

Guideline and assessment of sustainable design from product service system (PSS) under low carbon society

HONGYI CHEN², KUNCHIEH WANG³, HUICUN SHEN^{3,5}, CHICHING YANG⁴

Abstract. The trend of "sustainability" issues and "low carbon" has become an important issues today. Technology development and industrial revolution, bring the human a high degree of material comfort, but also an unprecedented catastrophe for the global environment and natural resources. EU environmental directives have been put forward "reduce, recycle, re-use" resources to improve efficiency, it will become the new economic model and life style. Therefore, "A Guideline and Assessment of Sustainable Design from Product Service System (PSS) under Low Carbon Society" can reduce product carbon emissions of enterprise and increase efficient usage of resources. So that the material usage can form a closed loop.

Under the low-carbon of the products and services' concept have a characteristics of a low environmental impact. In order to understand the "sustainable product design of product-service system of low-carbon society", the researcher experimental instruments included literature review: low-carbon society, product service systems, sustainable product design. Also, study used expert interviews and grounded theory to achieve the goal and used the cases of proven ways to validation strategy model. The findings obtained three results: sustainable product design of product-service system of low-carbon society's guidelines, sustainable product design's checklist and sustainable product design's process. As a result of study, it can improve product life-cycle phases of environmental impact and the impact of its assistance and recognition of sustainable product development goals to reach.

The results of the LC-PSS green products sustainable design different from green product sustainable design is "early in the design of education". It emphasizes understanding of the production

¹Acknowledgement - This work is financially supported by The Industry-Academia cooperation project of Fujian Province(No. 2017H6018), The Project of Special funds for modern marine fisheries of Ningde City(No.201611), The Cooperative innovation center of intelligent manufacturing of mechanical and electrical equipment between Fujian and Taiwan, Ningde Normal University(No. 2015Z03) and The Research and innovation team for intelligent design and manufacturing of mechanical and electrical products, Ningde Normal University (No.2015T07).

²Workshop 1 - Overseas Chinese University, Taiwan

³Workshop 2 - Ningde Normal University, Fujian, China

⁴Workshop 3 - Hsiuping University of Science and Technology, Taiwan

⁵Corresponding author: Huicun Shen

designer of products used, the use of the material properties of the various stages and the production process of the problems faced in order to improve the product in the production process defect rate.

Key words. Low carbon society, product service system (PSS), sustainable design.

1. Introduction and Purpose

As environmental awareness grows, given the proliferation of the concept of the pursuit of sustainable development, international set off a wave of "sustainable design", follow the trend of this stock of environmental protection, in product design and development company, began to focus on reducing the product production, use and after use may cause environmental impact, and focus on the recovery efficiency of various goods and re-use. Therefore, the "product service systems" (product service system; PSS) to sustainable design and development of products it can offer, extending the concept to the level of service, in-depth study products and services, consumer demand and the relationship between marketing management, it If products and services will find that as a whole, to meet consumer demand for products and services portfolio to provide utility companies a way to replace the tangible products, will be more conducive to sustainable development.

In this study the concept into its policy framework on sustainable product design, and from the perspective of sustainable design, including design specifications and the main development process, through the development of design specifications with designers for the future of green products based on the development process was designed to engineer the future manufacturing steps to follow. To achieve these objectives, this study developed the following specific purposes of the study, were described as follows:

Analysis of low-carbon society and sustainable product design, product service systems products and services systems and low-carbon standard, and the establishment of sustainable product design and development base for development.

Analysis of low-carbon standard developed under the sustainable product service systems product design criteria, and the development of sustainable product design assessment check lists and sustainable product design and development process.

2. Research Methods and Procedures

2.1. Research structure

The research framework shown in Figure 1, each of the steps described below will be

1. Method through literature review and summarize the information analyzed, and interviews and surveys by experts, a clearer understanding of low-carbon society under the product life cycle, product service systems theoretical frame-

work, and sustainable product design specifications and sustainable product design and development patterns

2. Using rooted theory analysis of low-carbon products and services under standardized system design criteria for sustainable products, while the development of sustainable product design assessment checklists and sustainable product design and development process.
3. Finally, the case will be ASUS Tablet PC to verify the way the system construction of sustainable low-carbon society products and services product service systems product design product design strategy of sustainable modes.

