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Measuring Service Value Based on Service Semantics

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ABSTRACT

Service participants can obtain different service values through participating in multiple service solutions with the same function but different performances and these solutions are usually represented as the pre-designed service models. Whether or to what degree the service values can be implemented under the support of the pre-designed service models is as a critical criterion for evaluating and selecting the most appropriate one from these service solutions. Therefore an approach of service value measurement based on service semantics (*i.e.* meaning of service models) is presented in this paper. Starting from a definition of service value, we present a series of concepts (e.g. *value indicators*, *value profit constraints*, etc.) and measure them based on the pre-designed service models. This paper also defines the value dependency relationships among the corresponding service values due to the uncertainty of relationships between multiple quality parameters of service elements, and then analyzes the impact of the value dependency on service value measurement. In order to complement the discussions above, a real-world case study from ocean transportation service is conducted for demonstration.

Keywords: Service Value; Value Measurement; Value Dependency; Uncertainty; Service Element

1. Introduction

With the rapid development of modern service industry, the market competition has become increasingly fierce. In order to obtain larger value persistently, service providers need to constantly provide better service for customers through service innovation. So service providers need to evaluate the profitability of the innovative service. On the other hand, with more and more services available, customers can obtain various services with different values of the same function. So customers need to select the most appropriate service from multiple existing services measured by service value.

For instance, ocean transportation service is a typical IT-enabled modern service, and it includes some business scenarios such as cabin booking, land transportation, customs inspection, etc. The business scenario of cabin booking is taken as an example to explore the above issues. In this business scenario, the ship company can directly provide cabin booking service for the consigners. But this business is not belonging to the core business scope of the ship company. In order to decrease in its cost and pay more attention to its core business, it can outsource this business to the forwarders, and ask the forwarders to assist it to provide cabin booking service for the consigners. So the ship company needs to evaluate whether the latter service solution can really bring him larger value than the former one. On the other hand, one consigner wants to book a cabin, he can directly send a request to the ship company, and can also send a request to the forwarders, asking the forwarders to help him to book the cabin. So the consigner needs to evaluate which service solution is better by comparing the values that the two solutions bring him. In summary, the consigners and the ship company all face the problems of which service solution is best.

Customers and service providers all expect to obtain largest value during the participation in service. In order to obtain largest value, customers need to find out the most appropriate service solution among multiple existing services solutions with the same function but different performances by comparing the values that these service solutions bring them. In order to obtain largest value, service providers need to constantly provide innovative and more attractive service solution for customers. And then service providers need to evaluate whether the innovative service solution can really bring them larger value than the service solutions that already exist. Therefore, customers and service providers all need a method to measure the values brought through the execution of service solution.

So what is value actually? Some researchers think: for customers, value is whether or to what degree their

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requirements are met by services or goods, and for service providers, value is whether or to what degree their utility (or profit) is brought by delivering services or goods to customers [1]. Some other researchers mainly focus on customer value and believe that customer value is the price that customers are willing to pay for delivered services or goods [2].

The above concepts of value are all used to explore the relationship between value and service business activity at the macro level. But in this paper, the concept of value is supposed to explore the relationship between value and service activity at the operational level, because that customers need to decide which service solution (represented as the service process model that consists of service activities and their corresponding physical resources and information at the operational level) should be chose by comparing the values obtained from the service solutions, and service providers need to decide which service solution (represented as the service process model at the operational level) should be used to provide service for customers by comparing the values brought through service delivery.

Therefore, a service value's intuitive definition is given here. The state or degree of specific aspects of a participant (customer or service provider) will be improved after the execution of service, and the profit or utility that such improvement brings to him is defined as the service value. More specifically, there are two types of service values: the first refers to the values generated by transferring specific "things" (e.g., information, a product, money, or the right to use resources) from value producers to value receivers; the second refers to the values generated by improving certain states (e.g., physical states, spiritual states, physical states of possessions) of value receivers.

Moreover, any state improvement or any thing transfer is implemented under the support of various service elements (e.g., service activities, physical resources, or information) in service models [3]. So whether or to what degree service values can be implemented depends on the pre-designed service model related to the existing service solution. If one pre-designed service model enables and supports service values implementation most sufficiently, the corresponding service solution should be chose by customers (or service providers). Therefore, a method of service value measurement based on service semantics (*i.e.* meaning of service model) is presented in this paper.

Many researchers have begun to pay attention to service value measurement. According to different usages of measurement results, the several common kinds of measurement methods are as follow:

- For economic investment

Value only refers to benefits. Value is defined as a value structure that consists of several value factors in the first layer and there are several relevant measures in the second layers for each value factors. An automated Analytical Hierarchy Process (AHP)-based tool can enable the entire process to be achieved [4].

- For service business analysis

Some researchers measure the values that service system generates, taking into account the economic values [5]. The values are calculated according to the exchange of offerings (goods, services) and the participants' satisfaction.

Some other researchers think that the values are generated not only by exchange of goods, services, or revenue, but also by the exchange of knowledge and intangible benefits [6-8]. They qualitatively measured the values of various participants according to the exchange of goods, services, revenue, knowledge or intangible benefits.

In general, the above two kinds of researchers use measurement results of values for analyzing, evaluating and optimizing service business at the macro level.

- For innovative service idea evaluation

In this kind of method, some researchers present an e3-value model (*i.e.* a business model) to describe how economic values are created and exchanged in an innovative service idea [9-12]. According to the number of exchanged value objects (e.g., products, services, revenue and experience, etc.) between the various participants in e3-value model and the economic values generated by each value object exchange, the values of each participant are calculated, and then a profit table is built to reflect the potential profit of participants.

Our approach to measure service values is based on the meaning of service models (refer to process model at the operational level, not business model at the macro level), because this paper mainly focuses on which pre-designed service model enables and supports service values implementation most sufficiently. The approach combines the meaning of service models with service values to calculate service values and to enable the measurement result of service value to reflect whether or to what degree service values is implemented under the support of service models.

In addition, the relationships between quality parameters of multiple service elements may be uncertain, which may result in the value dependency relationships between the corresponding service values. Therefore, the method of service value measurement not only needs to explore how to measure an independent value, but also take into consideration the impact that the value dependency has on service value measurement.

For an independent value, firstly, the quality parameters belonging to its *Value Profit Constraint* are calculated based on the meaning of the pre-designed service model, secondly, the influences (produced by the gaps between the realized quality parameters and those constraints) are calculated by utilizing some typical functions, and then the influences are mapped to the initial values of *Value Indicators*. Finally, the realized service value can be obtained according to the realized *Value Indicators*. For a non-independent value, the calculation of the quality parameters belonging to its *Value Profit Constraint* is related to the dependency function (that is introduced to measure the influences of other values on the non-independent value). The influences should be taken into consideration in the whole measurement process of the non-independent service value.

This paper is organized as follows. Section 2 introduces some basic concepts of service semantics and service value. Section 3 presents an approach of the independent value measurement. And the approach of the non-independent value measurement is explored in Section 4. Section 5 shows a simple case study. Section 6 closes with a conclusion.

2. Service Models and Service Value

2.1. Service Models

Semantics is the meaning of models (*i.e*. meaning of the systems represented by a set of logical components), such as activity, state, attribute, etc. [13]. So the concept "service semantics" refers to the meaning of service models. The pre-designed service model is the basis of service value measurement. Therefore, it is necessary to explore which kind of service model specification should be selected to represent service solution and what service semantics should include.

