Innovative Design Method of Product Service System by Using Case Study and TRIZ Method

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Abstract

This paper presents a TRIZ based eco-innovative design methodology to support designers to develop product service systems (PSS). This method is based on TRIZ, which was developed in the former Soviet Union by Altshuller, who had analysis over 400,000 patents to build 40 inventive principles and contradiction matrix tool. In this paper, current PSS cases are collected and analyzed to identify consumers' use habit in the PSS cases. Find out the relations between product and service in those cases. Analyzing product with its characteristics to get suggestions which for design new PSS. Then use the TRIZ 40 inventive rules to conclude innovative design rules for PSS. Product design may have more innovative possibilities by using these inventive rules. PSS innovation example was demonstrated to illustrate the effectiveness of proposed methods.

Keywords

PSS, Eco-Innovation, TRIZ

1 INTRODUCTION

The development of technology plays a crucial role in modern economic growth, but is also the key factor of environmental crisis. It is usually emphasizing the novelty and economic usefulness of an innovation product but neglects its environmental impact. Currently, many eco-design methods have been combined with eco-innovation. However, even there is eco-design method to design product, it's hard to say that all the eco-products are used by an eco-efficiency concept. Therefore a new concept of product service system (PSS) that defined a system of products, services, and supporting infrastructure to fulfil a customer need with less environmental impact than traditional ones is proposed [1-3]. Though there are many PSS examples that can be followed, it still needs a method to provide product designers some inspirations.

The use of TRIZ method in eco-innovative design tasks is one of the interests, which have been proposed since 2000 [4-5]. They identified ways in which tools and methodologies from TRIZ might be used in eco-innovation. The simplest way to adapt TRIZ into eco-innovation is using TRIZ classical method by identifying the contradiction parameters and finding suitable principles from contradiction matrix [4, 7-9]. Chen and Liu established the link between seven major eco-efficiency elements from WBCSD (World Business Council for Sustainable Development) with TRIZ engineering parameters and developed an inventive design method to solve engineering innovative design problem without contradiction information by using TRIZ inventive principles [10-12]. Chen [13] developed green evolution rules and ideality laws for eco-innovative design, which can help designer to locate an evolutionary direction in eco-design process. Chang and Chen proposed a design around and extension method [7, 14] and collected 40 eco-innovative examples for TRIZ inventive principles [15], which cover a wide range of products and processes design. Chen and Chen [16] used TRIZ method in design for active disassembly. Chen and Huang [17] proposed an eco-innovation method by integrating biomimetic concepts with TRIZ. Chen and Wu [18] proposed an eco-innovation method by combining TRIZ with iNPD process.

The use of TRIZ method in PSS development methodology is proposed by Abdalla [19-20]. Lin and Su [21] apply the TRIZ inventive principles to create new services. Kondoh and his co-authors [22] have proposed some rules for planning new eco-business or PSS. Chen and his co-authors [23] have proposed TRIZ ideality and trend of evolution in eco-business. Chen and Huang [24-25] have presented an eco-innovation method to support designers to develop product service systems (PSS). This method is based on TRIZ 40 inventive principles and contradiction matrix tool. Current PSS cases are collected and divided into five categories. A relationship table between TRIZ inventive principles and PSS cases is established in this paper to presents a new design guideline for PSS. Some green evolution rules are observed and identified by investigating patterns and lines of technological evolution of different PSS.

In this paper, current PSS cases are collected and analyzed to identify consumers' use habit in the PSS cases. Find out the relations between product and service in those cases. Several design tables are developed and used as tools for PSS eco-innovation. PSS innovation example was demonstrated to illustrate the effectiveness of proposed methods.

2 TOOLS FOR PSS ECO-INNOVATION

In this section, several design tools for PSS eco-innovation were presented and described in detail. The tools include some design table, PSS categories, TRIZ inventive principles, and PSS cases.

