Rather, we shall state that this paper itself presents a definition of service. However, when “service” is simply mentioned in the text, it means a service in general terminology except otherwise noted.

## 2 Basic Framework

### 2.1 Service in general

Service action is an action taken by a person with some intent or motivation to influence another person (or other people) in some way. In general, it is a time-series or a temporal process. It does not happen when a person lives alone. It occurs when people form a society, and thus service is a fundamental reason of forming a society. There are also a service to oneself and a service as a blessing of nature, but these services will be considered special or degenerated service.

A person donates service to another person. This is a service-donating action. Then the other person takes a certain action in response to the service received. This is a service-receiving action. The person is the donor of service and the other is the receptor of service. In general, each action is time-serially characterized by temporal element. When all the service actions are completed, a change occurs to the external world as well as to the donor and the receptor. The summation of changes is called a service effect. The series of process may be called a service phenomenon.

When only one person donates a service to another person, it is “a primitive service.” Figure 1 shows some examples. A primitive service is donated directly or through some medium (called “vehicle”). In case of a primitive service

Meaning (Contents)	D's preparation (design & planning)	D's providing action	D: Donor R: Receptor effect: ① Body ② Mind ③ Material			
			R's receiving action	R's effect (Function level)	Example of D	Example of R
① Medical care	Diagnosis	Treatment	Accepting	Health level	Mother	Child
Elderly care	Judgment	Elderly care	Dependence	Action level	Youth	Elderly
Assistance	Request	Assistance	Cooperation	Achievement level	Strong man	Weak man
Transfer	Designation	Transportation	Obedience	Distance	Driver	Passenger
Eating & drinking	Cooking	Serving	Eating & drinking	Satisfaction level	Husband	Wife
Beauty	Decision	Make-up	Make-up	Appearance	Person	Self
Lodging	Preparation	Providing	Sleep	Rest	Innkeeper	Customer
Education	Evaluation	Preaching	Listening	Learning level	Parent	Child
Information	Creation	Transmission	Reception	Information level	Person	Acquaintance
② Consultation	Analysis	Proposal	Solution	Problem solution	Wise man	Troubled person
Music	Direction	Performance	Hearing	Excitement	Performer	Listener
Story	Production	Speaking	Listening	Entertainment	Storyteller	Listener
Entertainment	Direction	Performance	Viewing	Relief	Person	Family
Storage	Evaluation	Maintaining	Entrustment	Volume x Time	Keeper	Entrustee
③ Transportation	Packaging	Delivery	Entrustment	Volume x Distance	Truck	Receiver
Maintenance	Diagnosis	Repair	Reception	Recovery & performance	Fixer	Non fixer
Production	Design	Manufacturing	Use	Convenience	Skilled person	User

Fig. 1 Example of primitive service.

that can only be donated through medium because it cannot be donated directly, the medium may amplify the service as described later, and therefore it is necessary to set a standard medium for a primitive service. Primitive services may form a chain. If the service is not a primitive service, the following terms are used. In case there is one donor and two or more receptors, it is called a distributed service; in case there are two or more donors and one receptor, it is an integrated service; and in case there are two or more donors and receptors, it is a socialized service. Through a chain with those combinations, the services form a network.

When each action which is taken for the purpose of donating a service is completed, the temporal sum of these actions up to that moment is called the amount of service donated. A change that occurs to the receptor is a result of the donated actions motivated by the donor, and this is called a main service effect. The main service effect is temporal sum of changes that occur as a result of receptor's receiving action, and this can be divided into physical, corporeal, and mental.

Changes that occur to subjects other than receptor includes those that occur to donor (for example, fatigue) and change in medium or tool used (for example, wear). Such changes are called sub-effects. The change in the external world that results from service donating actions by donor (for example, the environmental pollution) is called a ripple effect. Each change is the result of respective action (reaction in case of change in object). Such a change is diverse, and it can be divided into corporeal and mental in human, and physicochemical for object.

The above definition of service is consistent with the conventional stimulus-response concept. The service-donating action is stimulus whereas the service-receiving

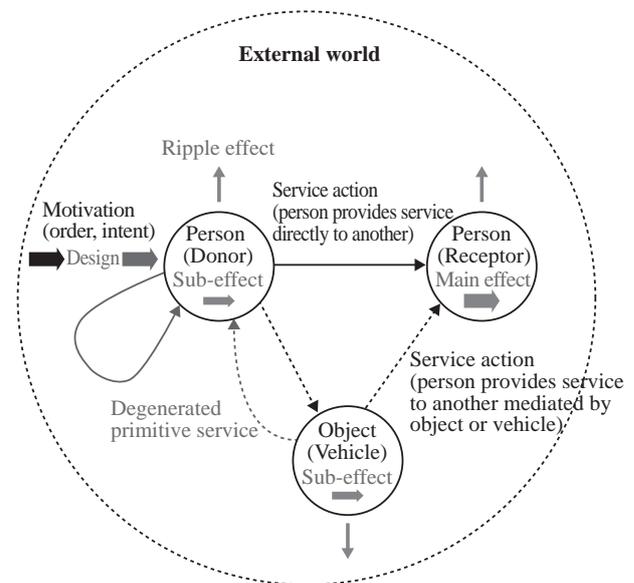


Fig. 2 Basic system of primitive service.

action is the response. However, as it will be explained later, service structure that is equivalent to stimulus-response possesses unique structure as shown in Figure 2, and true nature of service cannot be discussed without clarification of this structure. The stimulus-response model may be applied if the service is discussed in a macroscopic or phenomenal perspective without considering this structure.

