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A TRIZ-based Approach to Generation of Service-supporting Product Concepts

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***Abstract*—**Recently, business environment and customer needs have become rapidly changing, hence it is very difficult to fulfill sophisticated customer needs by product or service innovation only. In practice, to cope with this problem, various manufacturing companies have developed services to combine with their products. Along with this, many academic studies on PSS (Product Service System) which is the integrated system of products and services have been conducted from the viewpoint of manufacturers. On the other hand, service providers are also attempting to develop service-supporting products to increase their service competitiveness and provide differentiated value. However, there is a lack of research based on the service-centric point of view. Accordingly, this paper proposes a concept generation method for service-supporting product development from the service-centric point of view. This method is designed to be executed in five consecutive steps: situation analysis, problem definition, problem resolution, solution evaluation, and concept generation. In the proposed approach, some tools of TRIZ (Theory of Solving Inventive Problem) such as ISQ (Innovative Situation Questionnaire) and 40 inventive principles are employed in order to define problems of the current services and solve them by generating service-supporting product concepts. This research contributes to the development of service-supporting products and service-centric PSSs.

***Keywords*—**TRIZ, PSS (Product Service System), service-supporting product, concept generation

I. Introduction

RECENT years, business environment and customer needs have become rapidly changing and increasingly diversified. Under this circumstance, it is very difficult for companies to keep growing and fulfill sophisticated customer needs by product or service innovation only. In practice, to cope with this problem, various manufacturing companies such as General Electric, Xerox, Cannon, Parkersell, etc. have developed services to combine with their products since the mid-1990s [1]. These attempts can be considered as PSS (Product Service System) which was firstly defined as "a system of products, services, networks of players and supporting infrastructure that continuously strives to be competitive, satisfy customer needs, and have a lower environmental impact than traditional business models" [2].

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Along with the emergence of PSS in practice, many academic studies on PSS have been carried out based on the product-centric point of view [3]–[10]. These studies focused on how to effectively integrate services into products. On the other hand, in practice, service providers are also attempting to develop service-supporting products and integrate into their services in order to increase their service competitiveness and provide differentiated value. Amazon's Kindle and personal healthcare devices/services are examples of this case. However, there is a lack of research based on the service-centric point of view, although it is significant and imperative for service providers to develop service-supporting products.

In response, this paper suggests an approach to generating concepts of service-supporting products for service-centric PSS development. In the proposed approach, some tools of TRIZ (Theory of Solving Inventive Problem) are employed in order to define problems of the current services and solve them by generating service-supporting product concepts. In this paper, products encompass not only hardware product such as devices and machines but also software product such as information systems or applications. The model is designed to be executed in five consecutive steps: (1) situation analysis by conducting a survey based on ISQ (Innovative Situation Questionnaire) of TRIZ, (2) problem definition by identifying the most problematic factors among 13 service decision factors, (3) problem resolution by applying 40 inventive principles of TRIZ, which is modified for service industry, (4) solution evaluation by aggregating solutions and identifying contradictions, and (5) concept generation by resolving contradictions and finalizing the concept. This research could facilitate the development of service-supporting products and service-centric PSSs.

The remainder of this paper is organized as follows. A general background of TRIZ is introduced in Section II. The approach suggested in this research is explained in terms of process and tools in Section III. Finally, Section IV offers our conclusions including summary, contribution, and future research.

II. TRIZ

TRIZ is a Russian acronym of Teoriya Resheniya Izobretatelskikh Zadatch, which means theory of inventive problem solving in English. TRIZ was firstly developed by Altshuller, beginning in 1946, and has been improved and modified up to the present. Based on the scientific and systematic analysis of more than 2 million patents, Altshuller found innovation patterns that resolve contradiction problems

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occurring in engineering and technological inventions. Accordingly, TRIZ provides a series of tools for generating creative thinking and innovative ideas which lead to new inventive solutions for problem solving [11]. A distinct characteristic of TRIZ for problem solving is the systematic problem resolution without compromise. The set of TRIZ tools leads problem solvers, through the entire problem solving processes, to explore solutions in directions that have already been proven successful [12].

TRIZ tools are divided into analytical tools and knowledge base tools [13]. The former tools include ISQ, contradiction analysis, substance field analysis, and ARIZ (Russian acronym for Algorithm of Inventive Problems Solving), which are used for problem definition, analysis, and transformation. The latter tools include 40 inventive principles, four separation principles, and 76 standard solutions, which are used to develop inventive solutions.

