

Sustainable Design Process and Factors Considered for Product Service System

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Abstract

“Sustainability” is apparently reflected in corporate management and product development. Technology development and industrial revolution not only provide human beings luxury living quality but also causes global environmental problems and natural resources crisis on earth. Therefore, quite a few environmental protection policies in the world have been made. “Reduce, reuse and recycle” definitely becomes a new life trend. Under this circumstance, Product Service System (PSS) is a new way to satisfy the customers’ needs by means of a complete process in products and services. It can make resource usage become a closed loop, thus reducing total product quantity and enhancing resource usage sufficiency. PSS has a characteristic of lower environmental impacts. Therefore, the author incorporates the concept of PSS into sustainable design strategy. This study first utilizes Analytic Network Process (ANP) to analyze both service categories from PSS and ranking priority of life cycle structure to be the foundation of sustainable design. Secondly, this study adopts Modified Delphi(MD) method to inspect the sustainable design factors considered for the application of PSS on case study. Furthermore, the author develops evaluation guidance and check list to make sure the target achievement of product sustainable design. Finally, this research accomplishes an applied process of PSS’s sustainable design. By employing PSS on sustainable design, the study improves the impact of product life cycle on environmental quality. As a result, this study provides the PSS’s design factors considered of sustainable products for corporations, and supplies a continuous service to create an operation mechanism with higher profit and lower risk as well.

Keywords: *Product Service System (PSS), sustainable design, product development strategy, Analytic Network Process (ANP)*

1. Introduction

The main purpose of “Sustainability” is to improve living environment for human being and also to keep ecological balance [1]. From ecological efficiency point of view, it can increase product recycling and product life with a closed loop of resource usage [2,3]. Europe Union first requires the control of hazardous substance and then stipulates the related environmental regulation continuously such as Restriction of Hazardous Substance (RoHS) and Waste Electrical and Electronic Equipment (WEEE). As a result, the environmental protection is oriented from the traditional operation aspect of pollution prevention to the product aspect of extensive producer responsibility. In the meantime, the rate of recycle and reuse for products increases by means of the arrangement and planning of recycling system and recycling organization. On the other hand, “Product Service System – PSS” is a present system of product, service and supporting structure [4,5]. PSS not only concerns network of customer needs on market satisfaction but also decreases the environmental impact [6,7]. A completed PSS can satisfy consumer needs and decrease total amount of product manufacturing [8]. It can also increase efficiency of resource usage and decrease resource consumption and waste produced through reuse and recycle of product, material or parts [9]. PSS can fulfill the goal of anti-substance and improve environmental impact in product life cycle [10,11].

In term of PSS, manufacturers provide services instead of actual goods sale and consumers enable to use after pay for it. From the manufacturer perspective, they still have the product ownership and also are responsible for taking care of ongoing procedures. From the customer perspective, they consume the products’ functions and services instead of products themselves [9]. As a result, the study adopts PSS concept into product sustainable design strategy in order to satisfy consumer needs on product functions and service and finally to fulfill sustainable development. Furthermore, this study accomplishes the sustainable design factors considered, evaluation guidance, check list and an applied process for the application of PSS.

2. Research methodology and steps

2.1. ANP model

The study utilizes Analytic Network Process (ANP) Model and ANP Super Decisions software to acquire both service categories from PSS and ranking priority of life cycle structure. Furthermore, this study adopts Modified Delphi (MD) method to inspect the sustainable design factors considered for the application of PSS. Finally, this research establishes an applied process of PSS’s sustainable design on the process of product design and development. Delphi method is a process which can acquire a concerted opinion in a group of experts after a series of continuous questionnaires with opinion feedback. Furthermore, Modified Delphi (MD) method is modified from traditional Delphi method because of some special consideration in a research.

The primary step of ANP decision process is to form the structure of questions. According to the structure of questions system in research decision, there divides into three aspects in question structure: service categories in PSS, life cycle structure of product and the dependent relationship between service categories in PSS and life cycle structure of product (refer to Figure 1).