### **2.2 Donor of service**

One who donates service is called a “donor” and takes an action according to some motivation. Motivation can be diverse, but it can be divided into autonomous or intent and heteronymous or order. Intent and order indicate the main effect to be extended to the service receiver called “receptor”. When an intent or an order is expressed, the service action that is useful for realizing the effect is designed. Sometimes it can be designed by the receptor who places the order, but in most cases it is designed by the donor. As it will be mentioned later, a specialist who is called a (professional) service designer may emerge as the service is socialized, but this may weaken the communication between the donor and the receptor, which is often a major issue in the service. This must be discussed separately (an issue of ready-made service in manufacturing industry).

In case the donor handles the design, the donor acts according to the design, and part of this action is delivered to the receptor as a useful service. Here, a gap may form between the order and the service, depending on the excellence of the design to fulfill the intent or the order, mastery of maneuver or expression of donor’s action, and the communication efficiency. This gap arises from the donor, and depends on the donor’s total ability, and the ability to control this gap is called the service-realization ability of the donor. These will be defined later.

### **2.3 Receptor of service**

When a receptor receives a service from a donor, he/she takes a certain action and the result of this action becomes the effect. Effect includes a physical change (such as a change in the situation or the location), a corporeal or a physiological change (such as a recovery from disease), and a mental change (such as an increased knowledge). The latter two are changes in the status that cannot be expressed in terms of a physical quantity. The receptor who will receive a service has an expectation previously for the main effect that will result from the reception, and this expectation is expressed as an order.

It should be emphasized that in this paper, the change in receptor’s status is not given heteronomously, but is caused by the own action of the receptor. That is, the flow is as follows:

Service donated → Receptor’s action → Change in the receptor’s status

The action here is not necessarily receptor’s voluntary action. For example, a patient who underwent a surgery is taking action as he/she recovers even while anesthesia is still in effect. Whether voluntary or not, recovery will not take place unless there is a physiological action of the patient. Such action of receptor includes physical, corporeal, and mental aspects.

This implies that the potential ability within the receptor is brought out by the external stimulus or service, becoming a receiving action, that causes an effect on the receptor. The fact that the effect of service is caused by the action of the receptor themselves, makes the issue of service return to an issue characterized by the basic property of living matter.

The reason for above thought process is because the concept where the service donated by the donor directly changes the receptor’s status is similar to the concept of human as a passive machine. This blurs the independence of the receptor which is the main subject of the service. In other words, the essence is to position the receptor’s action as an exertion based on the independent decision according to the receptor’s potential ability caused by donor’s stimulus, and then to think about the effect which this own action will have on the receptor. In this case, we must be careful not to lose sight of the essence of the service by ignoring the intrinsic structure of response. When a donation of the service and the realization of main effect are considered macroscopically to be stimulus-response phenomenon, the direct relationship between the two can be called a service receptivity, and the numerical value can be called a reception sensitivity.

Based on the above thinking, the service donated to oneself can be understood as follows. A person has an expectation that a certain effect will occur, and he/she takes a certain action to realize it. This is a donating action, and the receiving action occurs simultaneously or sequentially. The receiving action brings about an effect. Here, the donor and the receptor are the same person. This is a case of a degenerate service, whereas a service is normally donated by one person to another. Under this premise, the reason for receiving service from another is because the degenerate service cannot be donated or a person does not want to donate a service to themselves. The fact that there may be situation where the service cannot be donated themselves or a person does not want to donate the service to themselves is the exact reason that the service exists socially.

For a receptor, the quality of the service received can be measured by how much the service donated meets the receptor’s expectation. This is called a fulfillment level of service. The receptor’s expectation is reflected in the receptor’s order. The most difficult point in the service issue is the fact that the receptor him/herself does not completely understand this order. It is usually decided by the receptor’s values and sensitivity as well as the receptor’s circumstance

of making a decision or motivation to place an order. However, these are subjective in nature and are difficult to express objectively. In this paper, we shall avoid considering the internal structure or the content of subectiveness, and just state that the receptor's expectation is "the effect that the receptor wants to happen."

In general, the expectation becomes starting point from which the service originates. It is composed of the following transitions:

Receptor's expectation (effect that receptor wants to happen)  
 → Donor's design → Service donated → Service received →  
 Receptor's action → Effect on receptor

Here, definitions about the individual "excellence" of each transition are given, which can influence the service productivity to be discussed later. Improvement of the productivity occurs when the above chain forms a loop, and then the circulation of information in this loop causes the service to evolve.

- (1) Excellence of design (ability of the donor or the service designer): Relationship between the receptor's expectation expressed as an effect and the projected effect caused by the service designed to realize that effect. This includes a relationship between the receptor's ability to express his/her expectation as an order, and the donor's ability to understand the effect that the receptor wants to happen.
- (2) Skill mastery of donating the service (donor's ability): Relationship between the service donated by the donor according to the design and the actual design.
- (3) Communication efficiency (quality of medium between the donor and the receptor): Relationship between the service donated by the donor and the service received by the receptor.
- (4) Coefficient or function of receiving an action (receptor's property): Relationship between the service received and the receptor's action.
- (5) Coefficient or function of effect realization (receptor's property): Relationship between the receptor's action and the effect achieved.

Obtaining quantitative measures for the above indicators will become a major work in the service engineering research.

