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APPLICATION OF QUALITATIVE SIMULATION FOR EARLY-STAGE SERVICE DESIGN

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1. Introduction

With the global economy beginning to mature, several industries have started to regard the service sector as an effective way of enhancing customer satisfaction. The service industry accounts for more than 70% of the workforce and gross domestic product (GDP) in Japan, the United States, and the European Union [Japan's Ministry of Economy 2012]. Of late, some manufacturing companies have been making a fundamental shift from selling only physical products to providing services.

Until recently, research on services was conducted mainly in the marketing or management fields, and rational methods for realizing services with high productivity were still in the research phase. Of late, researchers have begun to examine services from an engineering or scientific perspective rather than from the traditional marketing or management view. For example, in Japan, Shimomura et al. conducted a study to design services from an engineering viewpoint. This research belongs to the "Service Engineering" [Arai and Shimomura 2004], [Shimomura and Tomiyama 2005] series. In other regions, especially in Europe, product-service systems (PSSs) [Tukker and Tischner 2006] are considered the new business model that will help manufacturing firms gain competitiveness. A PSS consists of tangible products and intangible services designed and combined to be jointly capable of fulfilling specific customer needs. Studies in service science, management, and engineering (SSME) [Maglio et al. 2006] have been conducted mainly in the U.S. market. SSME proposes a scheme to create the basis for systematic service with knowledge integration.

In product and service design generally, designers are required to spend additional money and time when design changes occur in the final stages of the design process. In order to obviate design changes, simulation methods are an effective way to predict problems that might arise in the last stages of the design process. This approach enables designers to address these problems in advance and decrease redesign work. Thus, it is important for designers to evaluate design solutions in the early stages of the design process using simulation methods.

While existing simulation methods are effective for decreasing the needs for redesign, difficulties remain in the construction of simulation models. Current simulation models are built with quantitative information; in the early stages of the service design process, however, most information about the design solution is still not defined. In addition, services are produced and consumed simultaneously in many cases. That is, services only exist while offering goods to or conducting activities for the customers. This characteristic of services is called "simultaneity" [Fisk et al. 2007]. In order to obtain quantitative information to construct simulation models, service providers need to offer a designed service to customers on a trial basis. Thus, service designers invest a great deal of time and effort in

building quantitative simulation models. Furthermore, it is difficult to express parameters quantitatively in service simulation models (e.g., “ability to manage”).
In contrast to this quantitative approach, some researchers in the field of product design have applied the concept of qualitative simulation [Bobrow 1984] to the conceptual design of products [Kiriyama et al. 1992], [Moritsu et al. 2001]. The qualitative simulation method can be used to analyze the behavior of systems with fuzzy qualitative information. This qualitative information is useful for evaluating the behavior of physical features in the early stages of the product design process. In order to address difficulties associated with constructing quantitative simulation models for service design, in this paper we apply qualitative simulation methods to the service design process. In particular, our work focuses on building a valid simulation model. The proposed modeling method could enable designers to evaluate a design solution in the early stages of the design process.

2. Service design process and simulation

2.1 Service design process

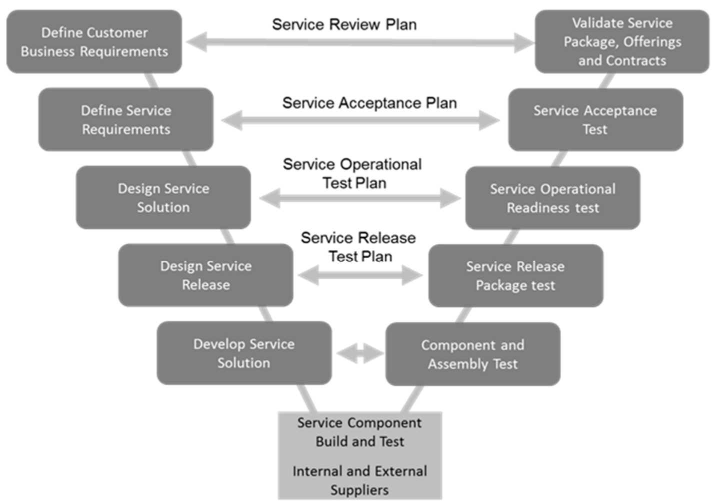

Figure 1. V-model representing the service design process [Office of Government Commerce 2007]