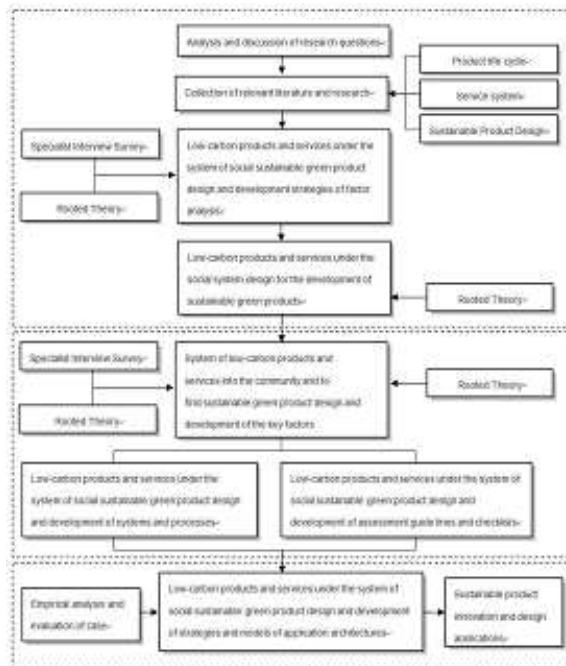


Fig. 1. Research Process

2.2. Research Object

This study focused on a green background and practical experience of experts to interview, to the design and development process as the main, to understand the different areas of professional experts to provide insights and recommendations. To explore in depth along with the low-carbon society and a sustainable product service systems design.

2.3. Data analysis methods

In this study, rooted theory, analysis and discussion of the low-carbon products and services under the social system of sustainable green product life cycle design of products, and as a low-carbon products and services under the social system of the green product design sustainable research base.

3. Research and Analysis

3.1. Analysis of interview topics

The study interviewed a green background and practical experience of five experts, will be obtained from interviews conducted research and analysis, and make links to new product development process. From the interview, after the low-carbon society, products and services systems, sustainable design decoding analysis, the concept of all the principles to organize, to be "sustainable product design criteria," "sustainable product design process," "sustainability product development process", "sustainable Product checklist "to raise four major areas.

3.2. Analysis of expert interviews

In this study, five experts interviewed in "sustainable product checklist analysis", the archive out: "material", "process", "assembly", "Use", "demolition", "recycle" six major areas the edge.

Analysis found that the main focus on sustainable design education, materials, processes and recovery phase, interviews of sustainable products covered by the checklist of issues and factors are described as follows.

Material : Application materials for product design is an important part of stress at the design stage before the material must be used for doing in-depth understanding of their characteristics and discussion, In addition to operating companies and manufacturers point of view, will be taking into consideration the amount of material and cost considerations, from a designer's point of view, the majority of the users towards the product and lease purchase of products in the very attitude a big difference,Therefore, the user's state of mind will be the key material to use.

Process : Products during the manufacturing stage, in addition to sustainable design used in the manufacturing process of the steps and materials used in manufacturing processes effects, defective products to reduce the production has become the focus of much attention. Machinery used in manufacturing process equipment, enterprise system change will affect the manufacturing process steps and sequence, correct or amend the reform of enterprises can reduce not only manpower, but also can reduce energy consumption and carbon emissions.

Assembly : Products in the assembly, when, if the assembly efficiency, reduce labor costs,

In the assembly process, all parts are fool-proof device, or install simplified resistance, so that operators in the assembly of products to reduce the failure rate and the production of defective products, Easy assembly can be assembled to consumers in their own steps. Quickly assemble the right products can also reduce the production of defective products. Unified standardized parts, the structural design of the product itself, the appropriate guidelines for manual assembly allows the user more convenient products.

Use : In the use stage and design stage, designers should use the product when the user happens to do analysis and discussion of the situation, reducing the user in the use of phase errors that occur or injury, through the use of the product approach, so the use of this product lengthen the life cycle stages, reducing the failure rate, and reduce the user the opportunity to re-purchase related products.