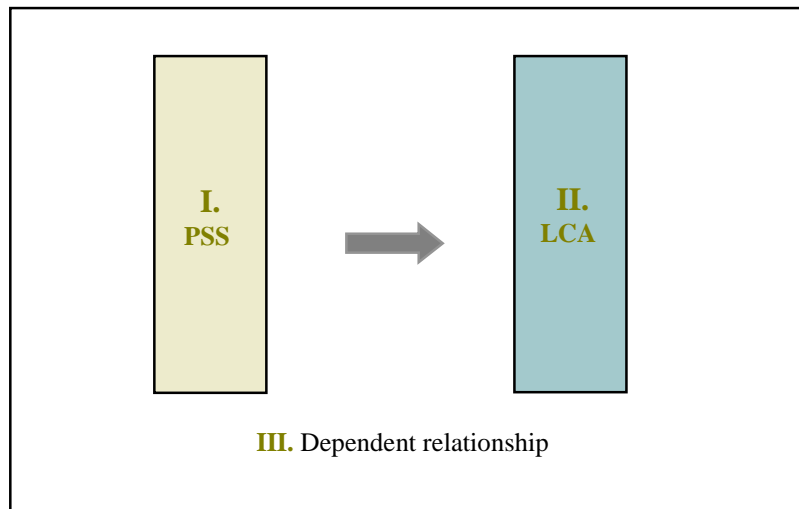


Figure 1 Diagram of ANP Model Structure

Brezet [11] groups PSS into 5 categories based on service types, there are 1) Supporting System 2) Sales Service 3) Different Product Usages 4) Maintenance Service 5) Service after Sale. And, from the ANP model of sustainable design and development strategy with PSS application, the relationship between groups and elements is indicated as Figure 2.

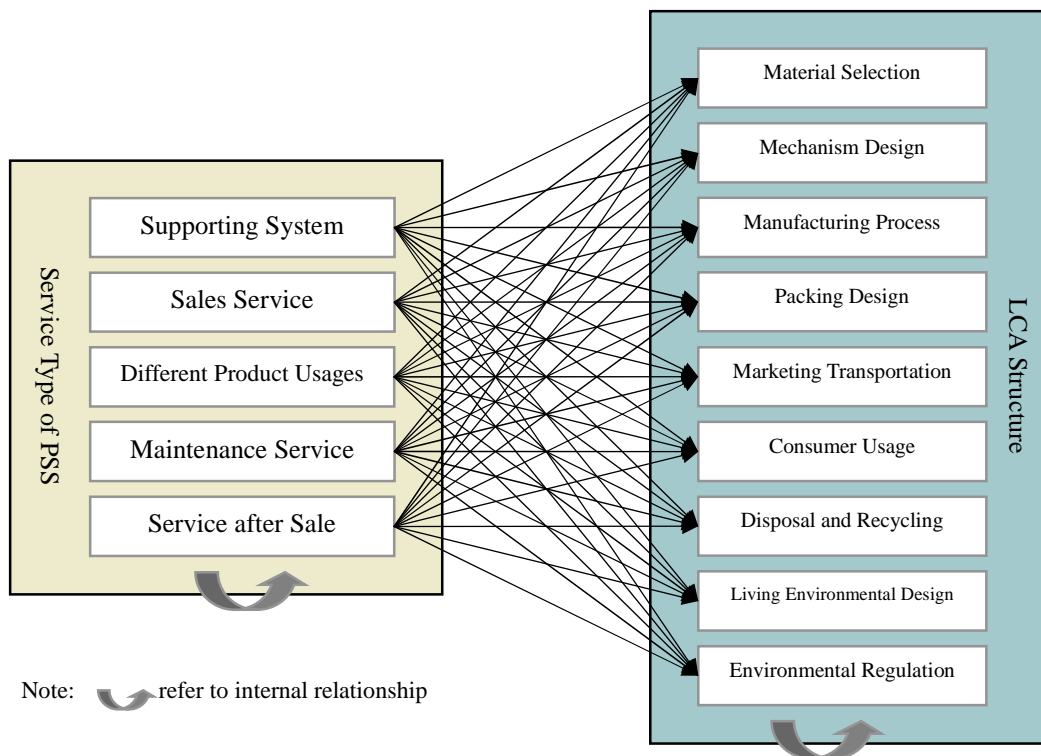


Figure 2 ANP Model

2.2. Research framework (refer to Figure 3)

In this paper, we first conduct literature review and experts survey with interview in order to establish theoretical