The V-model [Office of Government Commerce 2007] is widely used to describe service design processes (such as the design of an IT-enabled service). The V-model is a process model that shows the correspondence between the design/development process and the test execution phase in a V shape (Figure 1). In Figure 1, the design and development phases are shown on the left-hand side of the model. In the Define Service Requirements phase (the second stage on the left-hand side), customer requirements, business targets, and service levels are defined according to the results of the previous phase (Define Customer Business Requirements). The third stage, i.e., the Design Service Solution phase, focuses on designing the system architecture. In this phase, an overview of the service solution is developed that includes availability management, capacity management, and cost of providing the service. Subsequently, in the Design Service Release phase, fundamental policies and procedures in the real environment are defined. Finally, in the Develop Service Solution phase, the detailed service design and all required coding are conducted.
The test execution phases are shown on the right-hand side of the model. These phases focus on test activities performed against the specifications defined in the design and development process.

2.2 Existing service simulation

As was mentioned in Section 1, designers are forced to spend much additional time and money when design changes happen in the later phase, i.e., the right side of the V-model. Thus, it is important for designers to foresee problems that might occur in the last stages of the design process and take measures to prevent them. A number of computational simulation technologies have been developed for predicting problems and evaluating design solutions [Hatakeyama and Yokomura 1990], [Yamaguchi et al. 2002], [Tan and Takakuwa 2007], [Tsubouchi et al. 2010].

Petri net models [Murata 1989] are commonly used to visualize service behaviors. For example, Yamaguchi developed a modeling method for analyzing the workflow in a restaurant. In this context, a Petri net simulation is useful for evaluating the effectiveness of introducing an information and communications technology system to the workflow [Yamaguchi et al. 2002]. Hatakeyama developed a simulator called "TEMPO SYSTEM" that analyzes a customer's purchasing behavior in a fast-food restaurant by using Petri net models, and Tsubouchi developed a simulator to enhance the efficiency of operating on-demand buses that people use for ride-sharing through a reservation system [Tsubouchi et al. 2010].

Various simulation and modeling methods have been investigated in the extant research on PSS design. For example, Meier proposed a PSS simulation method for predicting the business growth of companies [Meier et al. 2013], [Meier and Boßlau 2013], [Akasaka et al. 2013], and Akasaka proposed a modeling and simulation method to design PSSs that could realize high values for each stakeholder [Meier et al. 2013]. These prior studies aimed at delivering a design and engineering approach for dynamic PSS business models using system dynamics (SD) [Sterman 2000].

3. Approach of this study

In existing simulation systems, models are generally built with quantitative information obtained from results of service offerings in a real situation. As a result, existing methods can cost additional time and capital to obtain the quantitative information needed to construct the model. Furthermore, in order to improve its business, it is necessary for the company to develop a strategy related to organizational reforms and business processes from various perspectives such as the customer perspective. As one of the tools that promote strategic management, the Balanced Scorecard [Kaplan and Norton 1996] has been introduced into a number of companies. Thus, in constructing a qualitative simulation model, we have applied a qualitative simulation method based on the Balanced Scorecard that can be used to analyze behaviors of systems with fuzzy information. We expect this qualitative simulation method to predict service behaviors in the early stages of service design, even when it is difficult to obtain adequate quantitative information to build a simulation model.

3.1 Qualitative reasoning

Qualitative reasoning is an area of artificial intelligence that provides the means to formally represent reasoning with conceptual knowledge. Qualitative reasoning has proven to be a cost effective, reliable, and efficient means of analyzing the behavior of systems without numerical information. The qualitative prediction of behavior is conducted by reasoning about how the physical world changes over time. This prediction is called qualitative simulation. In a qualitative simulation model, the state of each parameter consists of a qualitative value and a derivative value. The qualitative values are expressed by a finite number of landmarks; the derivative values are expressed by a qualitative value: "increases," "decreases," or "becomes stable".

3.2 Qualitative process theory

In a series of studies, Forbus developed a process-based approach for qualitative reasoning called the qualitative process theory [Forbus 1984]. A typical example of such a process is heat flow or movement. According to the qualitative process theory, there are two causal relations between parameters: direct influence and indirect influence. Direct influence I+/- (Q2, Q1) causes the parameter Q2 to increase/decrease if Q1 takes a positive value.