Business Process Modeling Notation (BPMN) is the service model specification that is generally adopted to represent service solution. Comparing with other service models (e.g. Unified Modeling Language, Service Model Driven Architecture, etc.), BPMN provides the service elements that are more complete and more suitable to describe service business process of service solution, and can be directly supported by executable Business Process Execution Language for Web Services. Therefore, BPMN is selected

BPMN model, like other service models, consists of service elements and their relationships. In BPMN model, the service elements that directly affect service value measurement include service activities, their information and physical resources. The corresponding graphic modeling construct of them is *Activity*, *Data Object* and a new *artifact* (defined by service model designers for modeling physical resources) respectively.

In BPMN, *Activity* can represent task and sub-process. Sub-process is a set of tasks which are inter-connected. In order to support service value measurement, the attributes of task should include:

- the set of participants who are concerned with task;
- the set of action objects which are manipulated by task and their states are changed by the effect of task;
- the set of action objects' state transitions;
- the set of resources that support task's execution to realize state transitions of action objects;
- the set of quality parameters that are attached to task to measure its execution performance.

For the other graphic modeling constructs, their attributes should uniformly include: the resource name, the resource classification (including physical resources and information resources), and the set of quality parameters attached to the resources. The quality parameter set of task and resource are all used to measure some characteristics of service elements, so they are uniformly called quality of service (*QoS*).

For the above attributes, only *QoS* is used to directly calculate service values, the other attributes enables and supports value annotation approach [14,15] for identifying the corresponding relationships between service elements and service values. These corresponding relationships are the basis of service value measurement. Therefore, all the above attributes should be expressed by service model designers in BPMN model.

In addition, the quality parameters of service elements and the relationships between quality parameters of multiple service elements may be uncertain. The uncertainty of quality parameters can be described by probability distribution of discrete random variable, and then the uncertainty of relationships can be described by a set of conditional probability.

It is assumed that there are two service elements se_i and se_j, whose quality parameters are uncertain. The uncertainty of a se_i's quality parameter q_x can be described by the probability distribution for discrete random variable *A*, and *A* represent the value of quality parameter $se_i{\cdot}q_x$. All the possible values of *A* is $a_k\left(k=1,2,\cdots,n\right)$, a_k is a range of value of quality parameter $se_j \cdot q_x$. The uncertainty of $se_i{\cdot}q_x$ can be denoted by $P\left\{A=a_k\right\}=p_k$, $k=1,2,\cdots,n$. The expression of uncertainty of $se_j \cdot q_x$ is similar to one of $se_i \cdot q_x$, and it can be denoted by $P\left\{B=b_h\right\}=p_h, h=1,2,\cdots,m$. Therefore, the uncertainty of the relationship between $se_i \cdot q_x$ and $se_j \cdot q_x$ can be denoted by $P(B_h|A_k)$ $\left(\text{for } k=1,2,\cdots,n; h=1,2,\cdots,m\right)$, where A_k is the event "$A = a_k$", and B_h is the event "$B = b_h$".

The uncertainty of relationships between quality parameters of multiple service elements can result in value dependency relationships between the corresponding service values. And value dependency relationships can affect service value measurement. Therefore, the uncertainty of relationships is useful for service value measurement and also should be expressed in BPMN model.

Service semantics is introduced to explain the known condition of service value measurement. The above service elements and their attributes, especially *QoS* and uncertainty, are taken as the known condition of service value measurement.

2.2. Service Value

In our definition, service value (*i.e.* economic profit) is defined as $v = B - C + \alpha \times E$, where:

- $B - C$ is the direct economic profit that value's receiver obtains, B is the direct benefit, and C is the direct cost.
- $\alpha \times E$ is the contribution made by an indirect profit to the direct profit, E is the indirect economic profits that value's receiver obtain, α is the influence coefficient that is used to measure the influence of E on $B - C$.

Service value v is mainly affected by B, C and E. They are uniformly called *Value Indicator*. Moreover, according to the definition of service value, the *Value Indicator* is affected by the state improvement or degree improvement of the specific aspects of value's receiver. Therefore, *Value Profit Constraint* (*CON*) is introduced to measure the state improvement and the degree improvement. *CON* is a set of quality parameters.

The specific aspect of value's receiver is called *Value Realization Carrier* (*rc*). The state (or degree) improvement is represented as the *rc*'s state transition which is the transformation from the *rc*'s initial state to its expected final state. This state transition brings economic profit "$B - C + \alpha \times E$" to service value receiver.

A quality parameter of *CON* is used to measure a specific characteristic of the *rc*'s state transition. In the above concepts, *CON* is used to directly calculate service values, other concepts (*rc*, initial state, expected final state and the state transition) are used to support value annotation approach.

Referring to the quality parameters that are used to measure services in the reference [16], *CON* also include five dimensions: Time/Efficiency, Price/Cost, Service Content, Resource/Condition and Risk/Credit. There are several relevant quality parameters for each dimension. The quality parameters are chose according to the actual application domain.

Any state transition of *rc* is implemented under the support of various service elements. So the quality parameters of *CON* rely on the quality parameters of corresponding service elements in BPMN model.

As shown in **Figure 1**, service value v is mainly dependent on B, C and E. The *Value Indicators* are affected by *CON*, which can be calculated by utilizing the function f_C, f_B, and f_E. The quality parameters of *CON* should be calculated according to the corresponding service elements' *QoS* by utilizing the function G. At last, service value v affects the satisfaction degree of v's receiver, which can be calculated by utilizing the function H. By this way, the service value can be very well combined together with the *QoS* of service elements, to support service value measurement based on service semantics.

Moreover, according to different roles of v's receiver and different kinds of service interaction, the meaning of *Value Indicators* is different. There are two types of role in service interaction: customers and service providers. There are two kinds of service interaction, as shown by **Figure 2**. In the first hind, service providers provide service for customers and charge customers for certain reasonable fees. In the second kind, service providers provide free service for customers C1 and obtain some "*utility*", and service providers provide service for customers C2 by utilizing the "*utility*" and charge customers C2 for certain reasonable fees. In the service interaction between service providers and customers C1, service provider only can obtain the indirect profit which is the economic profit may be transformed from the "*utility*" in the future during the service interaction between service providers and customers C2 occurring.

For the first kind of service interaction, the meaning of *Value Indicators* is given as follows. For customers, the value that he receives is *customer value* (represented as *cv*). The meaning of *cv*' *Value Indicators* is given in **Table 1**. For service providers, the value that he receives is *provider value* (represented as *pv*). The meaning of *pv*' *Value Indicators* is also given in **Table 1**.

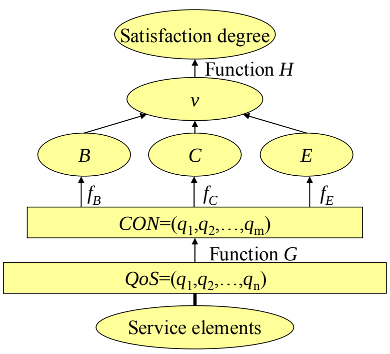

Figure 1. The computation structure of service value.

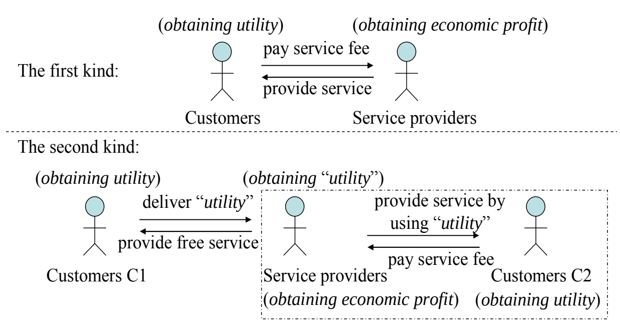

Figure 2. Two kind of service interaction.

