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# Application review of LCA (Life Cycle Assessment) in circular economy: From the perspective of PSS (Product Service System)

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**Abstract**

At present, the enormous environmental pressure caused by the manufacturing industry has promoted the development of the recycling industry. The recycling industry is pivotal for sustainable utilization of regional resources, pollution reduction and environmental protection. LCA (Life Cycle Assessment), as a comprehensive analytical tool, plays an important role in the analysis of the cyclical industry from different levels, including regional level, industry level, enterprise level and product/service levels. The product service system, a new production system with high integration and overall optimization of products and services, is conducive to obtaining complete product/service information and management. The LCA based product service systems in the field of circular economy is not only crucial in the life cycle management of the product/service for the enterprise, but also contributes to the comprehensive assessment of the environmental benefits of the recycling enterprise. This paper summarizes and systematic reviews the applications of the LCA and PSS (Product Service System) integration in circular economy from a micro perspective. Based on that, the study identifies the challenges for current researches and propose future research directions to promote the development of LCA in circular economy from the perspective of enterprises.


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*Keywords:* LCA (Life Cycle Assessment); circular economy; PSS (Product Service System); recycling, enterprises

## 1. Introduction

At present, the overall deterioration of the ecological environment has not been fundamentally reversed, and the environmental pollution situation is becoming increasingly serious. The water, the atmospheric and the pollution of solid waste is becoming increasingly prominent. Besides, the rate of harmless treatment of municipal solid waste is low, and the rural environmental problems are serious. At the same time, from the perspective of manufacturing industry, the cost of products is mostly constrained by resource endowment, but the efficiency of resource utilization is not high enough. Therefore, the development of circular economy is conducive to not only alleviating environmental pollution, but also alleviating resource constraints, improving the economic efficiency of the industry.

As an effective environmental management tool, life cycle assessment has broad application prospects in circular economy. LCA (Life Cycle Assessment) is considered as one of the important tools of environmental impact assessment. However, theoretically, there is a lot of work to be done on the research on the application of life cycle assessment in circular economy. From the application of LCA in the field of circular economy, most of the current research on LCA focuses on the macro-regional level and part of the meso-industrial level, while most of the research on micro-enterprises is based on the analysis of a specific production process, rather than the whole enterprise. Besides, most of these studies are case studies. The representativeness of these studies and their

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contribution to application and promotion are still unclear, and there is a lack of a more general analytical framework. This is because the LCA evaluation for enterprises needs many different types of data integration, and the current data integration is mostly manual operation, so it faces the problem of time-consuming growth and high cost. Therefore, it is very important to combine LCA with PSS. This is not only conducive to promoting enterprise environmental impact control and management, but also conducive to promoting the development of circular economy from the source, because construction, manufacturing and other industrial enterprises are still the biggest source of environmental pollution.

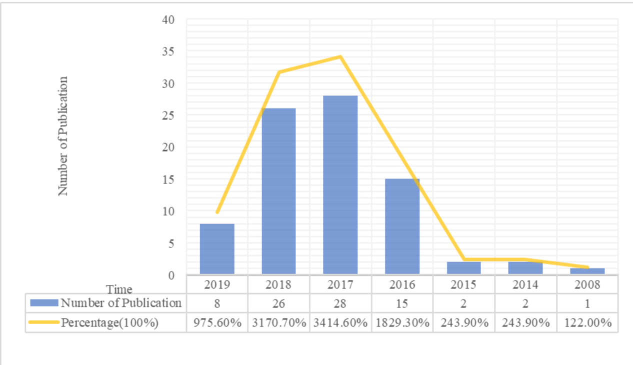


Fig. 1. statistic results of the integration of LCA and PSS related researches.

According to Fig.1, the research on integration of LCA and PSS has been increasing since 2014 and has been growing rapidly in 2016 and 2017 (The bland marked by X means there is at least one related research on this issue). This shows that the integration of LCA and PSS has attracted more and more attention. On the other hand, the rapid growth of LCA and PSS in a short time and the relatively small number of literatures mean that there are still many problems to be solved in this field.

This paper summarizes the existing literature in integrating environmental analysis methods with PSS in the context of LCA and other circular economy, from the perspective of integrated methods/frameworks and major application industries. Based on the summary, the gap in the field of environmental assessment and PSS is put forward. Based on this, this paper puts forward the potential direction of future research from the perspective of research industry and method to promote the combination of LCA and PSS and realize the transition from theory to application.

The contributions of this paper are mainly reflected in the following three aspects. Firstly, the current review of methods is generally general, mainly aiming at the application goals and significance of environmental impact assessment in PSS environment, lacking analysis and summary of how to realize data integration of LCA and PSS and the technical problems of replacing manual operation with automated models. Although there is not much research in this area, this paper introduces the integration method into the review. This is mainly because the method research is the key link to realize the integration of LCA and PSS into application.

Secondly, the current applications of LCA in PSS system seldom summarize specific cases, such as classification and comparative analysis of cases based on different industries. This is mainly because the current research for different industries is mostly specific case analysis, lack of systematic framework. Besides, there are some differences in the specific process of LCA application in different industries. This paper tries to find out the characteristics and commonalities of LCA application in PSS systems of different industries from these cases and to provide some theoretical support for the realization of LCA-PSS data integration and dynamic environmental impact analysis.

Thirdly, this paper adds the application review of PSS in the general circular economy environment. Although some of the environmental impact assessment methods used in these studies are not LCA, these methods are conducive to a more comprehensive understanding of the needs of environmental impact assessment in PSS system and the assessment scope that can be provided. Thus, the goal of combining LCA with PSS could be made clearer. Moreover, these methods and frameworks of integration with PSS are helpful to provide some enlightenment for the related research on the combination of LCA and PSS.