Indirect influences correspond to relationships between two parameters that represent some mechanisms for the process. They set the derivative of the target parameter depending on the derivative of the source parameter. An indirect influence can be also be positive (P+) or negative (P-) P+ ($Q2 \propto Q1$) causes the parameter Q2 to increase (decrease) if another parameter Q1 increases (decreases). P- ($Q2 \propto Q1$) causes the parameter Q2 to decrease (increase) if another parameter Q1 increase (decrease). Therefore, indirect influences are referred to as qualitative proportional relations.

A qualitative reasoning engine generally takes as input a scenario that describes the initial state of the system. Subsequently, the qualitative engine produces a state graph that qualitatively captures the distinct states of the system. A state graph consists of a set of states, i.e., state transitions. Thus, a state graph shows a set of possible paths of system behaviors. A state transition specifies how one state changes into another state, and a sequence of states connected by state transitions is called a behavior path. The following example describes a qualitative simulation for heat flow (Figure 2) [Bredeweg et al. 2009].

1. After the heater is turned on, the heat flow process causes heat to flow from the heater to the container and the water. This causes the temperature of the container and water to increase. This behavior may lead to other states (state 2 or state 3).
2. The temperature of the water in the container is now equal to the temperature of the heater. From here on, no further changes can take place.
3. The water temperature reaches the boiling point. A new process, "boiling," becomes active, which causes the generation of steam. This behavior may lead to another state (state 4).
4. All the water has now turned into steam. The boiling process has stopped, but the heat flow continues. This behavior may lead to other states (state 2 or state 5).
5. If the heater is warm enough, it may ultimately cause the container to melt if it reaches its melting point. Hence, the simulation stops here.

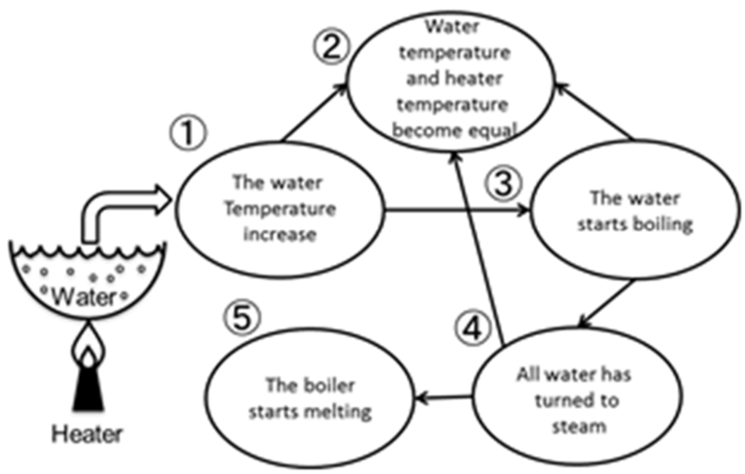

Figure 2. Behavior of heat flow [Bredeweg et al. 2009]

3.3 Balanced scorecard

Organizations are now competing in highly complex environments, and it is vital to accurately understand their goals and methods in order to realize effective service design. The Balanced Scorecard (BSC) is widely used, as it is a tool that helps designers identify what should be done and measured. The BSC provides a framework that translates a company's strategic goals into a coherent set of performance measurements. The BSC measures organizational performance across four balanced perspectives: financial, customer, internal business processes, and learning and growth. The financial perspective prompts designers to ask how a company should appear to its shareholders to succeed financially. The customer perspective focuses on how a company should appear to its customers to achieve its vision. The internal business processes perspective refers to the business processes needed to satisfy shareholders and customers. The learning and growth perspective suggests how a business can sustain its ability to change and improve in order to achieve its vision.

The BSC enables companies to track financial results while simultaneously monitoring progress in building capabilities and acquiring the intangible assets they need for future growth.

4. Service design process using qualitative simulation based on the balanced scorecard

This paper proposes a method for constructing qualitative simulation models. A qualitative simulation model is constructed based on the four balanced perspectives of the BSC. As mentioned in 3.3, designers need to understand their goals and the methods necessary for the realization of effective service design. The parameters are determined by a company's strategic objectives and performance measures of the BSC. This qualitative simulation model includes direct/indirect influences between the parameters in the manner proposed by qualitative process theory. For the simulation, the initial state of the system needs to be defined. According to the initial values of each of the parameters, the possible system behaviors are produced by qualitative simulation.