2.1 Eight PSS categories

Tischner and Verkuijl [1] have divided the PSS into three big categories: product, use and result orientated PSS. Furthermore, Tukker [26] has classified into eight small categories. The first two small categories, (1) product-related service and (2) advice and consultancy, are identified as first big category, product-oriented PSS, which product is owned by the user/consumer with added services. Second large category is use-oriented PSS which product is owned by the service provider and used by the consumer. The service provider sells functions

PP		Pr		IU		UC		CP		PV		PW		RT		UR	
Product Property		Price		Idle-Using Ratio		Using Cycle		Using Period		Product Volume		Product Weight		Rearrange Time		Used Ratio	
Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank
Fixed / Solid	1	<100	1	<1	1	1 hr↓	1	1 hr↓	1	10^{-3} m^3↓	1	1Kg↓	1	0	1	1	1
		100 ~ 1000	2	1~2	2	1hr~ 1Day	2	1hr~ 1Day	2	15X 10^{-3} m^3	2	1~5	2	1 hr↓	2	2~10	2
Movable	2	1000 ~10,000	3	>2	3	1Day~ 1week	3	1Day~ 1week	3	65X 10^{-3} m^3	3	5~30	3	1hr~ 1Day	3	10~100	3
consuming / Non-Solid	3	10,000 ~100,000	4			1week~ 12 month	4	1week ~ 1 month	4	1 m^3	4	30~200	4	1Day~ 1week	4	100↑	4
		100,000 ~10 million	5			1 year↑	5	1 month ↑	5	1 m^3↑	5	200↑	5	1week ~ 1 month	5		
without main Products/ Solutions	4	>10 million	6							None	6	None	6	1 month ↑	6		
		Special price	7														

Table 1: Product's characteristic factor level table of PSS.

instead of products, such as leasing, and renting. Three small categories, (3) product lease, (4) product renting or sharing, and (5) product pooling, are classified as second big category. Third big category is result-oriented PSS which a customer only purchases a service result and does not care which products are used, such as new service by new technologies. The small categories, (6) activity management or outsourcing, (7) pay per service unit, and (8) functional result, are identified as result oriented PSS.

In this study, 103 PSS cases are collected and divided into above eight categories. Some PSS cases have more than one category since their feature can be classified into many small categories.

2.2 Product's characteristic factor level table of PSS

After collect 103 PSS cases, an index system to exploit similarities among PSS cases is proposed for identifying most similar PSS case in database as eco-innovation direction for new PSS problem. An index system signifies all the important characteristics required to classify different PSS groups. Each group is identified by a nine-digit alphanumeric code. Each digit is a notable feature and represented by a different number for each different PSS according to its characteristic. The significance of each digit is represented in detail later and also shown in Table 1.

Nine product's characteristic factor for PSS are product property (PP), price (Pr), idle-using time (IU), using cycle (UC), using period (CP), product volume (PV), product weight (PW), rearrange time (RT), and used ratio (UR) respectively. The level of each factor and the rank of each level are all shown in Table 1.

2.3 PSS case database

Each PSS case is recorded in database with information about this PSS, such as case number, categories, name of PSS case, service model, related product, Nine product's characteristic factor, and characteristic of PSS, as illustrated in Table 2. In Table 2, only partial list of PSS case database is shown. Detail list of all 103 PSS case database can be found in Reference 27. The characteristic of PSS is special business feature of each PSS case and contains four types, such as user interface for customer, business strategy, cost reduction, and

increasing function or service efficiency. The number inside the bracket of the example of characteristic of PSS associated with each PSS case is the number of related TRIZ inventive principle.

2.4 TRIZ Inventive principles for PSS

The 40 TRIZ inventive principles were original developed for using in engineering and technology domain. They are not very suitable for employing into PSS innovation directly. Therefore, a new definition for each TRIZ inventive principle for PSS innovation is proposed in this study. A relationship table between TRIZ inventive principles, New definition, and PSS cases is established in this paper to presents a new design guideline for PSS, as illustrated in Table 3. In Table 3, only partial list of TRIZ inventive principles is shown.. Details of this table can be found in Reference 27.