## 2.4 Supplementary concept

We have explained basic concepts needed to discuss the service, and supplementary concepts will be mentioned next. In a real service, it is necessary to consider the relationship between the effect achieved and the effect one wants to happen. In practice, this can be called a service fulfillment level. Since an expectation (an effect which one wants to happen) is transformed into an effect in the order of

(1) → (2) → (3) → (4) → (5),

the fulfillment level is the relationship between (1) and (5). Since (1) and (2) are donor's ability, and (3) is usually selected by the donor, (1), (2), and (3) can be called donor's ability to realize the service. On the other hand, (4) and (5) are receptor's property. They are abilities to receive the service, so they can be called receptor's sensitivity. Then, setting the effect on receptor as the main effect, the following relationship can be obtained:

Main effect = Donor's ability to realize \* Receptor's sensitivity \* Effect wanted to happen

Currently, \* is unknown, but it is an important relationship in discussing the service. Here, when {Donor's ability to realize \* Receptor's sensitivity} can be obtained, it will represent the level of achievement of the expectation provided from the donor's viewpoint, and the fulfillment level of the service from the receptor's viewpoint. This is a useful expression when discussing service as a phenomenon.

The service realization level (from donor's viewpoint) and the service fulfillment level (from receptor's viewpoint) are the same, and this is integrated characteristic that contains both properties (abilities) of donor and receptor. The receptor's coefficient of receiving action and quality of the service donated are not necessarily independent, and are, in most cases, dependent on each other. A practical or phenomenal expression for the above main effect holds clear meaning when the two are independent, and is not very useful when they are dependent. Therefore, it is necessary to select properties so that the two are independent, and this is a research topic for the service engineering. Also, when

Donor's ability to donate service \* Receptor's sensitivity to receive service = 1

The service can be called perfect because levels of the achievement and the fulfillment are both 1. While this can be realized with a perfect design, the highest skill mastery, a communication without loss, an accurate response, and a proficient exertion of function (a sufficient condition), it is not realistic. The issue of service engineering is to seek a maximum realization under limited conditions.

## 2.5 Temporal consideration in service

As mentioned in 2.1, a service is a time-series. Although this was not stated explicitly in the above discussions, it did not mean that time can be ignored. One of the characteristics of the service is time course, and this discussion is one of the most important elements. The reason that time was not taken up until now is because the consideration of time in function study has not yet been established, and to discuss the temporal aspect of the service implies the discussion on time in function, which adds an extremely complex underlying issue. Therefore, let us attempt to consider the time aspect in

a topical manner limited only to service.

(1) Relationship of function and service

Human action and the use of things bring out potential ability, and the activation of the ability is considered to be an exertion of function, so the potential ability can be called a latent function here. Then the function manifests “slowly” through the action and the use. The relationship can be described as follows. The latent function is  $L$ , the manifest function is  $F$ , and the speed of manifestation is  $f$  with following relationship:

$$L_{d0} = L_{d1}(t) + F_{d1}(t)$$

$$f_d = -k_d \cdot d(L_{d1})/dt$$

$d$  represents the donor.  $L_0$  is the initial value of the latent function, and the service can no longer be donated when this reaches 0, and it determines the donor’s lifespan for donating a service.  $f$  is a speed of appearance of the function, and is a time-speed for donating service, and service in general meaning falls into this category.  $k$  is a parameter which includes diverse meanings, and must be defined separately.

(2) Relationship between effect and service

Definition is necessary for receiving actions of receptor. Reception is a situation where the function flows in at a certain speed. However, the function that flowed in at  $f_r$  does not immediately become receptor’s latent function, but some part is wasted. The latent function  $L_r$  that the receptor already possessed does manifest as  $f_r'$  to generate effect. This is service effect  $e$ . Then, we obtain some relationships as follows:

$$f_r = k_r \cdot d(F_{r1})/dt$$

$$F_{r1} \neq L_{r1}$$

$$L_{r0} = L_{r1}(t) + F_{r1}'(t)$$

$$f_r' = k_r' \cdot d(F_{r1}')/dt$$

$$f_r' = -k_r' \cdot d(L_{r1})/dt$$

$$F_{r1}(t) = (\text{Excellence of design, mastery, communication efficiency}) * F_{d1}(t)$$

$$f_r' = (\text{Coefficient of receiving action}) * f_r$$

$$e = (\text{Coefficient of effect realization}) * f_r'$$

$r$  is for the receptor. The service  $F_d$  becomes  $F_r$  when delivered to the receptor, and flows into the receptor at  $f_r$ . Receptor who received it exerts function from  $L_r$  at speed  $f_r'$ , and increases  $F_r'$ . These relationships are possible, of course, when both are quantitatively expressed, but quantitative expression is conventionally not easy. However, quantitative considerations are sometimes done unconsciously in an actual practice, so precise consideration of this unconscious quantification is useful. This is an important topic of the service engineering, and the outline of the issue will be presented using an example.