Table 1. The detailed information of six kinds of Value Indicators in the first kind of service interaction.

Value Indicators	Nature	Influencing Factor	Initial Value of Value Indicators
cv_B	Variable	cv_CON_B	cv_B_{best} is the max amount of money that customers are willing to pay for the utility that they perceived in the best service, which is proposed by customers.
cv_C	Constant		cv_C is the amount of money that customers actually needed to pay for the obtained service, and is the service price confirmed through the negotiation between customers and providers before the execution of service.
cv_E	Variable	cv_CON_E	cv_E_{best} is the max amount of money that customers can obtain when cv_CON_E is best fulfilled. cv_E_{best} is proposed by providers.
pv_B	Constant		pv_B is confirmed through the negotiation before the execution of service. $pv\_B = cv\_C$
pv_C	Variable	pv_CON_C	pv_C_{best} is the max amount of money that providers pay for delivering the best service, which is proposed by providers.
pv_E	Variable	*sat*	pv_E_{best} is the max amount of money that providers may obtain in the next service interaction when sat is highest. pv_E_{best} is proposed by providers.

For the second kind of service interaction, the meaning of *Value Indicators* is given as follows. For customers, the meaning of cv_B and cv_C is the same as their meanings in the first kind of service interaction. But because the service obtained by customers C1 is free, cv_C equals 0 and cv_E no longer exists.

For providers, the meaning of pv_B and pv_C is also the same as their meanings in the first kind of service interaction, especially pv_B equals 0. But the meaning of pv_E is different from its meaning in the first kind of service interaction. pv_E is the amount of money that service providers may obtain in the future by providing service for customer C2 by using the "*utility*" that is obtained from customer C1 in the current service interaction. It is affected by the value profit constraint pv_CON_E proposed by providers. The quality parameters of pv_CON_E are used to measure some specific characteristic of customers' behavior. The initial value of pv_E is represented as pv_E_{best}. pv_E_{best} is the max amount of money that providers may obtain by delivering the "*utility*" in the future when pv_CON_E is best fulfilled. pv_E_{best} is proposed by providers.

2.3. Value Dependency Relationship

Service value does not exist independently. There could be value dependency relationship among multiple service values. Value dependency relationship is defined as the implementation degree of a service value is completely or partially dependent on one of the others, which is denoted as $d = \{v_1, v_2, \cdots, v_n\} \xrightarrow{g} v_i$. Obviously, value dependency relationship can affect the service value measurement. Dependency function g is used to measure the impact of $\{v_1, v_2, \cdots, v_n\}$ on v_i. As mentioned above, the value dependency relationship among multiple service values are caused by the uncertainty of relationships between various quality parameters of the corresponding service elements.

As shown in **Figure 3**, there are two service values v_i and v_j, and v_j is affected by v_i. The value dependency relationship is denoted as $d = v_i \xrightarrow{g} v_j$, where g is used to measure the impact of v_i on v_j. The impact is actually caused by the uncertainty of relationships between the quality parameters of se_j related to v_j and the quality parameters of se_i related to v_i. A quality parameter of se_i directly affects the corresponding one of se_j, and can indirectly affect the corresponding quality parameters of v_j'*CON*. And then it continues to indirectly affect v_j' *value indicators*, at last indirectly affect v_j.

Value dependency relationship may be caused by one or more quality parameters of service elements. For one, its dependency function is denoted as $g = P(B_h|A_k)$ (for $k = 1, 2, \cdots, n; h = 1, 2, \cdots, m$) which represent the uncertainty of relationships between $se_j \cdot q_x$ and $se_i \cdot q_x$ (as mentioned in Section 2.1). For more quality parameters, its dependency function is also represented as the set of conditional probability.

3. Measurement of Independent Service Value

Independent service value refers to the service value that is not dependent on other service values. Its implementation is not affected by the implementation of the others. It

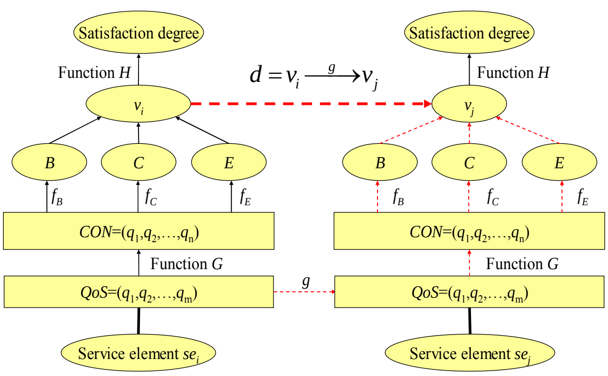

Figure 3. The impact of value dependency relationship.

is measured only based on *Qos* of its corresponding service elements.

3.1. Independent Customer Value

In the first kind of service interaction, for *cv*, its *cv_B* is affected by cv_B_{best} and cv_CON_B, and its *cv_E* is affected by cv_E_{best} and cv_CON_E. Therefore, *cv* can be denoted as

$$cv = f_B\left(cv\_B_{best}, cv\_CON_B\right) - cv\_C + \alpha \times f_E\left(cv\_E_{best}, cv\_CON_E\right),$$

where the function f_B is:

$$cv\_B = cv\_B_{best} \times \left(\sum w_x^S \times g_x\left(q_x^S\right)\right) \times \prod f_x\left(q_x^H\right), \quad \text{where } \forall q_x^S, q_x^H \in cv\_CON_B \tag{1}$$

In the formula (1), q_x^H is the *hard quality parameter*, which means its expected constraint must be fulfilled. The function f_x is used to measure whether q_x^H's expected constraint can be fulfilled by the value of q_x^H. The proposition of q_x^H's expected constraint and the q_x^H's calculation is as follow.

The quality parameter q_x^H's constraint is proposed by customers, and its constraint range is divided into the expected range and the unacceptable range. There are two kinds of quality parameters: the first one is that the bigger the quality parameter is, the higher the quality of the corresponding service is; and the second one is that the smaller the quality parameter is, the higher the quality of the corresponding service is.

Taking q_x^H that belongs to the first kind as an example, its expected range can be denoted as $q_x^H \geq Q_e$, and q_x^H's unacceptable range is denoted as $q_x^H < Q_e$, where Q_e is the smallest one in all the acceptable values of q_x^H. For q_x^H, any values that do not belong to the expected range can not be acceptable.

The quality parameter q_x^H is calculated based on the *QoS* of a service element (or a set of service elements). If q_x^H is related to a service element *se*, then $cv \cdot q_x^H = se \cdot q_x$. If q_x^H is related to a set of service elements $\{se_1, se_2, \cdots, se_n\}$, then

$$cv \cdot q_x^H = G_x\left(se_1 \cdot q_x, se_2 \cdot q_x, \cdots, se_n \cdot q_x\right),$$

where according to different q_x^H and the different sequence relationships between various service elements, the function G_x may be one of the simple operations (e.g. Π, Σ, min, max etc.).