structure of PSS, sustainable design and development model. Then, the study utilizes Analytic Network Process (ANP) to analyze both service categories from PSS and ranking priority of life cycle structure to be the foundation of sustainable design. Secondly, this study adopts Modified Delphi (MD) method to inspect the sustainable design factors considered for the application of PSS. Furthermore, the author develops evaluation guidance and check list to make sure the target achievement of product sustainable design. Finally, this research accomplishes an applied process of PSS's sustainable design. The research framework is showed as figure 3.

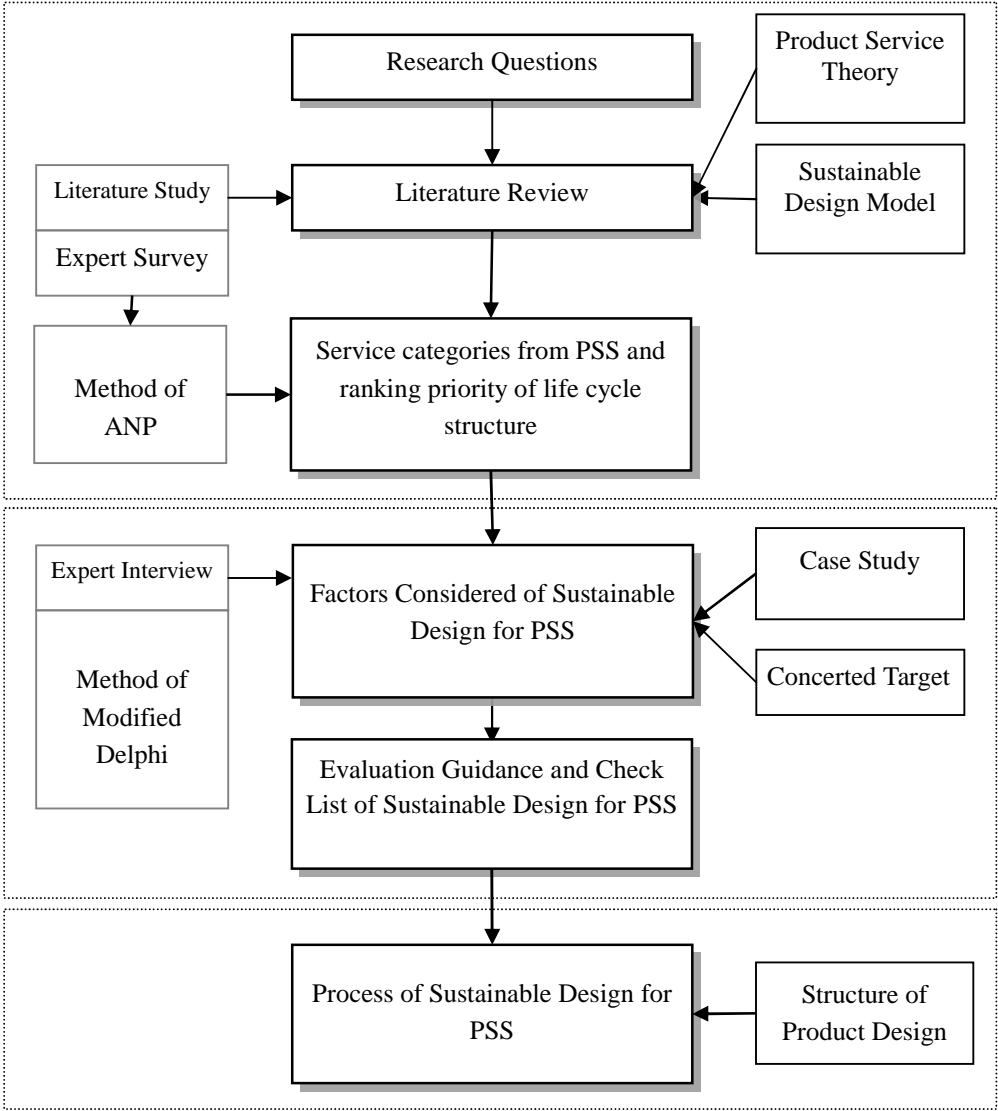


Figure 3 Research Framework

2.3. Research objects

According to the characteristic of case study, this study selects bike manufacturing companies to find out the key factors and problems of sustainable design and development through survey. In addition, the electronics industry such as notebook computer will be applied as well in the future. Furthermore, the study develops evaluation guidance and check list to make sure the target achievement of product sustainable design for the application of PSS on case study. Finally, this research accomplishes an applied process of PSS's sustainable design. The survey companies include MERIDA, GIANT and Cycling & Health Tech Industry R&D Center (CHC). The

experts interview in this study mainly depend on research and design officer covering 1 director from MERIDA company; 1 high-level chief and 3 designers from GIANT company and 2 high-level chiefs, 4 senior designers and 1 designer from CHC company. There are total 12 members in survey.

3. Research results

3.1. Process of questionnaire survey

From the paired comparison under PSS “dependent relationship”, a paired geometric mean is inputted to Super Decisions software to analyze characteristic vector quantities. These characteristic vectors represent corresponding weights of various factors, which can generate the priority for those factors. On Table 1, the supporting system of PSS service categories appears that the important ranking is “Different Product Usages > Sales Service > Service after Sale > Maintenance Service”. In addition, expert evaluation also shows the consistent result due to Characteristic Ratio (C.R)=0.0116 less than 0.1.

Table 1 Matched Matrix Between “Supporting System” and the other categories

Supporting System					
	Sales Service	Different Product Usage	Maintenance Services	Service after Sale	Characteristic vectors
Sales Service	1	1/2	3	2	0.277
Different Product Usage	2	1	4	3	0.467
Maintenance Services	1/3	1/4	1	1/2	0.095