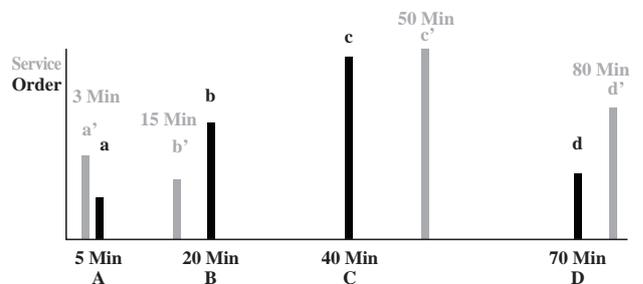
Example) Dining at a restaurant

A person goes to a restaurant to have a meal. He sits down; looks at the menu, and selects aperitif (A), appetizer (B), main dish (C), and desert (D). Then he places an order. This is an order by the receptor. The cook who hears the order considers the customer’s preference (service design), cooks (service maneuver), and serves the dish (service donation). It is immediately apparent that timing for serving the dish is important. First, the order of aperitif, appetizer, main dish, and desert must be observed strictly. Also, the time interval between each meal elements is extremely important. However, the customer usually does not designate the interval. Therefore, estimation of the receptor’s expectation by the donor is a part of the service design. In this example, the donor’s motivation of providing action is an order. To simplify, let us assume that the receptor sets the order time, and his expectation is completely fulfilled when the order is provided as designated, or in other words receiving action and effect realization are perfect, that is both coefficients are 1. The result, for example, may be as shown in Figure 3. There is a gap between the order and the providing action. The gap consists of quality or quantity between expectation and provision (the Figure evaluates quality; it is quantified as  $x$  and  $x'$ ) and gap in time (expectation  $t$ , provision  $t'$ ), and results in decreased level of achievement. Of course, the fulfillment level also decreases. The value can be calculated as follows:

Fulfillment level or Achievement level =  $1/4\sum (xx' / x^2) (1 - (|t - t'| / t)) = 0.69$

The fulfillment level is about 70 %. As in this example, the problem cannot be solved practically unless the service is considered as a time course. In this example, only the time of serving dish is shown, and this is an approximation by discretization.

Originally, donation and reception are considered to be a continuous function of time. If the individual service is



R’s order: Wants to enjoy good meal. Selects items A, B, C, and D from menu. Expects that the items will be served according to time course a, b, c, and d, and places order.

D’s service: Makes preparation, i.e. cooks, to meet R’s order, and serves items at appropriate timing a’, b’, c’, and d’.

Fig. 3 Dining at restaurant.

designed and analyzed in terms of engineering by observing the behaviors of the donor and the receptor, it is necessary to describe the service more microscopically and consider it as a continuous process. In the above example, the cook or the donor has time course of designing dish and preparation involving movements (included in the donation), while the customer or the receptor has a time course of reception including the expectation until the dish arrives, eating and drinking, and resting between dishes. Although it is not easy, it is possible to express the time course with some conditions. For example, the donor increases the “latent function for the donation” through preparations (“function for cooking” has been already exerted). When the providing action occurs through serving of dishes, the function for the receptor is exerted, and it becomes a manifest function or service, and the cumulative latent function decreases. In this sense, service is change (temporal differentiation) in latent function accumulated by preparation. The time course is as follows: receptor’s reception increases rapidly on arrival of the dishes, this leads to the receiving action of dining, the fulfillment increases, and a new fulfillment occurs as the receptor enjoys the afterglow of meal. The elements of the donor and the receptor are not independent, and, of course, the relationship that characterizes the service exists between the two elements. Therefore, the service issue is a mutual relationship between limited continuous processes with autocorrelation.

### 3 Amplification of service

Here, let us address the amplification of the service. This is an important issue related to the fact that the service is drawing attention as an industrial or an economic problem. It is also related to the productivity of service industry. These issues will be discussed in the future, and here we shall describe only the basic concepts that must be understood to enter into the discussion.

A service can be amplified. The amplification can be accomplished by a medium (or a vehicle). Setting a primitive service in which a person donates a service to another person as a basic unit of the service, the rate of service amplification can be expressed as the ratio of (amount of) service to (amount of) primitive service.

There are two modes of amplification. The first is strengthening by a medium within the condition of primitive service. When one person donates a service to another person, not directly, but through a medium (in most cases, through tools), the service may become higher in speed or wider in range (when transporting a person, higher speed service can be donated using a motorcar rather than carrying the person on back), and this is called a strengthened primitive service. The primitive service in which the person is carried on back is amplified through strengthening medium (tool) called motorcar. The second mode is the proliferation.

The amount of service is increased when a network is built using media and the service is delivered to many people without losing the amount donated per person. One service donor can donate the same service to several receptors (Rakugo, a Japanese traditional art for telling humorous stories, told to one person can be heard by tens of thousands of people through the television media). The delivery of the service in this manner is called amplification by proliferation.

The medium (vehicle) that bridges relationship between the donor and the receptor includes tools such as devices and machines, circumstances such as stage and building, and social system such as laws, regulations, rules, and customs set by nation, government, region, or organization. Examples are shown in Figure 4. In order to calculate the amplification quantitatively, respective consideration must be taken for each case. Using the aforementioned example, number of television sets can be used as rate of amplification due to proliferation. In terms of strengthening, if the transportation service can be donated in 5 min by car while it is 30 min by carrying the passenger on back, the rate of amplification by strengthening is 6. However, it cannot always be measured, and along with qualitative improvements, the quantification is not easy. For example, in the restaurant example, the fulfillment for the cooking (taste, for example) was quantified, but this is not necessarily accurate. In this point, effective measurement method must be determined by employing the knowledge of related disciplines and by introducing new points of view to the each field of service.

When considering the cost of amplification, the perspective shifts to economy. There are many issues including the productivity of service industry. Many issues that are currently drawing attention and are being investigated belong to this topic.

### 4 Summary: related disciplines and research topics

Amplifying media	Types of media	Example of service amplifying media
Tool	Tool, device, machine, database, software, etc.	Television, message device, automobile, word processor, search engine (all devices are service amplifiers)
Circumstance	Structure, spatial configuration, network, etc.	Theater, hotel, recreation hall, information network, road
Social system	Law, system, rule, organization, custom, etc.	Government, ward office, police box, bank, store, communication system, traffic system, hospital, school, company (administrative, financial, distribution, communication, transportation, medical, and education services)
Integration	Integration of above	

Fig. 4 Example of service media.