In order to express the meanings of q_x^H in the formula (1), the range of $f_x\left(q_x^H\right)$ is defined as {0, 1}, and the corresponding weight of $f_x\left(q_x^H\right)$ is defined as 1. It is assumed that the range of q_x^H can be denoted as [min, max], then the function f_x is:

- For q_x^H belonging to the first kind, the function f_x is

$$f_x\left(q_x^H\right) = \begin{cases} 1 & \text{iff } q_x^H \subseteq \left[Q_e, \max\right] \\ 0 & \text{otherwise} \end{cases}.$$

- For q_x^H belonging to the second kind, the function f_x is $f_x\left(q_x^H\right) = \begin{cases} 1 & \text{iff } q_x^H \subseteq \left[\min, Q_e\right] \\ 0 & \text{otherwise} \end{cases}$.

If the value of q_x^H belongs to the expected range, $f_x\left(q_x^H\right) = 1$, or else $f_x\left(q_x^H\right) = 0$. When $f_x\left(q_x^H\right) = 0$, the weight of $f_x\left(q_x^H\right)$ is 1, then *cv_B* = 0, which means that when the value of q_x^H is not belonging to the expected range the value's receiver will not be willing to pay any money.

In the formula (1), the part "$\sum w_x^S \times g_x\left(q_x^S\right)$" is similar to the formula to calculate the overall quality proposed by the reference [17]. The formula to calculate the overall quality is firstly to calculate the gaps between expectations of various quality parameters and their perceptions, and then, each gap multiplies with its weighting, and finally the result of the overall quality is obtained. The function $g_x\left(q_x^S\right)$ is also related to the gaps between expectations of various quality parameters q_x^S and their perceptions. But the objective of the function $g_x\left(q_x^S\right)$ is not to simply calculate the gaps but to measure the impact of the gaps on cv_B_{best}. And then, each impact degree multiplies with its weighting w_x^S, and finally the result of *cv_B* is obtained. In this paper, the expectations of quality parameters are represented by the expected constraints that are proposed by value receivers, and the perceptions of quality parameters are represented by the values of quality parameters that are designed by service model designers.

In formulas (1), q_x^S is the *soft quality parameter* that means whether or to what degree its constraint is fulfilled is not strictly required. The function g_x is used to measure whether or to what degree q_x^S's expected constraint is fulfilled by the value of q_x^S. w_x^S is the weight of $g_x\left(q_x^S\right)$, and $w_x^S \in (0,1)$. According to the importance of $g_x\left(q_x^S\right)$ to *cv_B*, w_x^S can be assigned by the experts in correlative domains.

Similar to q_x^H, q_x^S is calculated based on the *QoS* of a service element (or a set of service elements), which is denoted as $cv \cdot q_x^S = se \cdot q_x$ or

$$cv \cdot q_x^S = G_x\left(se_1 \cdot q_x, se_2 \cdot q_x, \cdots, se_n \cdot q_x\right).$$

The quality parameter q_x^S's constraint is proposed by customers, and its constraint range is divided into the expected range, the acceptable range and the unacceptable range. As the space is limited, taking q_x^S belonging to the first kind as an example, the proposition of q_x^S's constraint and some typical formulas of g_x are given as follow.

For q_x^S belonging to the first kind, the expected range of q_x^S is denoted as $q_x^S \geq Q_e$, the unacceptable range of q_x^S is denoted as $q_x^S < Q_a$, and the acceptable range of q_x^S is denoted as $Q_a \leq q_x^S < Q_e$, where Q_e is the smallest one in all the expected values, and Q_a the smallest one in all the acceptable values.

The range of $g_x\left(q_x^S\right)$ is [0,1]. For q_x^S belonging to the first kind, some typical formulas and their images of the function g_x is given as follow.

In **Figure 4**, the formula (a) is applicable to the case, where the impact of q_x^S's change on *cv_B* is linear. The formula (b) is applicable to the case, where the impact of q_x^S's change on *cv_B* is nonlinear and segmented. In the formula (c), $0 < a < 1$, $b > 0$, it is applicable to the case, where the impact of q_x^S's change on *cv_B* is nonlinear and coincides with the law of marginal effect.

The approach for measuring *cv_E* is similar to *cv_B* measurement, and the only difference is that the constraints of the quality parameters of cv_CON_E and cv_E_{best} are proposed by providers.

For the second kind of service interaction, as mentioned above, for value *cv*, its value indicator *cv_B* is affected by cv_B_{best} and cv_CON_B, its value indicator *cv_C* is 0, and value indicator *cv_E* does not exist. Therefore, *cv* can is denoted as $cv = f_B(cv\_B_{\text{best}}, cv\_CON_B)$, where the function f_B is the same as the function f_B which is used in the first kind of service interaction.

3.2. Independent Provider Value

In the first kind of service interaction, for *pv*, its *pv_C* is affected by pv_C_{best} and pv_CON_C, and its *pv_E* is affected by pv_E_{best} and *Sat*. Therefore, *pv* can be denoted as

$$pv = pv\_B - f_C\left(pv\_C_{\text{best}}, cv\_CON_C\right) + \alpha \times f_E\left(pv\_E_{\text{best}}, sat\right),$$

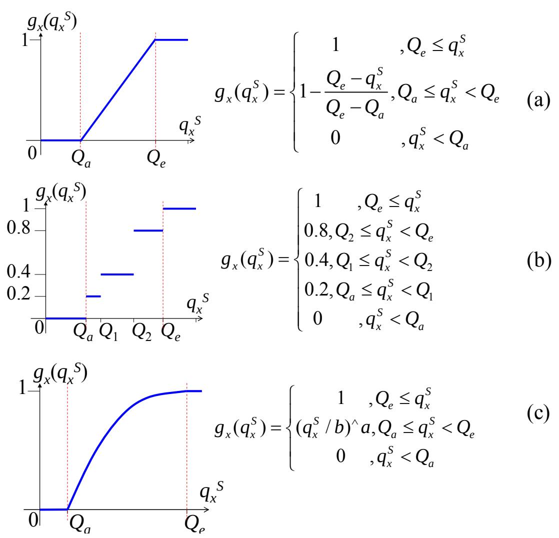

Figure 4. Some typical formulas of the function g_x.

where the function f_C is:

$$pv\_C = pv\_C_{\text{best}} \times \left(\sum w_x \times h_x\left(q_x\right)\right), \quad \text{where } \forall q_x \in pv\_CON_C \tag{2}$$

In formula (2), the function h_x is used to measure the degree that the constraint of the quality parameter q_x is fulfilled by the value of q_x·w_x is the weight of $h_x(q_x)$, and $w_x \in (0,1)$. According to the importance of $h_x(q_x)$ to *pv_C*, w_x can be assigned by the correlative domain experts. The quality parameter q_x is calculated based on the *QoS* of a service element (or a set of service elements), which is denoted as $pv \cdot q_x = se \cdot q_x$ or

$$pv \cdot q_x = G_x\left(se_1 \cdot q_x, se_2 \cdot q_x, \cdots, se_n \cdot q_x\right).$$

The quality parameter q_x's constraint is proposed by providers, and its constraint range is divided into the biggest cost range, the variable cost range and the smallest cost range. As the space is limited, taking q_x belonging to the first kind as an example, the proposition of q_x's constraint and some typical formulas of the function h_x are given as follow.

For q_x belonging to the first kind, the biggest cost range of q_x is denoted as $q_x \geq Q_{\text{end}}$, the smallest cost range of q_x is denoted as $q_x < Q_{\text{start}}$, and the variable cost range of q_x is denoted as $Q_{\text{start}} \leq q_x < Q_{\text{end}}$, where Q_{start} is the smallest value of q_x which can cause the change of $h_x(q_x)$ that represents the impact of q_x's change on *pv_C*, and Q_{end} is the biggest value of q_x which can cause the change of $h_x(q_x)$. Q_{end} is actually the smallest value of q_x which service providers can provide by paying the biggest cost.