Demolition : Demolition products, pay attention to whether there is damage to the product itself, beware of products have the edge to avoid sharp corners hurt Demolition should be a operating manual.

Recycle : Promote the concept of sustainable design, recycling is the basic appeal, Sustainable design philosophy emphasizes the recovered material can be used repeatedly, In which case the material in the product, the use of previous generations of products will be recycled after use in 30% -40% for the next generation of products, Premise is that previous generations of products enclosure does not have other processing, must maintain the integrity of the plastic, cannot have printing.

4. LC-PSS Design Specifications Tablet PC

Product life cycle impact assessment and pollution hazards will be the product of Design.

ASUS Tablet PC to do the verification for this case study objects, hoping to bring low-carbon society is the product, through product service system design, promote Taiwan's electronics industry to implement sustainable green product design.

In this study, grounded theory analysis through interviews with five experts, by analysis of the results obtained the following LC-PSS sustainable green product design specifications.

Table 1. LC-PSS Sustainable green product design specification

Product life cycle	Green product design specification
Educational and re-research	<p>In the design of products, designed to assess the environmental impact of products.</p> <p>For the design of the product has in-depth understanding.</p> <p>Understanding of the overall product design and development process, and simplify the work of projects to reduce unnecessary energy consumption.</p> <p>From the planning stage of analysis to understand the relevant information, reducing the problem of the product.</p>
Material selection	<p>Raw material / materials made whether to adopt the way of the supply base of raw materials recently.</p> <p>Raw materials with the need to correct.</p> <p>According to material properties, select the appropriate product use of the material.</p> <p>Materials used in the mining, manufacturing, use and waste recycling at all stages of environmental impact to a minimum to decide.</p> <p>Avoid the use of toxic and harmful ingredients of raw materials.</p> <p>For use of hazardous substances should be easily identified and removed.</p> <p>Make use of recyclable, recycled materials, biodegradable materials to reduce material consumption and reduce environmental impact.</p> <p>Use of simple materials, and to prevent mixing of different materials used, such as synthetic plastics: plastic paper, stone paper.</p> <p>Reducing material attached labels, decoration and secondary processing.</p> <p>Reduce the handling of chemical materials to do, such as paint, coated, coating, plating, etc.</p> <p>Recovered materials used can be used to provide relevant products, such as recycling of raw materials available after the second and third generation products to use.</p> <p>All parts should be marked with material</p> <p>Note the characteristics of materials and conditions.</p> <p>Characteristics of the materials used are compatible.</p> <p>Multi-use latch design to reduce the use of screws.</p> <p>For the demolition of part of the adjacent parts, and use of compatible materials.</p>
Mechanism Design	<p>Avoid disposable lost design.</p> <p>The use of product properties of the materials to do mechanical design to minimize the use of spare parts.</p> <p>Using the same material as the material product, to facilitate ease of recycling.</p> <p>Minimize the volume.</p> <p>Parts as a single, too complex to reduce the types of parts.</p> <p>Use the same parts, can be extended to a number of recovered product.</p> <p>Material structure simplification, reducing material usage and total weight of the product</p> <p>With dismemberment design for easy removal combination.</p> <p>With easy to replace parts of the structure.</p> <p>Note whether the assembly or disassembly process, due to poor design is responsible for personal injury caused by</p> <p>Minimize assembly and disassembly steps to facilitate the recovery of future product waste after</p> <p>Increase the structural strength</p> <p>Ensure the maintenance of clean and convenient.</p> <p>Improve people's attitude towards the use of the product.</p>
Manufacturing process	<p>In the space used to make the most effective equipment furnishings</p> <p>The use of equipment in accordance with the production of the product purchase patterns can provide the performance of the equipment</p> <p>Select County materials processing.</p> <p>Manufacturing process to reduce waste generation.</p> <p>Maximize the use of natural energy in manufacturing</p> <p>Reduce the manufacturing process waste water, waste, toxic waste emissions and reduce noise</p> <p>Complete set of pollution treatment facilities.</p> <p>Avoid damage to the ozone layer, to make use of the cleaning process to replace CFCs</p>

5. LC-PSS Sustainable Green Product Design Checklist

Through expert interviews to do rooted theory analysis of the results, expert interviews and literature review into the LC-PSS green products do sustainable design checklist??The purpose of 3C industries and low-carbon type of lease can be in accordance with the Tablet PC LC-PSS criteria for green products, sustainable design checklist that. By rigorous vetting process to ensure low-carbon and the type of tablet production lease. The Checklist for this study's focus and purpose of the work.