Above is the description of a basic framework for discussing service with assumption that it can improve service in the real world. It is a basic model for the service, and the work to verify this model is to follow. For a model to become a scientific or engineering model, it must follow the formality that can be objectively verified. Although the model described in this paper is proposed as having such formality, its verification cannot be done by the laboratory experiment. In this case, the following process is necessary for verification.

First, related fields must be defined. There are many fields as discussed below. In respective fields that are extracted, items that can be explained with an existing knowledge and those that require a new knowledge must be distinguished. If the new knowledge is necessary, that is within a research on scientific or engineering discipline of the service. Next, the relationships among disciplines must be clarified. Since the general method for integrating different disciplines are still under investigation<sup>[8]</sup>, at this point, it must be solved as a problem unique to the service, and this can be called a systemic research on service.

Described below are the related fields that are necessary for creating the framework explained in the above section, together with the reason for the extraction of those fields, the completeness and incompleteness of knowledge in them, and what we shall do in respective fields as the research into service. Let us start them, keeping the primitive service and its amplification in mind. Then, we shall identify the direction of the systemic research on service. This will also be an overlook of synthesesiological research for how we shall build a good service based on scientific investigation of the service elements.

#### (1) Function

As discussed in Section 1, a service is assumed to be a manifest function, so if we understand what function is, then we will be able to understand the service. However, although the function has been addressed in various fields over the history, it has been difficult to define what it is exactly. It is not systematized to be called as “functionology”, and the quantification of function has been unsuccessful<sup>[1][4][5]</sup>. Therefore this discussion will proceed without seeking a general expression of function, but by provisionally defining a functional content of the individual service. As a simple example, as discussed in Section 2.5, the latent function of serving dish to customers is increased when the cook creates the dishes, and the latent function is accumulated by the cooking time. The properties of the service as a temporal differentiation become realistic through such quantification.

Yet generally, the function is more complex, and it can hardly be simplified as in this example. This will become clarified through discussions relying on the basic structure of the

service described below.

#### (2) Service-donating action

We have discussed the service design and following service action responding the motivation of service, that is, own intent or the order from another person. Each has the excellence of design and the mastery of maneuvers. The intent or the order consists of mental, corporeal, and physical components, and from another perspective, it consists of immediate personal motivations to wider social motivations, and thus understanding them requires a diverse perspective. Since an immediate order is met in real time, education and training to understand the person’s unique receptivity are necessary. A specialized knowledge in diversified specific fields is necessary. For example, the pedagogic knowledge is needed for the education service, while knowledge of medicine, physiology, pharmacology, and others are essential for the medical service. On the other hand, language, psychology, and semiotics are useful as a general background. Of course, learning by experience is necessary. Sociology, behavior science, and market survey are necessary for the social service, and the methodology of social science is useful.

There is unique design method for each specific field, but the study of general design theory will be basic. Also, an original method for the service design is necessary, and the data accumulation for the service and development of service CAD<sup>[9]</sup> are useful. Creation of a perfect digitized expression of human form including its movement<sup>[10]</sup> is a useful information source for the service design to be applied to various fields.

The service maneuver based on the design is a discipline in itself. Mastering language and physical expression are necessary, and expression science and sports medicine are also related fields.

#### (3) Service-receiving action

When a person to whom the service is donated receives it, reception is not passive but active as mentioned in Section 2.3, and therefore receiving action is selective. There is a unique selection by the receptor. This is an important characteristic of the service, and also a point that makes service complex. What is the selection in reception including the rejection when the service is donated? It is necessary to clarify the factors that determine the nature of service, including influential factors and influencing mechanism in the selection. An action taken by the receptor and the mechanisms of exertion of effect must be understood in those terms. Here, knowledge from psychology, physiology, behavior science, and life science including brain science, which is yielding many interesting findings, may be useful. However, knowledge and method for understanding the receptor and improving the receiving action are currently

extremely insufficient. As reasons, in response to the current social situation where the professionals become donors, conventional specialized knowledge is employed only for the preparation of providing action and is not considering the receptor. This point must be addressed in the future as a subject about the structure of academic knowledge for service engineering research. For example, although the perspective of accessible design is gaining attention<sup>[11]</sup>, academic maturity of this field is urgently requested..

#### (4) Delivery of service

A service may be delivered directly from the donor to the receptor in a primitive service, but it is mediated in many cases. It not only travels through the network as information, but it is communicated riding on various objects (products). A service takes on several forms when it rides on objects, and we have no organized knowledge for this. This may be a function of the object, and here again is the relationship of the service and the function.

A service that is communicated over network as information characterizes the modern society. There are countless researches and its diffusion as a real technology is dramatic. Its further development is desired, but considering the impact on the society, perhaps we have reached a stage where “information ethics” must be considered from the service viewpoint. On the other hand, the service that rides on the media must be understood in terms of the service amplification of manufacturing industry, which will be discussed later.

#### (5) Ripple effect of service

Some kind of effect occurs in the external world when the service phenomenon takes place in the real society. Although this can be ignored in case of a primitive service where one person donated a service to another person, it becomes an issue when it involves the industry, and must be dealt as environmental load. This point is not considered sufficiently and left as a future issue.

#### (6) Amplification of service

A service issue is drawing attention because the influence of the service industry on economy has increased particularly in advanced countries and is increasing in developing countries. In Japan, it has been pointed out that the productivity of service industry is much lower compared to the productivity of manufacturing industry. Actually, except in information field, the service industry has not been able to increase quality and productivity by using the results of rapidly advancing basic scientific research like in the manufacturing industry.