In actual services, the cost that providers pay is impossible to become infinitely smaller along with that the quality of the service that providers deliver to customers becomes infinitely lower. Therefore, the range of $h_x(q_x)$ is defined as $[\beta,1]$. If all the quality parameters of pv_CON_C belong to the smallest cost range, $pv\_C_{\min} = pv\_C_{\text{best}} \times \beta$. The cost $pv\_C_{\min}$ is the smallest value of *pv_C*. Some typical formulas and their images of the function h_x are given as follow.

In **Figure 5**, the formula (a) is applicable to the case, where the impact of q_x's change on *pv_C* is linear. In the variable cost range, the change of q_x makes the $h_x(q_x)$ change, and the rate of change of $h_x(q_x)$ is constant. The formula (b) is applicable to the case, where the impact of q_x's change on *pv_C* is nonlinear and segmented. In a subrange of the variable cost range, sometimes the change of q_x can not make the $h_x(q_x)$ change, and sometimes the tiny change of q_x can cause the step change of $h_x(q_x)$.

In the formula (c), $0 < a < 1$, $b > 0$, it is applicable to the case, where the impact of q_x's change on *pv_C* is nonlinear and coincides with the law of marginal effect. In the variable cost range, the rate of change of $h_x(q_x)$ is not constant. At the beginning of the change process of q_x

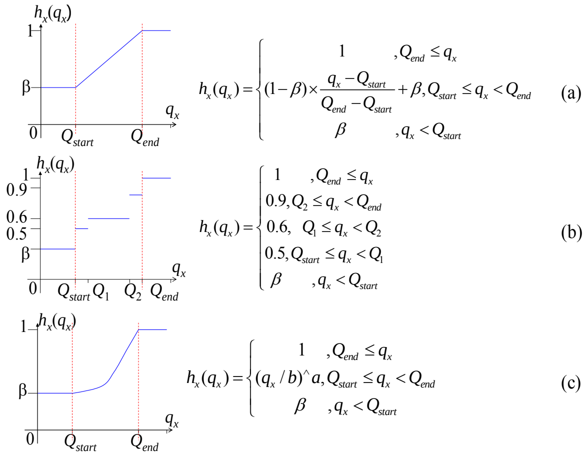

Figure 5. Some typical formulas of the function h_x.

(from Q_{start} to Q_{end}), the rate of change of $h_x(q_x)$ is lower. And the rate of change becomes higher gradually with the increase of q_x. Sometimes a combination of many kinds of formulas may also be selected for applying to some complicated service situation.

The function f_E is used to measure the impact of *sat* on *pv_E*, which is denoted as $f_E(pv\_E_{best}, sat) = pv\_E_{best} \times sat$, where pv_E_{best} is the max amount of money that providers may obtain in the next service interaction, and pv_E_{best} may be assigned to a value by some forecasting method [18]; *sat* is enumerated type, and its range is the fuzzy set {*very satisfied*, *satisfied*, *poorly satisfied*, *unsatisfied*}. In order to support the measurement of *pv_E*, the fuzzy set of *sat* may be quantified using the set {1, 0.8, 0.4, 0}, where *very satisfied* corresponds to 1, *satisfied* corresponds to 0.8, and so on. As mentioned in the above **Figure 2**, *sat* is dependent on *cv*, which is denoted as $sat = H(cv)$. The function H is used to measure the impact of the implementation degree of *cv* on *sat*. The formulas mentioned in **Figure 6** may be adapted to instantiate the function H when Q_e is defined as the smallest *cv* in all the *cv* that customers expect to obtain and Q_a is defined as the smallest *cv* in all the *cv* that customers can accept.

For the second kind of service interaction, as mentioned above, for the value *pv*, its value indicator *pv_B* is 0, its value indicator *pv_C* is affected by pv_C_{best} and pv_CON_C, and its value indicator *pv_E* is affected by pv_E_{best} and pv_CON_E. Therefore, *pv* can be denoted as

$$pv = 0 - f_C\left(pv\_C_{best}, pv\_CON_C\right) + \alpha \times f_E\left(pv\_E_{best}, pv\_CON_E\right)$$

where the function f_C is the same as the function f_C which is used in the first kind of service interaction.

The function f_E is different from the function f_E which is used in the first kind of service interaction. The function f_E is similar to the formula (1) in the Section 3.1

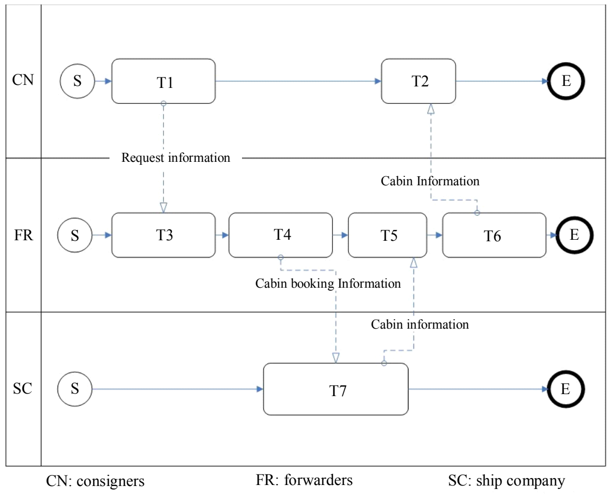

Figure 6. Service process model for the first solution.

which is used to calculate the function f_B of *cv* in the first kind of service interaction. The difference is that the constraints of the quality parameters of pv_CON_E and pv_E_{best} are proposed by providers. The quality parameters of pv_CON_E are used to measure some specific characteristic of customers' behavior. In order to support the measurement of *pv_E*, some new quality parameters are need to be added into the **Table 2** in the Section 2.2, for example, a quality parameter that is used to measure whether customers register to be free member, a quality parameter that is used to measure whether customers responded to the questionnaires after obtaining service, and so on.

4. Measurement of Non-Independent Service Value

Non-independent service value refers to the service value that is dependent on other service values. Its implementation of non-independent service value is completely or partially affected by one of the others. The dependency function *g* should be used to support the non-independent value measurement. For the first kind of service interaction or the second one, whether a non-independent value is *cv* or *pv*, its measurement process is similar to the one of an independent one. There is only one difference: the quality parameters of *CON* are calculated based not only on the *QoS* of the corresponding service elements but also on the corresponding dependency function *g*.

The dependency relationship

$$d = \{v_1, v_2, \cdots, v_n\} \xrightarrow{g} v_j$$

is caused by the uncertainty of relationship between the quality parameters of their corresponding service elements (se_j is related to v_j, and $se_1, se_2, \cdots, se_n$ is related to $v_1, v_2, \cdots, v_n$ respectively). Therefore, if a quality parameter q_x of v_j. *CON* is affected by the uncertainty, the

Table 2. The detailed information of service tasks.

se.ID	*se.Name*	*QoS* of *se*
T1	Send a request for assistance	*CA* = [100,200]
T2	Receive the cabin information	*CA* = [100,200]
T3	Accept a assistance request	*RRT* = [0.05,0.1], *ET* = [0.1,0.5], *US* = [85%,100%], *RE* = [99%,100%]
T4	Send a request for booking a cabin	*ET* = [0.1,0.5], *RE* = [99%,100%], *CA* = [500,800]
T5	Receive the cabin information	*ET* = [0.6,2.5], *RE* = [97%,100%], *CA* = [500,800]
T6	Transfer the cabin information to CN	*ET* = [0.1,0.5], *US* = [80%,100%], *RE* = [99%,100%]
T7	Receive a request, and return the cabin information	*RRT* = [0.08,0.15], *ET* = [0.5,2], *US* = [90%,100%], *RE* = [98%,100%]

RRT: Request response time; *ET*: Execution time; *US*: Usability; *RE*: Reliability; *CA*: Consumption amount.

measurement of q_x refers to not only the quality parameter $se_j \cdot q_x$ but also the quality parameter set

$$\left\{se_1 \cdot q_x, se_2 \cdot q_x, \cdots, se_n \cdot q_x\right\}.$$

And because the dependency function g is used to measure the uncer tainty of relationship between $se_j \cdot q_x$ and $\left\{se_1 \cdot q_x, se_2 \cdot q_x, \cdots, se_n \cdot q_x\right\}$, the dependency function g should be taken into consideration while calculating the quality parameter q_x of $v_j \cdot CON$. Because of the effect of the dependency function g, the value of the quality parameter q_x may not be a single range, but a set of range in which each range is with a probability.