5. Application to sample case

In this section, the proposed modeling method is applied to a sample case. The example involves outsourcing Information Technology (IT) operations. Collaboration between an IT-system provider and the IT department of a customer company can create high values. For example, the IT department of a customer company can improve its ability to make business proposals.

5.1 Modeling of the outsourcing service process

First, the parameters are set based on the four balanced perspectives of the BSC. In this example, parameters related to the financial perspective, "company profit" and "cost," were set. From the customer perspective, "disposable time," representing available time except for time used in system operations and maintenance, was set. In addition, "ability to plan IT strategy" was set as another customer perspective parameter, as was "outsourcing," based on the IT strategy of the customer company. From the internal business processes perspective, "workload," "design review," and "trouble occurred" were set as parameters. And from the learning and growth perspective, "ability of employees to manage" and "employee growth" were set as parameters. Each parameter has qualitative values and derivative values as quantity spaces. Table 1 shows the details of the parameters defined for this example case.

Table 1. Details of the parameters

Parameter	Perspectives of the BSC	Qualitative values
Company profit	Financial	{Plus, Zero, Minus}
Cost	Financial	{Plus, Zero}
Disposable time	Customers	{Long, Middle, Short}
Ability to plan a strategy	Customers	{High, Medium, Low}
Outsourcing	Customers	{Plus, Zero}
Workload	Internal business processes	{Long, Middle, Short}
Trouble occurred	Internal business processes	{Plus, Zero}
Design review	Internal business processes	{Plus, Zero}
Ability to manage	Learning and growth	{High, Medium, Low}
Employee growth	Learning and growth	{Plus, Zero, Minus}

Subsequently, the parameters were connected to one another with causal relationships. In this study, direct influences are expressed with the symbol I+/-. Similarly, indirect influences are expressed with the symbol P+/-. The result of the simulation model is shown in Figure 3, and the details are as follows:

<Indirect influences>

1. If the management ability of employees to develop the IT system is enhanced, designers may increase frequency of design review. Therefore, there is a positive indirect influence (P+) between the IT system provider employees' "ability to manage" and "design review" of the IT system provider.
2. If employees of the IT system provider enhance their ability to manage, employees of the customer company could gain time except for time used in system operation and maintenance. Therefore, there is a positive indirect influence (P+) between the IT system provider employees' "ability to manage" and "disposable time" of the customer company.
3. If the time except for time used in system operations and maintenance increases, employees of the IT department of the customer company could spend more time planning IT strategy. Therefore, there is a positive indirect influence (P+) between "disposable time" of the customer company and "ability to plan a strategy" for employees of the customer company.
4. If its employees' ability to strategize is enhanced, the customer company often requests outsourced IT development to enhance its own business. Therefore, there is a positive indirect influence (P+) between the customer company employees' "ability to plan a strategy" and "outsourcing" for the customer company.
5. When development workloads increase, the development cost also increases. Therefore, there is a positive indirect influence (P+) between "workload" of the IT system provider and "cost" for the IT system provider.
6. When company profits increase, the IT system provider often invests in employee training. Therefore, there is a positive indirect influence (P+) between "company profit" for the IT system provider and "employee growth" for the IT system provider.

<Direct influences>

7. When the qualitative value of "employee growth" for the IT system provider is a plus, the "ability to manage" for employees of the IT system provider increases. On the other hand, when the value of "employee growth" for the IT system provider is a minus, the "ability to manage" for the employees of the IT system provider decreases. Therefore, there is a positive direct influence (I+) between the IT system provider employees' "ability to manage" and "employee growth" for that provider.
8. Reworks increase when IT system development trouble occurs. Therefore, there is a positive direct influence (I+) between "trouble occurring" for the IT system provider and "workload" for that provider.
9. In order to decrease the workload of IT system development, designers need to review the design solution. Therefore, there is a negative direct influence (I-) between "design review" for the IT system provider and "workload" for that provider. In addition, when the qualitative value of "ability of employees to manage" is high, the "design review" for the IT system provider process becomes active.
10. The IT system provider can gain a profit from the customer's outsourcing. Therefore, there is a positive direct influence (I+) between "company profit" and "outsourcing." When the qualitative value of "ability to plan a strategy" is high, the "outsourcing" process becomes active.
11. The profit of the company may decrease when the development cost increases. Therefore, there is a negative direct influence (I-) between the IT system provider's "company profit" and "cost" for that provider.