In the information field, diverse information technologies are widely available, as symbolized by the term “information society.” These information technologies contribute to the increased productivity of the service industry. As a result,

the view became prevalent that the advancement of the service industry is achieved by the advancement of the information industry. However, the service is not only for the information field as shown in the example of the primitive service in Figure 1, Section 2.1. The productivity in wide-ranging service fields can be improved by the combining the knowledge of social sciences with knowledge of diverse science and engineering fields including life sciences, material sciences, environmental science, and physics. However, when considering the productivity of service being affected by those diverse science and technology, it is more convenient to consider the issue of the service amplification before considering the economic issue in order to discuss the service without losing the track of its nature.

In modern society productivity of the service industry is important, and thus opinions that service science is necessary for the improvement of the productivity have grown stronger<sup>[12]</sup>. These discussions start by setting the service as an economic issue and therefore take a different stance from this paper. IBM, where Spohrer works, has triggered the current widespread interest in service, and the service science described there is an integration of several disciplines. In fact, IBM uses the term SSME (Services Science, Management and Engineering). More multi-dimensional discussion is expected in the future.

Here, I must address the “mystery” that Japan is currently called a backward country in the information industry and the service productivity. Japan has improved the productivity by introducing information processing into manufacturing such as CAD-CAM (computer assisted design and manufacturing), FMS (flexible manufacturing system), and IMS (intelligent manufacturing system), and succeeded in taking a superior position in the international competition. Then, what is the relationship between this success and the backwardness? First, it should be noted that the information technology never ventured outside the factory. In fact, the informatization in the factory was amplification of the service action within the factory, and this could have been applied to the amplification of service action outside the factory if it was scrutinized in an abstract manner. Unfortunately this did not happen because the evaluation was done only from the economic viewpoint. However, a more fundamental reason is because the isolation of industrial sectors became the barrier.

Although the information technology was still in infancy at the factory compared with modern level, it pioneered a new territory by fusing with mechanical, electric, and material technologies, as exemplified by mechatronics<sup>Note)</sup>, a term coined in Japan. This allowed Japan to become a leader of international manufacturing industry. Japan will now introduce wider-ranging advanced technology into the service industry that is currently dominated by the information technology, hoping to become a good contributor

to realize the sustainable service industry.

Developing the theory of the service amplification and increasing the productivity of all industries including service and manufacturing industries, or “global productivity,” are necessary conditions for building a sustainable world.

#### (7) Issue as an engineering theory

The objective of this paper is to create a knowledge system that maintains consistency within the system, that is compatible with other disciplines, and that provides a useful method to improve the real service. This can be called the “service engineering theory.” The achievement of this objective depends on the future study, and some of the issues extracted in this paper will be summarized here.

#### (A) Definition of service

In this paper, it is assumed that a service is an expression of latent function (discussion of time as a function being differentiable is one example, and needless to say, it is necessary to discuss more generally without limitation). Although this is a basic definition, the service issue is replaced by the issue of the function as mentioned in the text, and it contributes to discussion of the function by identifying which properties must be clarified as a function in order to discuss the service. The function is a broader issue, and it is assumed that the function will be expressed in the form of mass and free energy (information), but there is a higher possibility of reaching the root of the issue if it is viewed as a service issue. Here, there is a major issue of accepting the “law of conservation” for the function, and this is a serious viewpoint for the service economy. It is necessary to continuously update the definition of the service while referring to the definition of the function.

#### (B) Uncertainty of service

In this paper, we purposefully called the provider a donor and the receiver a receptor. The provider is a donor because this provider does not consider the effect on him/herself and provides without seeing whether the service will be received by another. The receiver is a receptor because this receiver selectively receives what he/she wants. This can be called a social model of service, and the terms were chosen to reflect the actual service phenomenon. As a related basic model, the paper presents the following model of service reception. In this case, the service flows from the donor to the receptor, but the inflowing service does not generate a direct effect, but the receptor’s latent function manifests to cause an effect on self. In addition to the aforementioned social aspect, this model incorporates compatibility with the life maintenance of organisms, guarantee of receptor’s independence, and an explanation of real service phenomenon. These results imply that the service in society cannot be solved determinately, but must be reviewed from the viewpoint of the evolution theory.

#### (C) Factors that influence service

In order to approximate theory to reality, the necessary condition is to extract the influencing factors as faithfully as possible. This has not been done sufficiently in this paper, and must be relegated to the future research. In extraction, it is necessary to select factors that are mutually independent. Although statistical tests on data are useful, it is important to derive effective model (by abduction). This is a major work for future researchers.

#### (D) Quantification

In this paper, various properties of service are often handled quantitatively. However, as mentioned herein, in the service issue in which the major factors are function, human decision, and action based on the decision, discussion of quantification must be carried on carefully. Simplistic quantification or building theory based only on questionnaire and market survey must be avoided, although it may be sometimes useful to obtain figures using survey based on non-specialist models. One of the main roles of the service theory is to draw an insight from elements that are currently unobserved and to encourage observation of new elements. Quantification or measurement is necessary for refinement of the theory. However, it must be undertaken alongside the refinement of the model.