Taking the service value pv as an example, how to calculate the quality parameters of CON of a non-independent value is given as follow.

It is assumed that there is a value dependency relationship $d = pv_1 \xrightarrow{g} pv_2$, which is caused by the uncertainty of relationship between the quality parameters of se_2 and se_1 (se_1, se_2 is related to pv_1 and pv_2 respectively).

If only one quality parameter q_x of $pv_2 \cdot CON$ is related to the uncertainty of relationship, the dependency function can be denoted as $g = P(B_h|A_k)$ (for $k = 1, 2, \cdots, n$; $h = 1, 2, \cdots, m$).

As mentioned above, $pv_2 \cdot q_x = se_2 \cdot q_x$, and $se_2 \cdot q_x$ depends on $se_1 \cdot q_x$ and g. The probability set "$P\left\{A = a_k\right\} = p_k$, $k = 1, 2, \cdots, n$" may be transformed into the matrix $\left(P\left\{A = a_1\right\}, P\left\{A = a_2\right\}, \cdots, P\left\{A = a_n\right\}\right)$. The set of conditional probability $P(B_h|A_k)$ (for $k = 1, 2, \cdots, n;\ h = 1, 2, \cdots, m$) may also be transformed into the matrix $\left(P\left(B_h \middle| A_k\right)\right)_{n \times m}$.

$$\begin{aligned}&\left(P\left\{B = b_1\right\}, P\left\{B = b_2\right\}, \cdots, P\left\{B = b_m\right\}\right)^{\mathrm{T}}\\&= \left(P\left\{A = a_1\right\}, P\left\{A = a_2\right\}, \cdots, P\left\{A = a_n\right\}\right)\\&\quad \times \left(P\left(B_h \middle| A_k\right)\right)_{n \times m}\end{aligned}$$

and $\left(P\left\{B = b_1\right\}\right.$, and $\left.P\left\{B = b_2\right\}, \cdots, P\left\{B = b_m\right\}\right)^{\mathrm{T}}$ can be transformed from the probability set "$P\left\{B = b_h\right\} = p_h$, $h = 1, 2, \cdots, m$", therefore, $pv_2 \cdot q_x$ can be calculated by using the multiply operation of matrix. The data of the matrix $(P(B_h|A_k))_{n \times m}$ should be provided by service model designers, and the data of the matrix $M(A)$ may be obtained by analyzing all relevant historical data.

To bring $pv_2 \cdot q_x$ to the formula (2), and $h_x\left(pv_2 \cdot q_x\right)$ may be a set of values in which each value is with a probability, at last it may result in that pv_2 may also be a probability distribution.

If there are two quality parameters q_x and q_y which are related to the uncertainty of relationship, then the dependency function can be denoted as $g = \{P(B_h|A_k)$ (for $k = 1, 2, \cdots, n; h = 1, 2, \cdots, m$), $P(D_h|C_k)$ (for $k = 1, 2, \cdots, n$; $h = 1, 2, \cdots, m$)$\}$. The discrete random variable C represents the value of quality parameter $se_1 \cdot q_y$. The discrete random variable D is the value of quality parameter $se_2 \cdot q_y$.

Therefore, $pv_2 \cdot q_x$ is the probability set $P\left\{B = b_h\right\} = p_h$, $h = 1, 2, \cdots, m$. and $pv_2 \cdot q_y$ is the probability set $P\left\{D = d_h\right\} = p_h, d = 1, 2, \cdots, m$. To bring $pv_2 \cdot q_x$ and $pv_2 \cdot q_y$ to the formula (2), $h_x\left(pv_2 \cdot q_x\right)$ and $h_y(pv_2 \cdot q_y)$ can be obtained respectively. If the amount of members of the probability set related to $h_x\left(pv_2 \cdot q_x\right)$ is K and the one related to $h_y\left(pv_2 \cdot q_y\right)$ is L, then at last, by carrying on synthetical calculation, the amount of members of the probability set related to pv_2 may be K × L.

In the above measurement process, the result of the function h and the result of the value indicators pv_C are always a set of probability. For these probability sets, their corresponding event may be the same, which results in that the amount of members of the probability set related to output is less than the one related to input. In the most extreme case imaginable, pv_2 is a probability of an event, and the probability is 100%.

For the situation of that there are more quality parameters affected the uncertainty of relationship, the measurement process is similar to the above one, and it is unnecessary gives more details.

5. Case Study

As mentioned in Section 1, there are two service solutions for cabin booking service. In the first service solution, the consigners send a request to the forwarders, asking the forwarders to help him to book a cabin. The corresponding pre-designed service process model is shown in **Figure 6**. The detailed information of service tasks in this model is listed in **Table 2**.

In this service process model, the quality parameter T7.*ET*, T5.*ET* and their relationship are uncertain. The uncertainty of T7.*ET* is denoted as $P\{A = a_k\} = p_k$, $k = 1, 2$. A_1 is "A = [0.5,1]", and A_2 is "A = [1,2]". The uncertainty of T5.*ET* is denoted as $P\{B = b_h\} = p_h$, $h = 1, 2, 3$. B_1 is "B = [0.6,1]", B_2 is "B = [1,2]", and B_3 is "B = [2,2.5]". And the set of conditional probability $P(B_h|A_k)$ (for $k = 1, 2$; $h = 1, 2, 3$) = {{$P(B_1|A_1)$ = 5%, $P(B_2|A_1)$ = 80%, $P(B_3|A_1)$ = 15%}, {$P(B_1|A_2)$ = 0%, $P(B_2|A_2)$ = 70%, $P(B_3|A_2)$ = 30%}} can be used to describe the uncertainty of the relationship between T7.*ET* and T5.*ET*. The service process model and its relevant data are supposed to be collected and provided by model designers.

In the first solution, there are two service values cv_1 and cv_2. Their detailed information is given in **Table 3**. In this example, the unit of all the *value indicators* is *Yuan*.

$cv_2 = cv_2\_B - cv_2\_C + \alpha \times cv_2\_E$, where cv_2_B and cv_2_E is calculated as follow:

$$cv_2\_B = cv_2\_B_{\text{best}} \times f_4\left(q_4^H\right) \times \sum_{i=1}^{3}\left(w_i^S \times g_i\left(q_i^S\right)\right),$$

where $\forall q_i^S$, $q_4^H \in cv_2\_CON_B$, and they are calculated as follow:

- q_1^S = T7.*RRT* =[0.08,0.15];
- q_2^S = T7.*ET* =[0.5,2];
- q_3^S = T7.*US*= [90%,100%];
- q_4^H = T7.*RE* = [98%,100%].