Checklist is mainly based on the various stages of product life cycle design criteria for the product to do the standard checklist. Checklist for the sake of strict and specific, listed rating scale, to check the supply designers to quickly identify this product's weaknesses in environmental protection and the need to improve.

Table 2 LC-PSS Tablet PC sustainable green product design checklist of preparation, to view the LC-PSS used in Tablet PC sustainable green product design strategy presented in the effectiveness of green design, and then to suggest ways to LC-PSS sustainable green product design evaluation and revision, to ensure the implementation of sustainable design business.

Table 2. LC-PSS Tablet PC sustainable green product design checklist.

Life Cycle		Program Assessment	Score				Remarks
			Excellent	Standard	Improve		
Material identification of material		Are the materials of production components easy to be recognized?					
		Are recycle materials easy to be recognized?					
		Are hazardous substance or components easy to be recognized?					
		Are plastic components conformed the evaluation of environment criterion?					
Material reduction		Could it decrease the components size in design Process?					
		If using the alternative products which have tiny volume ,it could be operated in normal?					
		Can some of components decrease the whole volume?					
		Can the decreasing material use by developing technology method ?					
Material sources		Does it use materials in unity?					
		Is it not necessary to the material use attached in plastic?					
		Does it use the rare or hard-to-obtain materials?					
		Does it use the least original materials in extraction?					
Materials recycling		Are the material sources in the manufacturing center nearby?					
		Does supplier take the pollution control measures in material extraction process .					
		Is it have conflict between ecological preservation and material usage?					
		Does material supplier have already adopted good environmental management process?					
Material risks		Is the material recyclable?					
		Is The components made of recyclable material?					
		Does the producation have high recycling-ratio?					
		Can recycle materials decrease the energy consuming.					
Manufacturing process risk		Does it have the Potential endanger risk of human health in the components materials?					
		Is it under control to the hazardous substances which be produced in material extraction process ?					
		Is there a particular equipment could rescue the material sliding accident ?					
Manufacturing program		Whether it decrease the poison release in production?					
		Does it have the meacure equipment to control the hazardous substances?					
		Does it consideration for the environment controlling in production process?					

6. LC-PSS Tablet PC Design Sustainable Green Product Design Process

LC-PSS Tablet PC sustainable green product design major emphasis in the implementation planning process prior to data collection, through product demand, market research, consumer advice and environmental assessments as the basis for Planning, make the new product type Tablet PC. LC-PSS Tablet PC design architecture sustainable green products will mainly flow chart tablet design principles in the literature and expert interviews to do integration of grounded theory analysis, the flow chart for the description of the design phase to provide the relevant company's future in the implementation of LC-PSS plate sustainable design, green product computer, tablet PC for LC-PSS sustainable green products have a basic understanding of the design process and understanding.

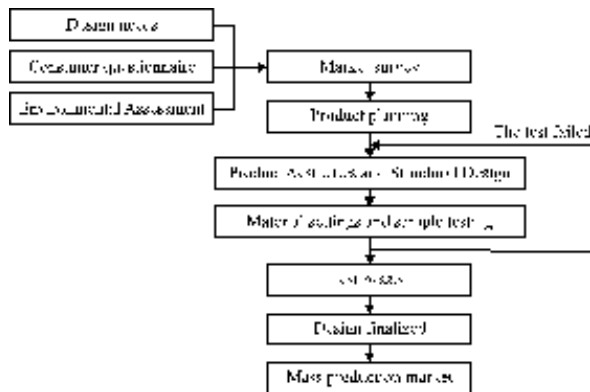


Fig. 2. LC-PSS Tablet PC Design Sustainable Green Product Design Process

7. Conclusion

Finally, this study will be pre-design phase of education for LC-PSS the importance of sustainable design green products, LC-PSS application of design methods in product design, professional recovery platform for the establishment and the government to help promote LC-PSS design sustainable green products for the four points. The following points illustrate.