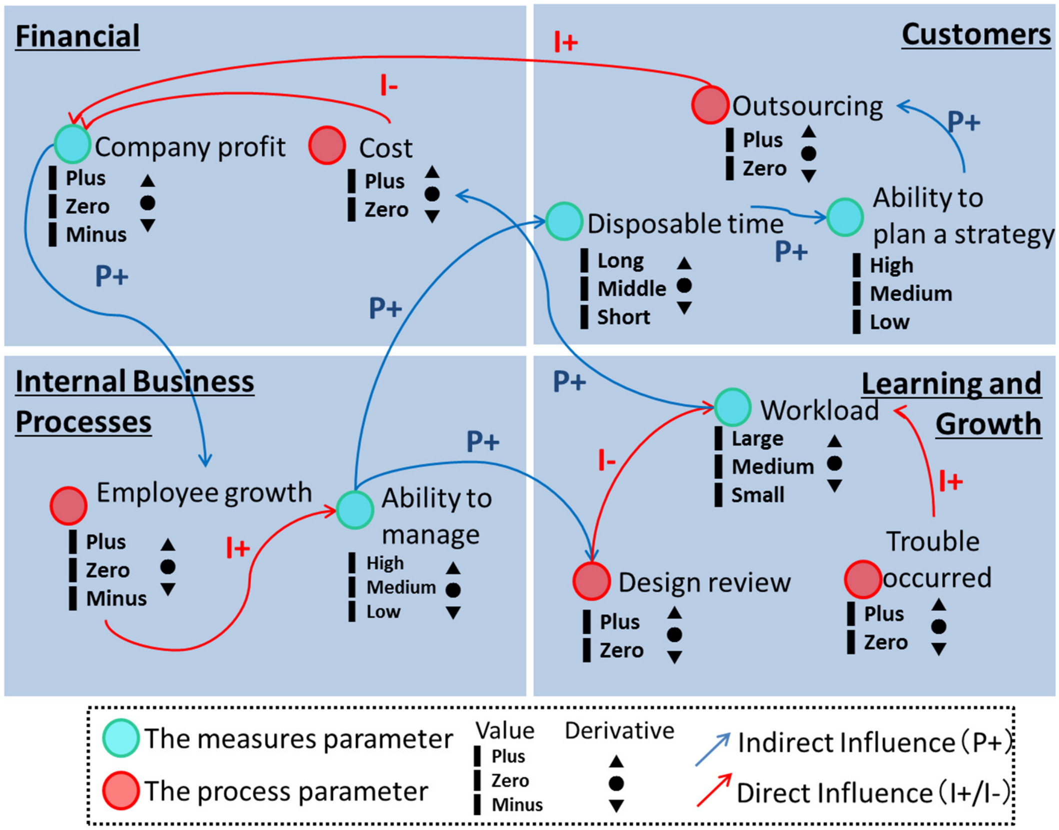

Figure 3. Result of the simulation model

5.2 Behavioral pattern

The qualitative simulation model was built and carried out using Garp3 [Bredeweg et al. 2009], a software for qualitative process theory-based simulation. The initial qualitative values of the parameters in the simulation are as follows:

- The value of "employee growth" is a plus
- The value of "trouble occurred" is a plus

In this example, the qualitative simulation model produced 31 state transitions and 56 states (see Figure 4). The produced behaviors were classified into various patterns based on the final state of the parameters and on the feature of behaviors. In this case, the qualitative simulation model produced four patterns (see Figure 5). Pattern 1 (for example, states 1, 2, 6, 13, 18, 25, 26, 11, 17, 12) in Figure 5 indicates that "ability to manage" and "ability to plan a strategy" increased at once and that the "outsourcing" process became active when "ability to plan a strategy" took a high value (in state 13). However, "ability to manage" and "ability to plan a strategy" decreased when "company profit" decreased and took a low value in state 11. This is due to the effect that "workload" caused "trouble occurred" to increase in state 11. Pattern 2 (for example, states 1, 2, 9, 10, 21, 23, 30, 28, 19) indicates that most parameters become stable due to neutral (zero) value of "employee growth." Pattern 3 (for example, states 1, 2, 9, 10, 21, 23, 29, 35, 40, 45, 49, 43) indicates that "employee growth" decreased depending on decreasing "company profit" until state 23, but "ability to plan a strategy" and "ability to manage" continued taking high values from state 23 on. Therefore, "design review" became active in state 23, and "workload" started decreasing from state 23 on. This can be interpreted as the negative direct influence of "design review" being greater than the positive direct influence of "trouble occurred." On the other hand, the behavior path branched in state 35 and generated Pattern 4 (for example, states 1, 2, 9, 10, 21, 23, 29, 35, 37, 46, 47). Pattern 4 indicates that "employee growth" continued to take a low value from state 35 on. For this reason, "ability to manage" and "ability to plan a strategy" decreased and "workload" increased.