$cv_2\_E = cv_2\_E_{best} \times g_5\left(q_5^S\right)$, where $q_5^S \in cv_2\_CON_E$, and q_5^S = T4.*CA*+T5.*CA* = [1000, 1600].

The constraints for q_1^S, q_2^S, q_3^S, q_4^H have been proposed by the forwarders. The constraints for q_5^S have been proposed by the ship company. And then the formulas of the functions $g_1\left(q_1^S\right)$, $g_2\left(q_2^S\right)$, $g_3\left(q_3^S\right)$, $f_4\left(q_4^H\right)$ and $g_5\left(q_5^S\right)$ are shown in **Figure 7**.

In the formula to caulcualte cv_2_B, the weights of the functions $g_1\left(q_1^S\right)$, $g_2\left(q_2^S\right)$, $g_3\left(q_3^S\right)$ are assigned to 0.4, 0.4, 0.2 respectively. Therefore, the results can be obtained: $g_1\left(q_1^S\right) = 0.8$, $g_2\left(q_2^S\right) = 0.8$, $g_3\left(q_3^S\right) = 1$, $f_4\left(q_4^H\right) = 1$, $g_5\left(q_5^S\right) = 0.4$, and then cv_2 = 84 – 40 + 8 = 52 (*Yuan*).

$cv_1 = cv_1\_B - cv_1\_C + \alpha \times cv_1\_E$. cv_1 is dependent on cv_2, and the dependency function is $P(B_h|A_k)$ (for $k = 1, 2$; $h = 1, 2, 3$). The calculation of cv_1 is similar to the one of cv_2, only one difference is that the quality parameter $cv_1 \cdot q_2^S$ is calculated based on not only the quality parameters T3.*ET*, T4.*ET*, T5.*ET*, T6.*ET* (related to cv_1) but also the quality parameter T7.*ET* (related to cv_2).

$$cv_1\_B = cv_1\_B_{\text{best}} \times f_4\left(q_4^H\right) \times \sum_{i=1}^{3}\left(w_i^S \times g_i\left(q_i^S\right)\right),$$

where $\forall q_i^S, q_4^H \in cv_1\_CON_B$, and they are calculated as follow:

- q_1^S = T3.*RRT* = [0.05,0.1];
- q_2^S = T3.*ET* + T4.*ET* + T5.*ET* + T6.*ET* = [0.3,1.5] + T5.*ET*;
- q_3^S = min(T3.*US*, T6.*US*) = [80%,100%];
- q_4^H = T3.*RE* × T4.*RE* × T5.*RE* × T6.*RE* = [94%, 100%].

The constraints for $cv_1 \cdot q_2^S$ have been proposed by the consigners. And then in the formula to calculate cv_1_B, the formulas of the function $g_2\left(q_2^S\right)$ is

$$g_2\left(q_2^S\right) = \begin{cases} 0, & 6 < q_2^S \\ 0.2, & 4 < q_2^S \le 6 \\ 0.4, & 3 < q_2^S \le 4 \\ 0.8, & 2 < q_2^S \le 3 \\ 1, & q_2^S \le 2 \end{cases}.$$

The formulas of the other functions in the formula to caulcualte cv_1_B are the same as the corresponding ones in the formula to caulcualte cv_2_B.

By analyzing all relevant historical data, $P\{A$ = [0.5,1]} = 80% and $P\{A$ = [1,2]} = 20% can be obtained. And then T5.*ET* can be calcualted by utilizing the multiply operation of matrix "($P\{A$ = [0.5,1]}, $P\{A$ = [1,2]}) × $(P(B_h|A_k))_{2\times3}$". The results of T5.*ET* can be obtained: $P(B$ = [0.6,1]) = 4%, $P(B$ = [1,2]) = 78% and $P(B$ = [2,2.5]) = 18%. Therefore, the results of $cv_1 \cdot q_2^S$ and $g_2\left(cv_1 \cdot q_2^S\right)$ can be given as follow:

Table 3. The detailed information of two values belonging to cv.

v.ID	*v.Name*	*v.P*	*v.R*	B_{best}	CON_B	*C*	E_{best}	CON_E	*se related to v*
cv_1	Usage of cabin	FR	CN	200	q_1^S, q_2^S, q_3^S, q_4^H	100	10	q_5^S	T1,T2, T3, T4, T5, T6
cv_2	Usage of cabin	SC	FR	100	q_1^S, q_2^S, q_3^S, q_4^H	40	20	q_5^S	T4, T5,T7

q_1^S : Request response time; q_2^S : Execution time; q_3^S : Usability; q_4^H : Reliability; q_5^S : Consumption amount.

$$1)\ g_1(q_1^S)=\begin{cases}0, & 0.25<q_1^S\\0.2, & 0.2<q_1^S\le 0.25\\0.4, & 0.15<q_1^S\le 0.2\\0.8, & 0.1<q_1^S\le 0.15\\1, & q_1^S\le 0.1\end{cases}\quad 2)\ g_2(q_2^S)=\begin{cases}0, & 6<q_2^S\\0.2, & 4<q_2^S\le 6\\0.4, & 2<q_2^S\le 4\\0.8, & 0.5<q_2^S\le 2\\1, & q_2^S\le 0.5\end{cases}\quad 3)\ g_3(q_3^S)=\begin{cases}1, & 0.9\le q_3^S\\0.8, & 0.6\le q_3^S<0.9\\0.4, & 0.5\le q_3^S<0.6\\0.2, & 0.3\le q_3^S<0.5\\0, & q_3^S<0.3\end{cases}\quad 4)\ f_4(q_4^H)=\begin{cases}1, & 0.9\le q_4^H\\0, & q_4^H<0.9\end{cases}\quad 5)\ g_5(q_5^S)=\begin{cases}1, & 2000\le q_5^S\\0.8, & 1500\le q_5^S<2000\\0.4, & 1000\le q_5^S<1500\\0.2, & 500\le q_5^S<1000\\0, & q_5^S<500\end{cases}$$

Figure 7. The formulas of the functions $g_1(q_1^S)$, $g_2(q_2^S)$, $g_3(q_3^S)$, $f_4(q_4^H)$ and $g_5(q_5^S)$.

- B_1 is the event "B = [0.6,1]", if B_1 occurred, $cv_1 \cdot q_2^S = [0.9, 2.5]$, $g_2(cv_1 \cdot q_2^S) = 0.8$;
- B_2 is the event "B = [1,2]", if B_2 occurred, $cv_1 \cdot q_2^S = [1.3, 3.5]$, $g_2(cv_1 \cdot q_2^S) = 0.4$;
- B_3 is the event "B = [2,2.5]", if B_3 occurred, $cv_1 \cdot q_2^S = [2.3, 4]$, $g_2(cv_1 \cdot q_2^S) = 0.4$.

And then by utilizing the other corresponding formulas of function, $g_1(cv_1 \cdot q_1^S) = 1$, $g_3(cv_1 \cdot q_3^S) = 0.8$ and $f_4(cv_1 \cdot q_4^H) = 1$ can be obtained.

$$cv_1\_E = cv_1\_E_{\text{best}} \times g_5(q_5^S),$$

where $q_5^S \in cv_1\_CON_E$, and q_5^S = T1.CA + T2.CA = [200,400].