1. Pre-design phase of education for LC-PSS importance of sustainable design green products: In the production stage, in addition to enterprises should have a good understanding of this specification, the project manager or designer in the design of the product before should have relevant expertise, and for follow-up process should be basic knowledge, the main reason for the decrease in the design and production process product defect rate.
2. LC-PSS application of design methods in product design: Users of the leased products purchased will be compared to their less treasure, so the designers

in the design of products, should consider the effects of PSS new lifestyle, to extend the product life cycle. The LC-PSS sustainable green product design, in the design of PSS for additional tracking system presented in a way, mainly in the product itself does not affect the principle.

3. The establishment of professional recycling platform: Recovery phases of a good recovery system and recycled by a professional platform for the implementation of green products in the LC-PSS sustainable design components under standardized products that do the recycling of demolition and rapid assessment of the professional use of parts, an indirect continuation of the zero components of the life cycle, and can be used to re-lease or after the product charity.
4. LC-PSS government to help promote sustainable design green products: Most consumers use second-hand product acceptance is not high, to be assisted by the government, or by major companies taking the lead, indirectly affect consumers in the selection of future use of the product used.

References

- [1] T. M. WARING, S. H. GOFF, P. E. SMALDINO: *The coevolution of economic institutions and sustainable consumption via cultural group selection*. *Ecological Economics* 131 (2017) 524–532.
- [2] B. COHEN, . MUÑOZ: *Sharing cities and sustainable consumption and production: towards an integrated framework*. *Journal of Cleaner Production* 134 (2016), No. 3, 87–97.
- [3] B. HANSE, E. E. M. RAAIJMAKERS, A. H. L. SCHOONE, P. M. S. V. OORSCHOT: *Stemphylium sp., the cause of yellow leaf spot disease in sugar beet (Beta vulgaris L.) in the Netherlands*. *European Journal of Plant Pathology* 142 (2015), No. 2, 319–330.
- [4] CARROLL, B. ARCHIE: *A Three-Dimensional Conceptual Model of Corporate Social Performance*. *Academy of Management Review* 4 (1979), No. 4, 497–505.
- [5] D. BROWN: *INDUSTRY INSIGHT It is good to be green environmentally friendly credentials are influencing business outsourcing decisions*. *Strategic Outsourcing: An International Journal* 1 (2008), No. 1, 87–95.
- [6] X. HAN: *The pricing of product and value-added service under information asymmetry: a product life cycle perspective*. *International Journal of Production Research* 53 (2015), No. 1, 25–40.
- [7] M. FREEDMAN, B. JAGGI: *An Analysis of the Impact of Corporate Pollution Disclosures Included in Annual Financial Statements on Investors' Decisions*. *Advances in Public Interest Accounting* 1 (1986) 193–212.
- [8] B. G. GLASER, J. HOLTON: *The Discovery of Grounded Theory*. *Strategies for Qualitative Research* 3 (1967), No. 6, 377–380.
- [9] MONT, OKSANA: *Clarifying the concept of product–service system*. *Journal of Cleaner Production* 10 (2002), No. 3, 237–245.
- [10] O. MONT: *Product service systems: panacea or myth*. Vdm Verlag Dr M Usa (2008).
- [11] A. STRAUSS: *Qualitative analysis for social scientists*. Cambridge: Cambridge University Press (1987).
- [12] H. FUKUDA: *Patient-related risk factors for surgical site infection following eight types of gastrointestinal surgery*. *Journal of Hospital Infection* 93 (2016), No. 4, 347.

- [13] S. ALVAREZ, M. SOSA, A. RUBIO: *Product and corporate carbon footprint using the compound method based on financial accounts*. The case of Osorio wind farms. *Applied Energy* 139 (2015), No. 139, 196–204.

Received November 16, 2017