**Note** Mechatronics: Japanese English word coined by Tetsuro Mori (Yasukawa Electric Corp.) in 1969.

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Studied design, manufacturing and maintenance at Faculty of Engineering, The University of Tokyo. In the design study, pioneered “general design theory” in which the design process is described topologically, and developed the basis of intelligent CAD. In manufacturing, pointed out the presence of common basic disciplines for manufacturing industry, proposed “International Intelligent Manufacturing System (IMS),” and lead the movement for 10 years. In maintenance, defined the general structure of maintenance and created a prototype for the maintenance robot MOOTY. Joined the National Institute of Advanced Industrial Science and Technology (AIST) in 2001. As president, established outline of the research institute to undertake Full Research to shift emphasis to sustainable industry based on 10 Rules of Research Administration.

Graduated from Faculty of Engineering, The University of Tokyo in 1956. Professor, The University of Tokyo; President, The University of Tokyo; President, The Open University of Japan; Chairman, Science Council of Japan; Chairman, Japan Society for the Promotion of Science; Chairman, College International pour la Recherche en Productique (CIRP); and Chairman, International Council of Scientific Unions (ICSU). Currently, President, National Institute of Advanced Industrial Science and Technology (AIST).

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## Discussion with reviewers

### 1 Compatibility of the paper with *Synthesiology*

#### Question (Motoyuki Akamatsu)

This paper was submitted as a paper on *Synthesiology*, but I think it will be better to mention the positioning of this paper within “synthesiology”. I think the study of the service engineering is “synthesiology” in two aspects. One is the service itself is synthesiological; the other is that the service engineering is synthesiological because an academic system must be created by integrating related disciplines. If there is a description that this paper is synthesiology in the beginning of the paper, I think the positioning of the paper will be clearer.

#### Answer (Hiroyuki Yoshikawa)

Type 2 Basic Research is a study to extract general inference, knowledge, and methods that underlie the activities to synthesize meaningful artifacts by integrating available knowledge, and I believe a *Synthesiology* paper is to present this process comprehensively. Therefore, it is necessary to consider its position as an academic journal for paper written by “person who makes (or synthesizes) theory (or an artifact).”

Colossal scientific knowledge system is composed of partial systems that are called disciplines. Science includes physics, chemistry, and biology each of which forms a closed and consistent system within its own discipline, which are also mutually consistent. Of course, each discipline includes phenomena that cannot be explained by other disciplines, harbors

issues that cannot be explained within its discipline, and solution to such issue is the motivation to do research. Type 1 Basic Research conducted from this motivation is the normal science as described by Thomas Kuhn.

What is the theoretical research that is not so? Kuhn called research that is not normal science “research that causes paradigm shift” and positioned it as the most important undertaking in the history of science. There is also research that is not research within discipline like normal science, and although not at history-of-science level, it may spin off theory that offer conclusion that has a direct impact of the real world. It also exists more frequently, at wider range, and on daily basis than paradigm shift study. Since theory that has effect on real world is a kind of meaningful artifact, the research to create such theory is synthesiological study. Moreover, such study has common theoretical structure as study that causes a paradigm shift. Of course, in the history of science, a research that causes a paradigm shift produces a theory that solves the problem that becomes publicly known an inconsistency of that age. On the other hand, the theoretical research of daily issues deals with issues that are interest of the age but has no common basis for consideration, and its motivation is the expectation to create a theory to build such basis. It is different, but isomorphic.

If research to create theory is explicitly stated and considered as a paradigm shift research, there arises question of whether it is necessary for the new journal *Synthesiology* to take up synthesiological research to create the similar theory on mundane level. However, it is necessary to recall the following fact. Taking the example of Newton’s Principia that influenced the history of science, Newton had a magnificent originality that generated disciplines, but he offered no explanation for “synthesis” of the central three laws (absolute coordinates, acceleration, and action-reaction). In Principia, after describing the laws, he simply states, “The above was a description of principles that were recognized by mathematicians and verified by abundant experiments” (Sir Isaac Newton, *Philosophiae Naturalis Principia Mathematica*, translated into Japanese by S. Nakano, Kodansha, 977, p. 38). This is followed by 600 pages (in Japanese version) of theorems derived from the laws. This became a major theme of the abduction study by C.S. Peirce, but it was unknown how Newton could “synthesize” such wonderful and useful laws.

Although the importance of the intellectual “synthesis” of creating theory is explicitly stated, neither theoreticians nor science historians could explain the mechanisms. Therefore, it is the work of researchers at AIST who are attempting to extract Type 2 Basic Research, to clarify the secret of theoretical synthesis, and I believe *Synthesiology* is the place where this should be attempted.

Of course, there are many additional matters that must be considered. There are conditions that must be met regardless of whether it is theory or not, as follows.

- (1) Is the goal necessary and appropriate? It is now understood that service theory is necessary.
- (2) What about the trends of research to be disciplinary? We should actively remove them.
- (3) Is the explanation for knowledge integration sufficient? We made effort.
- (4) How about the compatibility of explanation in theory? This is the main objective of this paper.

As a theory, the main subject is basically to define the concepts and to create relationships in the synthetic process. Since the theoretical basis of this paper is set as a hypothesis building, the paper itself is an abduction. Therefore, the propositions must be verified. The main issue is whether there is a format for verification,, and to enable this, variables (concepts) are to be employed by rejecting concepts that are thought non-measurable.

As the Reviewer points out, it is necessary to consider that service itself is synesthesiology, but it is difficult theoretically to consider them simultaneously, so please refer to the Author's paper, "Introduction to general design" (*Seimitsu Kikai*, 1979).

## 2 On terminology

### Question (Motoyuki Akamatsu)

Since the formulation of service is the main subject of this paper, I think it is important to clarify the definition of terminologies and variables as much as possible. When read from this viewpoint, there seems to be lack of unity and unclearness in terminologies. For example, terms "latent ability" and "latent function" seem to be used interchangeably to express similar concept.