2.5 PSS service modes

In addition to Tischner's eight PSS categories, a new service model categories for PSS based on motivation of service is proposed in this study. PSS cases are classified into six big service mode categories, such as potential value of product, saving of time & convenience, promotion competitive power, meets more needs, more specialized, and reducing cost, respectively. Furthermore, each six big service mode category is divided into three small service mode categories. Therefore, totally, there are eighteen small service mode categories, such as (A) remanufacture/ resale, (B) obtains the information, (C) reducing pollution, (D) appointment, (E) replace shipping, (F) service in everywhere, (G) change to sale function, (H) change business model, (I) unify function & entity, (J) multi-function, (K) extra service, (L) customization, (M) specialized management, (N) special se4rvice, (O) collection & reorganization, (P) sharing, (Q) software replace hardware, and (R) uses many times, respectively.

A position table for identifying the relationship between Tischner's 8 PSS categories and PSS service mode categories for all 103 PSS cases is shown in Table 4. Detail information about the case number shown in Table 4 can be obtained from Reference 27. As illustrated in Table 4, most PSS cases in product-oriented PSS are focused on "meets more needs" big service motivation category. As for use-oriented PSS, most PSS cases focus

Case No.	Categories (Tukker)	PSS case	Service mode	Related product	PP	Pr	IU	UC	CP	PV	PW	RT	UR
1	3	Recycling & remanufacture carpet	A	Carpet	1	4	2	1	2	3	2	4	1
5	4	Advanced rent mode	F, R	Bike; Renting station	2	3~4	3	2	2	3	2	3	3
34	7	24 hours self-washing store	R	Washing machine	1	4	3	2	1	4	4	1	3
49	2	Customized computer	L	Computer hardware	1	3	3	2	2	3	2	4	3
63	8,1	Advertisement service	F	Advertisement electronic monitoring system	1	3	1	4	5	4	3	5	2

Case No.	Characteristic of PSS (the number inside the bracket is the number of related TRIZ inventive principle)			
	User interface for customer	Business strategy	Cost reduction	Increasing function or service efficiency
1		1. The continuous revision maintenance carpet lengthens the servicing time (19)	1. Improving material for recycling & reuse (31)	1. The carpet material changes into reuse material (34) 2. Segment carpet into small unit (1)
5	1. Bank cooperation (38) 2. Mobil phone reservation (24)	1. Having multi-station for renting bike (14) 2. Member system (11) 3. Deposit (11)		1. The frame of bike adds on the electronic lock (11)
34		1. Business without manpower (2) 2. 24 hours business (12)		1. Joins throws the coin starting equipment (25)
49				1. Joins the service of guarantees against damage (20) 2. Provides the specialized consultation (29)
63				1. Utilizes the specialized design capability to design the outdoor advertising electronic monitoring system (32) 2, Outdoors electronic monitoring system regarding environmental durability (16)

Table 2: Partial list of PSS case database table.

on "reducing cots" big service motivation category and "(R) uses many times" or "(P) sharing" small service model categories. Furthermore, Many PSS cases are located in the "result-oriented PSS" category. In this category, most PSS cases are focused on "potential value of product, saving of time & convenience, promotion competitive power, and more specialized" big service motivation categories.

3 ECO-INNOVATION OF PSS

3.1 Design process for PSS eco-innovation

The tools, such as Table1-4, categories, TRIZ inventive principles, and PSS cases, for PSS eco-innovation developing in section 2 are organized as a design process for PSS innovation, as shown in Figure 1. As illustrated in Figure 1, the design procedure can be recognized as four stages. The significations of these four stages are explained in detail as follows.