Service after Sale	1/2	1/3	2	1	0.160
C.R=0.0116					

On the other hand, sales service of PSS service categories shows that the ranking order is “Maintenance Service > Service after Sale > Different Product Usages > Supporting System”. Different product usages of PSS service categories is “Maintenance Service > Sales Service > Service after Sale > Supporting System”. Maintenance service of PSS service categories is “Supporting System > Sales Service > Different Product Usages > Service after Sale”. Service after sale of PSS service categories is “Maintenance Service > Supporting System > Sales Service > Different Product Usages”.

3.2. Factors considered of sustainable design by PSS

The objectives of secondary questionnaire survey of Modified Delphi (MD) are internal chief officers and designers from three companies. There are 12 effective questionnaires and those can meet spirits of Delphi survey. The purpose of first questionnaire survey focuses on confirmation of factor considered items through concept of product life cycle and expert survey. Then, the secondary questionnaire survey incorporates the factor

considered items from first questionnaire survey into achieve the sustainable design factors considered for the application of PSS on case study (Table 2).

Table 2 Results of secondary survey analysis

Material Selection				
Factors considered of Sustainable design	No. of Agree	Ratio	No. of Disagree	Ratio
Fill the types of product usage	12	100%	0	0%
Avoid usage of poisonous material	12	100%	0	0%
Use recycling and reusing material	11	92%	1	8%
Decrease total amount of material	12	100%	0	0%
Use suitable materials	12	100%	0	0%
Pay attention to material characteristics and using condition	12	100%	0	0%
Decrease handle of chemistry	11	92%	1	8%
Possess mutual characters and avoid compound material	12	100%	0	0%
Mechanism Design				
Adopt simple style	10	83%	2	17%
Adopt simple mechanism on materials	11	92%	1	8%
Combine a design of easy disassembly and assembly	12	100%	0	0%
Possess a structure to change parts easily	12	100%	0	0%
Increase mechanism strength	12	100%	0	0%
Emphasize module design	12	100%	0	0%
Concern human factor	12	100%	0	0%
Stress consistent parts of new and old	12	100%	0	0%
Adopt simple mechanism for adjusting angle and height	11	92%	1	8%
Establish a checking process for maintenance	12	100%	0	0%
Manufacturing Process				
Save manufacturing process of materials	11	92%	1	8%
Decrease waste occurred	12	100%	0	0%
Decrease pollutants emission and decrease noise	10	83%	2	17%
Develop manufacturing technology for saving energy and resources	12	100%	0	0%
Packing Design				
Adopt a few and simple way	12	100%	0	0%