Among TRIZ tools, in this study, ISQ and 40 inventive principles are employed to develop a new concept of service-supporting product for the current service. ISQ, as a tool for problem definition, supports problem solvers to structuralize and document information on problem situation with question categories and items including information about the system and problem situation, ideal vision of solution, available resources, allowable changes to the system, criteria for selecting solution concepts, etc [14]. On the other hand, 40 inventive principles are related with problem resolution. In TRIZ, a technical contradiction can be solved by using contradiction matrix that has the form of a 39×39 matrix of 39 improving engineering parameters (rows) and 39 worsening engineering parameters (columns). Each cell of the contradiction matrix has up to four recommended inventive principles which can facilitate the development of innovative solutions for the relevant contradiction. 40 inventive principles are listed in Table 1 [15].

TABLE I
40 INVENTIVE PRINCIPLES [15]

No.	Principle	No.	Principle
1	Segmentation	21	Rushing through
2	Extraction	22	Convert harm into benefit
3	Local quality	23	Feedback
4	Asymmetry	24	Mediator
5	Combining (Integrating)	25	Self-service
6	Universality	26	Copying
7	Nesting	27	Disposable objective
8	Counterweight	28	Replacement of a mechanical system
9	Prior counteraction	29	Pneumatic or hydraulic construction
10	Prior action	30	Flexible film or thin membranes
11	Cushion in advance	31	Porous material
12	Equipotentiality	32	Changing the color
13	Inversion	33	Homogeneity
14	Spheroidality	34	Rejecting and regenerating parts
15	Dynamicity	35	Transformation of the physical/chemical states
16	Partial or excessive action	36	Phase transition
17	Moving to a new dimension	37	Thermal expansion
18	Mechanical vibration	38	Use strong oxidizers
19	Periodic action	39	Inert environment
20	Continuity of useful action	40	Composite materials

III. RESEARCH DESIGN

A. Research process

The overall research process consists of five steps as shown in Fig. 1. First, a survey based on ISQ of TRIZ is conducted for situation analysis. Second, based on the results of survey, the most problematic factors among 13 service decision factors are identified so as to define problems. Third, problems defined in the previous step are resolved by applying 40 inventive principles of TRIZ, which is modified for service industry. Fourth, solutions are aggregated and checked in order to identify contradictions among them. Last, contradictions are resolved by 40 inventive principles, and the concept of service-supporting product is finally generated.

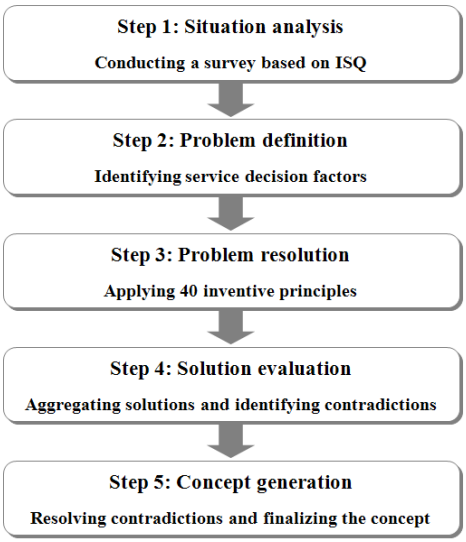


Fig. 1 Overall research process

B. Detailed process

1) Step 1: Situation analysis

First of all, to identify problems in the current service, a questionnaire is formulated based on ISQ of TIRZ. As mentioned in Section II, ISQ suggests question categories and items to help structuralize information on problem situation. In this research, some of ISQ items are selected and modified to develop a questionnaire, and the result is as follows.

Question 1: What are the existing problems in the current service?

Question 2: What is the ideal solution to each problem?

Question 3: What are the restrictions or constraints on realizing the ideal solution?

With this questionnaire, a survey of employees as well as customers is carried out, and respondents should be encouraged to answer in detail.

2) Step 2: Problem definition

In this step, problems identified in the previous step are defined by diagnosing the most problematic factors in terms of service decision factors. Service decision factors are elements to be considered when designing a service system for new service development. Table II shows the list of 13 service decision factors and their descriptions [16].

TABLE II
SERVICE DECISION FACTORS [16]

Service Decision Factors	Description
1. Facility location	Based upon proximity to customers
2. Facility layout	Depends on the presence of the customer at the location
3. Product and process design	Covers both the intangible and tangible aspects of the service offering
4. Scheduling	How the workers are assigned to the service
5. Worker skills	Depends on service strategy and concept, customer contact level and industrialization level
6. Quality control, measures, time standards	Focuses on the needs of the customer
7. Demand/capacity planning	Depends on the type of service and the immediacy of matching supply to demand
8. Industrialization level	Substitution of technology for people
9. Standardization	Level of uniformity provided in the service
10. Customer contact level	Physical presence and length of time that a customer spends with a service provider
11. Frontline personnel discretion	Denotes the flexibility of the service employee while interacting with a customer
12. Sales opportunity	Coincide with high customer contact and employee discretion
13. Customer participation	Substitution of consumer labor for provider labor

3) Step 3: Problem resolution

Until this step, problems in the current service are investigated, and the most problematic service decision factors are identified for each problem. In this step, problems are resolved by applying 40 inventive principles of TRIZ. For this aim, this study adopts the model for linking service decision factors and 40 inventive principles modified for service industry by Zhang [17] (see Table 3). According to the Table 3, suitable principles for each problem are employed to develop solutions in terms of service, hardware product, and software product.