The constraints for $cv_1 \cdot q_5^S$ have been proposed by the forwarders. And then in the formula to calculate cv_1_E, the formulas of the function $g_5(q_5^S)$ is

$$g_5(q_5^S)=\begin{cases}1, & 500\le q_5^S\\0.8, & 200\le q_5^S<500\\0.4, & 100\le q_5^S<200\\0.2, & 50\le q_5^S<100\\0, & q_5^S<50.\end{cases}$$

So, $g_5(cv_1 \cdot q_5^S) = 0.8$ can be obtained. At last, the measurement result of cv_1 is: $P\{cv_1 = 84\} = 4\%$, $P\{cv_1 = 52\} = 96\%$.

In the first solution, there are two service values pv_1 and pv_2. The detailed information is given in **Table 4**.

$pv_2 = pv_2\_B - pv_2\_C + \alpha \times pv_2\_E$, where pv_2_C and pv_2_E is calculated as follow:

$$pv_2\_C = pv_2\_C_{\text{best}} \times \sum_{i=1}^{4}\left(w_i \times h_i(q_i)\right),$$
$$\text{where } \forall q_i \in pv_2\_CON_C$$

and they are calculated as follow:

- q_1 = T7.ET = [0.08,0.15];
- q_2 = T7.ET = [0.5,2];
- q_3 = T7.US = [90%,100%];
- q_4 = T7.RE = [98%,100%].

$pv_2\_E = pv_2\_E_{\text{best}} \times sat$.

In the above two formulas, the formulas of the functions $h_1(q_1)$, $h_2(q_2)$, $h_3(q_3)$, $h_4(q_4)$ are:

$$h_1(q_1)=\begin{cases}0.3, & 0.25<q_1\\0.5, & 0.2<q_1\le 0.25\\0.6, & 0.15<q_1\le 0.2\\0.9, & 0.05<q_1\le 0.15\\1, & q_1\le 0.05\end{cases}$$

$$h_2(q_2)=\begin{cases}0.3, & 6<q_2\\0.5, & 4<q_2\le 6\\0.6, & 2<q_2\le 4\\0.9, & 0.5<q_2\le 2\\1, & q_2\le 0.5\end{cases}$$

$$h_3(q_3)=\begin{cases}1, & 0.8\le q_3\\0.9, & 0.6\le q_3<0.8\\0.6, & 0.4\le q_3<0.6\\0.5, & 0.2\le q_3<0.4\\0.3, & q_3<0.2\end{cases}$$

$$h_4(q_4)=\begin{cases}1, & 0.9\le q_4\\0.9, & 0.8\le q_4<0.9\\0.6, & 0.7\le q_4<0.8\,.\\0.5, & 0.6\le q_4<0.7\\0.3, & q_4<0.6\end{cases}$$

And then the weights of the functions $h_1(q_1)$, $h_2(q_2)$, $h_3(q_3)$ and $h_4(q_4)$ are assigned to 0.3, 0.3, 0.2, 0.2 respectively. Therefore, $pv_2 = 40 - 9.7 + 16 = 46.3$ (*Yuan*). Referring to the measurement process of pv_2 and cv_1, the measurement result of pv_1 can be obtained: $P\{pv_1 = 65.7\} = 82\%$, $P\{pv_1 = 71.2\} = 18\%$.

In the second solution, the consigners directly send a request to the ship company for booking a cabin. The detailed information of the corresponding pre-designed service tasks is listed in **Table 5**. Simultaneously, there are two service values cv_1 and pv_1 in this solution, as shown in **Tables 6** and **7**. The measurement process of cv_1 and pv_1 is similar in the first solution, and result is given in **Table 8**.

The comparison results between the first and the second service solution is shown in **Table 8**. As the table implies, for the consigners, the first service solution is better and should be chose because that: 1) the realized CON_B (1, <0.8, 0.4>, 0.8, 1) in the first one is be superior

Table 4. The detailed information of two values belonging to *pv*.

v.ID	*v.Name*	*v.P*	*v.R*	*B*	C_{best}	*CONC*	E_{best}	*sat*	*se related to v*
pv_1	Assistance fee	CN	FR	100	60	q_1, q_2, q_3, q_4	30	0.8	T3, T4, T5, T6
pv_2	Cabin booking fee	FR	SC	40	10	q_1, q_2, q_3, q_4.	20	0.8	T7

q_1: Request response time; q_2: Execution time; q_3: Usability; q_4: Reliability.

Table 5. The detailed information of service tasks.

se.ID	*se.Name*	*QoS* of *se*
T1	Send a request for booking a cabin	CA = [100,200]
T2	Receive the cabin information	CA =[100,200]
T3	Receive a request, and return the cabin information	RRT = [0.08,0.15], ET =[1,3], US = [50%,70%], RE = [98%,100%]

Table 6. The detailed information of cv_1 that the consigners receive.

v.ID	*v.Name*	*v.P*	*v.R*	B_{best}	CON_B	*C*	E_{best}	CON_E	*se related to v*
cv_1	Usage of cabin	SC	CN	180	q_1^S, q_2^S, q_3^S, q_4^H	90	20	q_5^S	T1,T2, T3

Table 7. The detailed information of pv_1 that the ship company receives.

v.ID	*v.Name*	*v.P*	*v.R*	*B*	C_{best}	*CONC*	E_{best}	*sat*	*se related to v*
pv_1	Cabin booking fee	CN	SC	90	50	q_1, q_2, q_3, q_4	30	0.6	T3

Table 8. The comparison results between the first and the second service solution.

Value receiver	Implementation of Value		First service solution	Second service solution
Consigners (CN)	CON_B	Request response time	1	0.8
		Execution time	<0.8(4%), 0.4(96%)>	0.4
		Usability	0.8	0.4
		Reliability	1	1
	B		<176(4%), 144(96%)>	100.8
	C		100	90
	CON_E	Consumption amount	0.8	0.4
	E		8	8
	cv		<84(4%), 52(96%)>	18.8
Ship Company (SC)	*B*		40	90
	CON_C	Request response time	0.9	0.9
		Execution time	1	0.9
		Usability	1	0.9
		Reliability	1	1
	C		9.7	46
	sat		0.8	0.6
	E		16	18
	pv		46.3	62

to the realized CON_B (0.8, 0.4, 0.4, 1)in the second one overall. And the realized *cv* <84, 52> in the first one is larger than the realized *cv* 18.8 in the second one. So the service delivered to the consigners in the first one are better.

For the ship company, although in the first solution the value that it receives is smaller (*i.e*. 46.3 < 62), on the one hand, the cost that ship company need to pay for providing cabin booking service is smaller (*i.e*. 9.7 < 46), which can lead to an increase of cash flow, on the other hand, the total value that it receives may is larger in the future period of time because that the forwarders can help the ship company to obtain more customers. So the first service solution should also be chose by the ship company.

6. Conclusions

In order to help service participants to evaluate the existing service solutions, and select the best one among them measured by value, this paper presents an approach of service value measurement based on service semantics. In this paper, an intuitive definition of service value is given firstly, and secondly several concepts (e.g. *customer value*, *provider value*, *value indicators*, *value profit constraints*, etc.) related to service value measurement are discussed, then a series of calculation formulas are introduced to measure the above concepts based on the pre-designed service process model (that is used to represent the service solution being evaluated), and last the effect of value dependency relationships on service value measurement is taken into consideration.

By utilizing the proposed approach, service participants can select the best service solutions among multiple existing service solutions measured by value. Simultaneously, the corresponding service process model has been also chose. And then by utilizing model-driven idea and component-based software development technology, the appropriate service systems can be developed rapidly based on the service process model. The proposed approach is a beneficial supplement to Service Engineering.

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