Enhance intensity using mechanism Design	12	100%	0	0%
Decrease vesicant plastic usage	11	92%	1	8%
Use nature resource and paper	11	92%	1	8%
Adopt packing material with non-poison, easy dissolution and reusable resource	12	100%	0	0%
Select simple material	10	83%	2	17%
Combine product and packing together	11	92%	1	8%
Marketing Transportation				
Use the most environmental protection way on transportation	10	83%	2	17%
Decrease pollution within the transportation process	12	100%	0	0%
Consumer Usage				
Increase using efficiency and satisfaction	12	100%	0	0%
Simplify functions and operation	12	100%	0	0%
Ensure user safety	12	100%	0	0%
Increase consumers' environmental protection cognition	12	100%	0	0%
Disposal and Recycling				
Establish a complete recycling system	11	92%	1	8%
Promote resource recycling and reusing	12	100%	0	0%
Use appropriate disposal approach	12	100%	0	0%
Living Environmental Design				
Provide a beautiful and suitable special design of city life	10	83%	2	17%
Consider overall outdoor landscape design and community planning	12	100%	0	0%
Environmental Regulation				
Follow the national regulation and standard on environmental protection	12	100%	0	0%
Look for confirmation on environmental protection mark	11	92%	1	8%

3.3. Checking and evaluation tool of sustainable design by PSS

The checking and evaluation tool of sustainable design is used for environmental analysis on green product development. In order to make the checking tool more faithful and specific, we set up four levels on evaluation for designers to select. By understanding the overall environmental problems and evaluating the product design and development in product life cycle, we can provide a more effective plan for green product design and development (Table 3).

Table 3 Checking and evaluation tool of sustainable design by PSS

	Life Cycle	Checking Items	Evaluation			
			High %	Lower %	Non	Remark
Sustainable Design Check List by PSS Application	Material Selection	Fill the types of product usage				
		Avoid usage of poisonous material				
		Use recycling and reusing material				
		Decrease total amount of material				
		Use suitable materials				
		Pay attention to material characteristics and using condition				
		Decrease handle of chemistry				
		Possess mutual characters and avoid compound material				
	Mechanism Design	Adopt simple style				
		Adopt simple mechanism on materials				
		Combine a design of easy disassembly and assembly				
		Possess a structure to change parts easily				
		Increase mechanism strength				
		Emphasize module design				
		Concern human factor				
		Stress consistent parts of new and old				
		Adopt simple mechanism for adjusting angle and height				
		Establish a checking process for maintenance				
	Manufacturing Process	Save manufacturing process of materials				
		Decrease waste occurred				
		Decrease pollutants emission and decrease noise				
		Develop manufacturing technology for saving energy and resources				
	Packing Design	Adopt a few and simple way				
		Enhance intensity using mechanism Design				
		Decrease vesicant plastic usage				
		Use nature resource and paper				

		Adopt packing material with non-poison, easy dissolution and reusable resource				
		Select simple material				
		Combine product and packing together				
	Marketing Transportation	Use the most environmental protection way on transportation				
		Decrease pollution within the transportation process				
	Consumer Usage	Increase using efficiency and satisfaction				
		Simplify functions and operation				
		Ensure user safety				
		Increase consumers' environmental protection cognition				
	Disposal and Recycling	Establish a complete recycling system				
		Promote resource recycling and reusing				
		Use appropriate disposal approach				
	Living Environmental Design	Provide a beautiful and suitable special design of city life				
		Consider overall outdoor landscape design and community planning				
	Environmental Regulation	Follow the national regulation and standard on environmental protection				
		Look for confirmation on environmental protection mark				
Total evaluation						

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