4) Step 4: Solution evaluation

Solutions derived in the previous step are independent of each other. These solutions should be checked whether there are contradictions or not when they are applied in the same service system. At this time, a service developer could refer to common contradictions found in service industries [18], which are as follows.

- Diversity vs. Focus
- Customization vs. Standardization
- Functionality vs. Ease of use
- General information vs. Detailed information
- Security/Privacy vs. Transparency
- Industrialization vs. Personalization

After aggregating solutions into service-related, hardware product-related, and software product-related, a service developer should find out contradictions arisen from them.

5) Step 5: Concept generation

In this step, contradictions are resolved and the concept of service-supporting product is generated as the final output. First, service decision factors resulting in contradictions are identified as described in step 2. Next, according to table 3, relevant inventive principles are applied to resolve contradictions as described in step 3. Finally, all solutions are completed, and the service-supporting product concept of service-centric PSS is generated by aggregating hardware product-related and software product-related solutions.

IV. CONCLUSIONS

This paper proposes an approach to generating concepts of service-supporting products for service-centric PSS development. In the proposed approach, ISQ of TRIZ is employed to develop a questionnaire with the purpose of identifying problems of the current service. Based on the result

TABLE III
SERVICE DECISION FACTORS AND MODIFIED INVENTIVE PRINCIPLES [17]

Service Decision Factors	40 Inventive Principles
1. Facility location	1. Segmentation; 2. Taking out; 10. Preliminary action; 13. Do it in reverse; 15. Dynamics; 28. Mechanical substitution; 39. Inert atmosphere
2. Facility layout	2. Taking out; 3. Local quality; 6. Universality; 15. Dynamics; 30. Flexible shells and thin films; 31. Porous materials; 32. Color change; 35. Parameter changes
3. Product and process design	6. Universality; 9. Preliminary counteraction; 10. Preliminary action; 15. Dynamics; 21. Skipping; 27. Cheap disposal; 36. Phase transition; 40. Composite materials
4. Scheduling	11. Beforehand cushioning; 18. Mechanical vibration; 20. Continuity of useful action; 24.Mediator; 38. Boosted interaction
5. Worker skills	2. Taking out; 6. Universality; 10. Preliminary action; 24. Intermediate
6. Quality control, measures, time standards	1. Segmentation; 6. Universality; 21. Skipping; 24. Intermediate
7. Demand/capacity planning	1. Segmentation; 19. Periodic action; 22. Blessing in disguise; 25. Self-service
8. Industrialization level	2. Taking out; 6. Universality; 21. Skipping; 27. Cheap disposal; 28. Mechanical substitution
9. Standardization	6. Universality; 10. Preliminary action; 16. Partial or excessive action; 22. Blessing in disguise
10. Customer contact level	2. Taking out; 15. Dynamics; 24. Intermediate; 25. Self-service; 38. Boosted interaction
11. Frontline personnel discretion	13. On the other way around; 15. Dynamics; 16. Partial or excessive action; 35. Parameter changes
12. Sales opportunity	9. Preliminary action; 15. Dynamics; 31. Porous materials; 38. Boosted interaction
13. Customer participation	18. Mechanical vibration; 19. Periodic action; 25. Self-service; 40. Composite materials

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of survey, for each problem, the most problematic factors are identified in terms of service decision factors. Subsequently, relevant inventive principles of TRIZ are applied to resolve problems. Afterward all solutions are aggregated and checked whether there are contradictions or not in the service system. If contradictions are found, they should be resolved in the same manner as an individual solution is resolved. Finally, the concept of service-supporting product for service-centric PSS development is generated by aggregating hardware product-related and software product-related solutions.

The contribution and potential utilities of this study are twofold. First, from an academic perspective, this study expands the scope of PSS research, which is hitherto based on product-centric point of view. This can establish a foundation for research on the development of service-supporting products and service-centric PSSs. Second, from a practical perspective, this study could facilitate the development of service-supporting products as well as service-centric PSSs. Due to its simplicity and ease of use, the proposed approach could be adopted by various service providers who consider the development of service-supporting products.

Despite these substantial contributions, this paper has some limitations that should be clearly solved. First, it is difficult to obtain detailed answers through a survey. Thus, future research should suggest a more suitable and systematic data collection method instead of a survey. Second, this research includes only research design. Therefore, future research should contain various case studies to validate effectiveness and applicability of the proposed approach.

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