3.2 First stage: find similar PSS cases

The designer can first propose the PSS problem that required improvement and find similar PSS cases based on Table 1 and Table 2. The first step is to identify the level value of nine product's characteristic factor from the definition of Table 1 for target product. Next, designer can searching the most similar PSS cases from database of Table 2 with target product by comparing the level value of nine product's characteristic factor. The PSS cases with low value of degree of difference will be the most similar cases. The degree of difference is calculated by the following equation.

$$\text{Degree of difference} = \sum_{i=1}^{9} |F_i - f_i|$$

No	TRIZ Inventive Principles	Redefinition of Principle in PSS Domain	Characteristic of PSS cases
1	Segmentation	1. Divides the object into independent components 2. Makes the object modualization 3. Increases the degree of division for object or service	1. Segment carpet into small unit (1) ......
2	Extraction	1. Takes out the partial functions to use 2. Takes out the partial flow to reduce harm	1. Business without manpower (34) ....
12	Equipotentiality	1. Change work's condition causes the object not to lift or lower 2. Change service pattern decreases with the competitor disparity	1. The traditional market use fast purchases window (81) 2. 24 hours business(34)
16	Partial, Overdone or Excessive Actions	1. Uses a stronger effect to promote the long-term potency 2. Uses durable material or long-life goods 3. uses more efficiency goods	1. Outdoors electronic monitoring system regarding environmental durability (63) .....
25	Service	1. The user may complete voluntarily 2. The manufacturer utilizes own specialty to complete the other entrepreneur complex or expensive service	1. Coin-operated laundry (34) ....
32	Changing the Color	1. Outward appearance art designing	1. Utilizes the specialized design capability to design the outdoor advertising electronic monitoring system (63) ......
.....	.....	.....	.....

Table 3: Partial list of TRIZ inventive principles for PSS.

Service Model Categories (Tukker)			Potential value of product			Saving of time & convenience			Promotion competitive power			Meets more needs			More specialized			Reducing cost		
			Remanufacture/ Resale	Obtains the information	Reducing pollution	Appointment	Replace shipping	Service in everywhere	Change to sale function	Change business model	Unify function & entity	Multi-function	Extra service	Customization	Specialized management	Special service	Collection & reorganization	Sharing	Software replace hardware	Uses many times
			A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Product Oriented	1	.Product-related service	13			3.16.63.91			66.81.41.71			56.64.84.86.99. 103			14.17.47					
	2	Advice and consultancy	43.77.78			16						49.51. 65			100.44			50		
Use Oriented	3	Product lease	1.22						11.29						12			48.75		
	4	.Product renting or sharing	22.74			5.76			29						23			5.6.25.36.37.74. 75.83.7		
	5	Product pooling							73									38.59.70		
Result Oriented	6	.Activity management /outsourcing.	8.22.78.79.80.82. 85.94.95.96.97. 102..13.10.45			72.87			29.92.93			68.86.84.51			14.18.39.58.89. 101. 102 15.55.90			48		
	7	Pay per service unit.																31.32.34		
	8	Functional result	43			2.28.53.54.63			35.68.27			40.60.67.98.19.5. 3.62			9.20.24.30.33.57. 4.21.26.88.46.61			61.52		

Note: The number in this table is the number of PSS case.

Table 4: Relationship between 8 PSS categories and PSS service modes.

After finding the most similar PSS cases, designer can process into second stage.

3.3 Second stage: identify PSS categories

Based on the most similar PSS cases found in the first stage, one can identify Tukker's categories and service mode categories of each one from the information in Table 2. If the designer find the Tukker's categories or service mode categories from anyone of the most similar PSS cases are valuable for offering eco-innovation direction for target product, then move to third stage. Otherwise, go to fourth stage.