### Answer (Hiroyuki Yoshikawa)

Latent function is an expression of a latent ability, so (1) of Section 2.5 is changed to: "Human action and use of things bring out potential ability, and here activation of the ability is considered an exertion of function, so the potential ability can be called a latent function. Then function manifests 'slowly' through action and use." Other terminologies were unified.

## 3 On latent function of receptor

### Question (Motoyuki Akamatsu)

In Section 2.5 (2), there is description: "Latent function  $L_r$  that the receptor already possessed is exteriorized as  $f_r$  and regenerates effect. This is the service effect  $e$ ." However, this is not presented explicitly in the equation presented below. Since the fact that receptor's latent function influences service effect is major point from viewpoint of service, I think the formula should be revised to express this point.

### Answer (Hiroyuki Yoshikawa)

Since the point indicated is important issue in service, I shall explain specifically and in details. Taking the example of restaurant, it is probably as follows:

- $f_d$ : Speed of provision of dish (food)
- $f_r$ : Speed on intake of dish (food)
- $L_r$ : Volume that can be consumed (hunger volume)
- $f_r'$ : Speed of consuming dish (food) perceived to be tasty (meaningful service for receptor)
- $F_r$ : Amount consumed
- $F_r'$ : Volume of tasty dish among dish consumed  $\leq F_r$

Therefore,

$$L_{r0} = L_{r1} + F_{r1}'$$

This equation means that initial hunger volume is filled with good food only. It raises question of whether one can be filled with bad food, but here, let us say that that does not happen. In this case, there is a problem to be considered because to reach satisfaction or to make the hunger level 0, the cook (donor) must make preparation

$$L_{d0} > L_{r0}$$

As indicated by the Reviewer, the relationship of  $L_r$  and  $f_r'$  is important, and there is basic problem of psychology of dining where food tastes differently depending on hunger level. However, at this stage this will not be addressed explicitly, and the possible future consideration can be expressed as:

$$f_r' = (\text{coefficient of receiving action}) * f_r$$

and is included in "\*".

The Author thinks that one of the purposes of the framework theory is that such problems become apparent, and I look forward to future study.

## 4 On $f_r$ and $F_r$ , and $f_r'$ and $F_r'$ in temporal discussion of service

### Question (Motoyuki Akamatsu)

Since  $f$  is defined as differentiation of latent function  $F$ ,  $f$  is speed of appearance, and it is stated, " $f$  is speed of service provision, and equivalent to service in general." Here, I can understand what  $f_d$  and  $F_d$  represents. However since  $f_r$  and  $F_r$ , and  $f_r'$  and  $F_r'$  are only described in the equation, the meaning of " " is difficult to understand, so I think it should be explained with words.

### Answer (Hiroyuki Yoshikawa)

In the example of dining, it is as follows. The dish is served by the donor (provided service  $F_d$ ), receptor recognizes it ( $F_r$ ), and consumes it ( $f_r$ ). At that time, receptor's hunger ( $L_r$ ) sets off the action of receiving service or eating the tasty food ( $f_r'$ ). As result, hunger ( $L_r$ ) decreases and fullness ( $F_r'$ ) increases. Therefore the following explanation was added: "The service  $F_d$  becomes  $F_r$  when delivered to the receptor, and flows into the receptor at  $f_r$ . Receptor who received it exerts function from  $L_r$  at speed  $f_r'$ , and increases  $F_r'$ ."

## 5 On difficulties and issues on systematization

### Question (Masaaki Mochimaru)

In this paper, service engineering is systematized into basic framework (provider, receiver, and time concept) and service amplification, to point out difficulties and technological issues in building specific engineering system and to seek hints for solution. I read it as a scenario for systematization to realize service engineering and to achieve goals, and a discussion of necessity to select, newly study, or integrate technological elements listed as topics. Therefore, I think by systematically organizing and describing the "difficulties and technological issues" that are discussed in "4. Summary," the objective of this research "to propose systematic methodology to advance Full Research for service engineering by selecting and integrating elemental technology" will become clearer.

### Answer (Hiroyuki Yoshikawa)

At end of "4. Summary," I organized and described the issues in "(7) Issues of engineering theory: (A) Definition of service, (B) Uncertainty of service, (C) Factors that influence service, and (D) Quantification."

## 6 On "Receptor's expectation $\rightarrow \dots \rightarrow$ Effect on receptor" in Section 2.3

### Question (Masaaki Mochimaru)

Five factors from (1) to (5) are defined according to "excellence" of transition influencing service productivity, and I understand that "Receptor's expectation  $\rightarrow \dots \rightarrow$  Effect on receptor" circulates and spirals upward. In this case, promoted by the effect that occurs to the receptor, receptor gains new (higher level) expectation, the receptor expresses (orders) that or donor does so (understands intent), and the next spiral is set off. I think the process within "excellence of design" in (1) includes the process of donor learning the receptor's expectation by communicating with receptor, and then expressing this as effect wanted to happen. It is implied in Section 2.2 that this kind of communication is important. If so, I think this should be clearly state in (1).

### Answer (Hiroyuki Yoshikawa)

It is exactly as the Reviewer indicates, so I described the process in which transition becomes loop. I also described the fact that "excellence of design" includes "ability of donor (understanding intent) and receptor (order) to express the receptor's expectation as effect wanted to happen to receptor, and the relationship between receptor's true expectation and expressed effect wanted to happen to receptor," as well as "relationship between ability to design to realize the expressed effect, and the projection of effect that will be caused by the design."