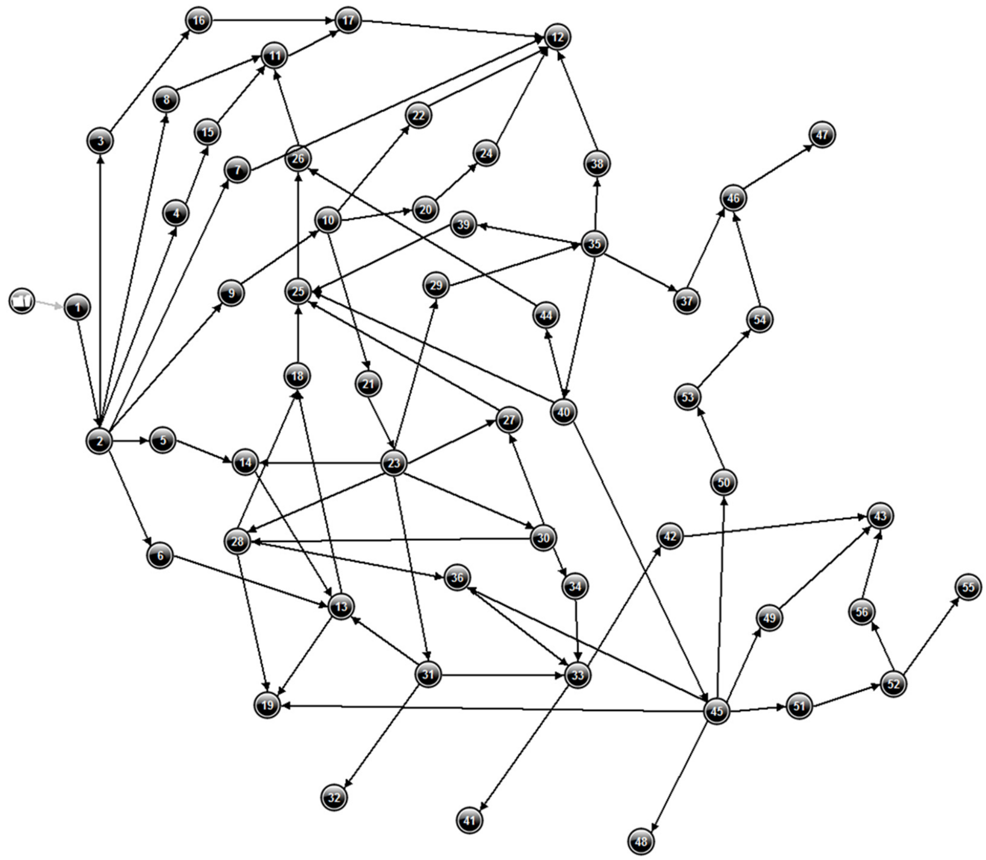

Figure 4. Behavior graph obtained in simulation

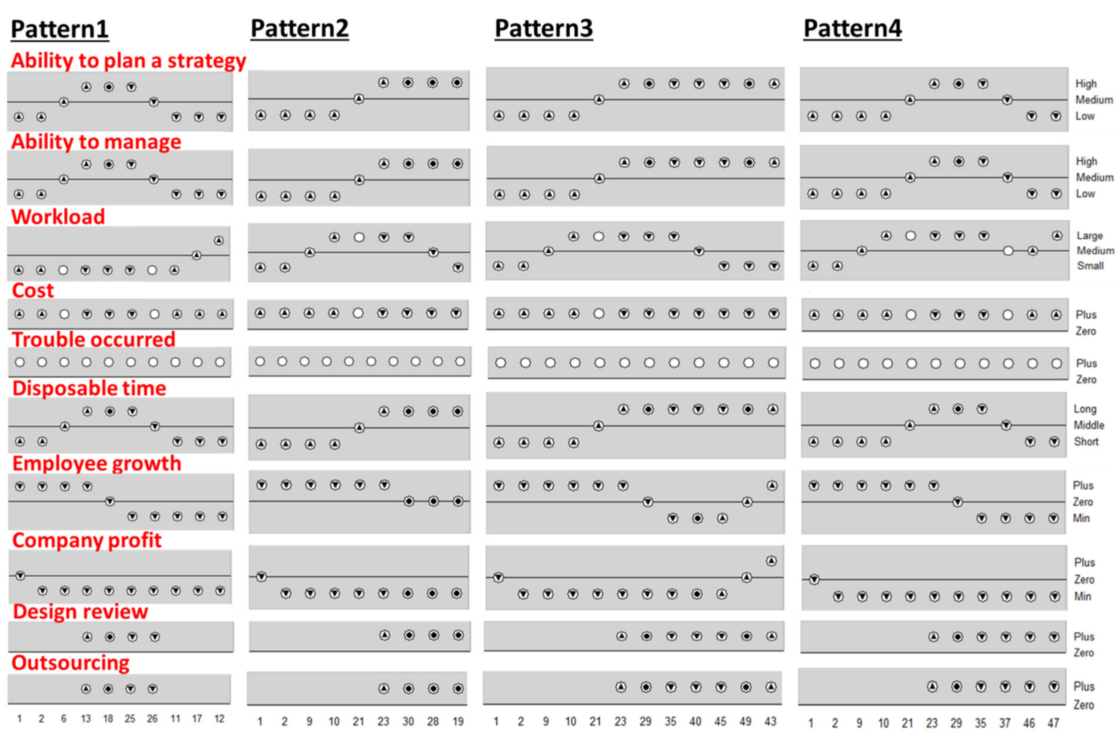

Figure 5. Behavioral patterns produced in simulation

6. Discussion

6.1 Modeling and behavior

In this paper, a qualitative simulation model was constructed by setting parameters and qualitative causal relationships based on the four perspectives of the BSC. The model contains some parameters that are difficult to express quantitatively (e.g., "ability to plan a strategy"). Therefore, we defined a quantity space using qualitative values. For example, "ability to plan a strategy" was assigned a quantity space {High, Low}. Furthermore, parameters were connected to one another with qualitative causal relationships based on the designer's experience and intuitive knowledge of service design. This made it possible to construct a simulation model using fuzzy information (e.g., if "ability to plan a strategy" increases, "outsourcing" also increases) in the early stages of the service design process when it is often difficult to obtain quantitative information. In addition, the simulation model produced behaviors that are assumed to occur in actual business situations. These results contain a practical evaluation based on the designer's experience that is an enhancing process of providers' abilities. In this paper, the simulation results could visualize some mechanisms of an enhancing provider's abilities. For example, if "ability to manage" increases, "ability to plan a strategy" also increases, ensuring a set amount of time for system operations and maintenance.

6.2 Service design