3.4 Third stage: find TRIZ inventive principles

In third stage, the designer can search the characteristic of PSS (special business feature of each PSS case) for
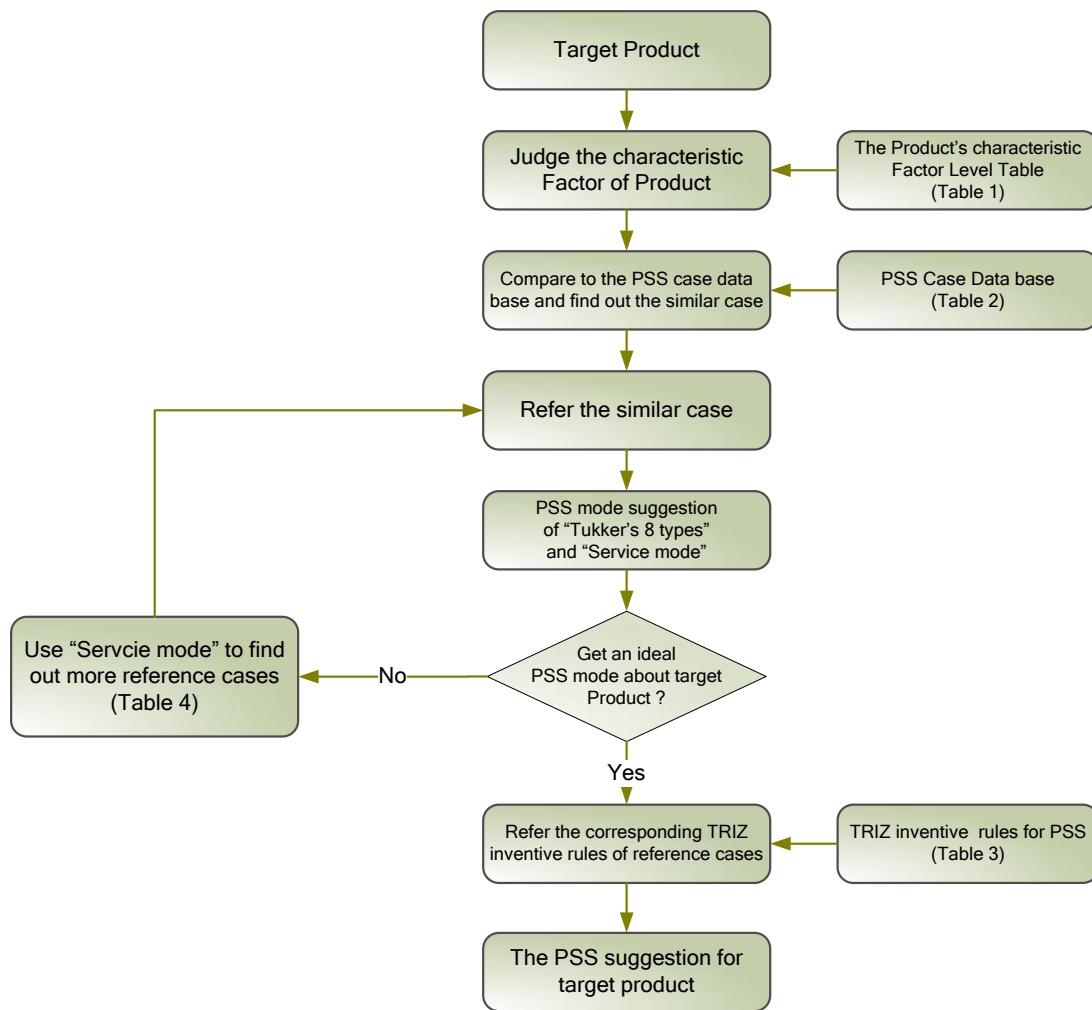
Figure 1: Flowchart of the PSS eco-innovation process.

selecting most similar cases from Table 2. The characteristic of PSS contains four types, such as user interface for customer, business strategy, cost reduction, and increasing function or service efficiency. Therefore, the designer can try to obtain new idea for PSS eco-innovation from the suggesting characteristic of PSS of each case in Table 2. Moreover, the number inside the bracket of the example of characteristic of PSS associated with each PSS case is the number of related TRIZ inventive principle. The designer can find the corresponding new PSS definition and related PSS cases for each TRIZ inventive principles from Table 3. Based on new definition of TRIZ inventive principles and related PSS cases, the designer can generate new PSS ideas.

3.5 Fourth stage: find other design suggestions

During the second stage, in case the finding PSS cases are not suitable to get an ideal PSS service mode. Then, the designer can move into stage four to obtain other different PSS cases for reference. In fourth stage, the designer can utilize information in Table 4 to obtain other PSS cases with the same motivation of service category of the most similar PSS cases in first stage. Selection of other PSS cases is based on the one identified in the Tukker's result oriented category. As another PSS cases are obtained, the designer can move forward to second stage.