Our simulation model was constructed based on aspects of the BSC identifying what actions should be taken and measured in the early stages of the service design process. For this reason, we considered it appropriate for constructing qualitative simulation models in the concept design phase corresponding to the service requirement phase of the V-model (Figure 1). In addition, the simulation result contains ambiguous but dynamic behaviors that could happen in actual business situations. Understanding of these behaviors in advance could be useful information to decide a policy for the service design in its early stages.

6.3 Future work

Difficulties remain for the proposed modeling method, including the fact that the quality of the simulation model depends on the skill level and experience of its designers. Furthermore, this paper applied the proposed modeling method to a small-scale example. Future work will include its application to a large-scale example and evaluation by experts specializing in management. Moreover, we prepared only one scenario representing our parameters' initial qualitative values. Future work should include a variety of scenarios in order to take different real-world situations into account.

7. Conclusion

The purpose of this study was to improve service design process efficiency. We proposed a method for constructing qualitative simulation models, and in a sample service case, we constructed a qualitative simulation model that produced behaviors assumed to exist in actual business situations. Therefore, the proposed method enable designers to evaluate a design solution in the early stage of a service design process, it can be expected to improve service design process efficiency. In future work, we will evaluate the efficacy of our proposed modeling method in light of discussions with experts specializing in management.

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