4 NOTEBOOK EXAMPLE

4.1 Problem description

Under normal condition, the average life range of notebook is 5 to 7 year. However, due to short technical cycle, customers are eliminating notebooks as outmoded products before its reached end-of-life. Therefore, one of the environmental impacts of the using notebooks relates to waste of resource. How to innovate PSS for notebook to reduce waste of resource is the object of this notebook eco-design case. The effectiveness of proposed PSS innovation method will be shown in this section.

4.2 PSS eco-innovation of notebook

By following the steps in Figure 1, one can first find the level value of characteristic factor for notebook from the definition of Table 1, as shown in Table 5. Next, designer can searching the most similar PSS cases from database of Table 2 with notebook by comparing the level value of nine product's characteristic factor between Table 5 and each cases in Table 2.

PP	Pr	IU	UF	CU	PV	PW	RT	UR
2	4	3	2	2	2	2	4	3

Table 5: The characteristic factor level of Notebook.

The most similar cases in this problem with degree of difference equals 2 are shown in Table 6. From the information in Table 6, the Tukker's categories for PSS case 5 (advanced rent mode) and 49 (customized computer) can be identified as (4) product renting or sharing and (2) advice and consultancy, respectively. As for service mode categories, three types service mode, (F) service in everywhere, (R) uses many times, and (L) customization are identified from the information in Table 6. Therefore, two new PSS concepts, such as notebook rent mode and customized notebook, can come out directly from above information.

Case No.	Tukker's categories	PSS case	Service mode	Related product
5	4	Advanced rent mode	F, R	Bike; Renting station
49	2	Customized computer	L	Computer hardware

Table 6: The most similar PSS cases for Notebook.

If above new concepts can not applying directly to obtain eco-innovative design for notebook, then move to fourth stage by using service mode in Table 4 to find more other PSS cases for reference. By using Table 4, The PSS cases related to service mode (F) service in everywhere and (R) uses many times are case 5, 76, 63 and 48, 75, 25, 5, 36, 37, 83, 74, 6, 34, respectively. Among those PSS cases, case 63 and 34 are identified as the Tukker's result oriented category and selected as reference cases.

In third stage, the designer can search the characteristic of PSS (special business feature of each PSS case) for case 63 and 34 from Table 2.

Case 63 is the "advertisement service" PSS case with "advertisement electronic monitoring system" product. The business feature of case 63 is identified as "increasing function or service efficiency". The example of characteristic of PSS associated with case 63 are (1) utilizes the specialized design capability to design the outdoor advertising electronic monitoring system and (2) outdoors electronic monitoring system regarding environmental durability. The related TRIZ inventive principles are #32 (changing the color) and #16 (partial, overdone or excessive actions).

The self-washing store (case 34) have been identified its business feature as "business strategy" and "increasing function or service efficiency". The example of characteristic of PSS associated with self-washing store (case 34) are (1) business without manpower , (2) 24 hours business, and (3) joins throws the coin starting equipment, respectively. The related TRIZ inventive principles are #2 (extraction), #12 (equipotentiality), and #25 (self-service).

TRIZ inventive principles #2, #12, #16, #25, and #32 can be used in this notebook problem to innovate new PSS idea. Detail information of TRIZ inventive principles related to PSS can be obtained from Table 3. The designer can generate new PSS ideas for notebook as self-service notebook renting station operating 24 hours, as shown in Figure 2.

Figure 2: Concept of self-service notebook renting station

5 CONCLUSIONS

The PSS innovation design methods based on case study and the TRIZ inventive design method was developed. 103 PSS cases are collected and analyzed to identify consumers' use habit in the PSS cases. Several design tables are developed and used as tools for PSS eco-innovation. A notebook PSS case was demonstrated to illustrate the effectiveness of proposed methods. This new methods provide the designer a supporting tool to develop new PSS with less environmental impact.

6 ACKNOWLEDGMENTS

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