The following parts of this paper are as follows. The second part mainly introduces the methodologies of the integration of LCA and PSS. The third part classifies and compares current applications of LCA in PSS according to the research industry. The fourth part summarizes the application of PSS in other circular economy. The fifth part is the summary and future research direction.

## 2. The methodology of the integration of LCA and PSS

Current research on integrating LCA into PSS can be divided into three main categories according to different purposes. They are the development of evaluation models and platforms for LCA in PSS (Santana et al, 2010), the construction of models for specific products, services or processes in specific PSS, and the evaluation of the effectiveness of current LCA in PSS applications. Integrated comparative analysis. The current main researches on methodology of the integration of LCA and PSS in Fig.2.

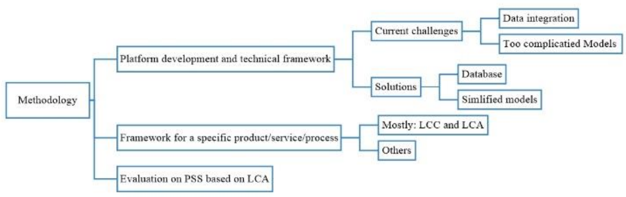


Fig. 2. researches on methodology of the integration of LCA and PSS.

From the perspective of model framework and platform development, Glatt et al (2019) believes that technology product service system composed of life cycle-oriented service enhancement technology products not only has economic advantages, but also has a positive impact on ecological sustainability. The complex structure of PSS challenges the quantification of various aspects of ecological sustainability (Doualle et al, 2014). Therefore, more targeted methods, such as Cumulative Energy Demand (CED) and

Eco-cost/Value Ratio (Vogtlander et al, 2002), have greater practical applicability than more comprehensive methods, such as Life Cycle Assessment (LCA). As an estimation of LCA, CED reduces the difficulty of data collection and the complexity of the model. Dal Lago et al (2017) believes that LCA evaluation in PSS framework is mostly evaluation of physical products but lacks guidelines for the form of conceptual framework supporting PSS life cycle assessment, especially for practitioners and platform and system developers, which can overcome the challenges faced in developing LCA in PSS. Corti et al (2016) proposes that current LCA tools are mainly product oriented, so solutions that can easily integrate service components are needed. Based on this, a reference architecture for LCI implementation is proposed, which considers how service and product information can be integrated and how to collect data needed for life cycle assessment. The architecture is as general as possible and can be used for any type of PSS. Pialot et al (2014) proposes a product-based scalable ecological innovation system that includes LCA and other methods to promote remanufacturing, PSS and longer product life.

From the perspective of building evaluation models for specific products, services and processes, most of the current studies are framework studies for product services in different industries (Xing et al, 2013; Vezzoli, Sciama, 2006). Zhang et al (2018) built an evaluation tool based on the combination of life cycle assessment (LCA) and life cost calculation (LCC) to support the development of high energy-consuming equipment (HECE) sustainable model. Fargnoli et al (2018) evaluates the market demand and customer demand model of medical devices based on quality function deployment (QFD) through life cycle modeling, which includes life cycle assessment (LCA) and life cost calculation (LCC). Pragoropoulos et al. (2017) constructed two LCC-based evaluation models to assess the impact of cost-benefit analysis on shipping industry service strategy formulation. Allais and Gpbet (2016) based on the concepts and tools of social sciences and environmental engineering sciences, constructed a sustainable business model assessment method for social and environmental change. This model not only considers the life cycle assessment of products, but also includes the cooperation among stakeholders and the use process of products/services by consumers. Costa et al (2015) developed product-oriented PSS and use-oriented PSS for furniture recycling, which can be used by enterprises to develop new products according to local conditions.

Zhang et al (2018) considers that the development of PSS may not always be a sustainable practice based on the analysis of the application conditions of different PSS modes from the point of view of the effectiveness evaluation of current LCA applications in PSS. Similarly, Kjaer et al (2016) put forward a similar view that PSS has the potential to reduce environmental impact, but the environmental benefits of PSS need to be quantified and put forward specific challenges to quantify environmental benefits. On this basis, Kjaer et al (2018) proposed an LCA process related to the specific consideration of PSS evaluation, and proved that the guidelines can significantly reduce the error of evaluation results based on case analysis.

Overall, the current research methods on LCA and PSS mainly focus on system development, especially on the framework construction of evaluation system (Amaya et al, 2014) and model construction and application for specific products. However, there are few studies on the evaluation of application effect of integrated evaluation system of LCA and PSS. This is mainly due to the scattered application fields of current research, the lack of a relatively uniform standard and comparable cases to compare and evaluate methods. In addition, the current research on methods and system development is mainly based on the framework. Few literatures have designed the technical implementation process of LCA integration in PSS system, which means that the data of LCA based on PSS is still mainly manual operation. Therefore, it can be considered that the current research still belongs to the category of static evaluation model, and there is still a long way to go to realize LCA evaluation in real-time PSS system. Therefore, this paper holds that the realization of data integration of PSS and LCA at the technical level is an important way for the future application of LCA in PSS system, and then to promote the development of circular economy in various industries. On this basis, the evaluation of integration schemes of LCA and PSS is more pertinent and instructive.

## 3. The Applications of LCA in PSS

At present, there are few articles about the application of LCA in PSS system for case analysis, and the scope involved is large. It is difficult to compare and analyze these cases. Overall, these applications can be summarized as life cycle analysis for products, life cycle management for a service or process, and life cycle assessment for the overall business model of an enterprise (Sakao et al, 2017). The current main researches on applications of LCA in PSS in Fig.3.

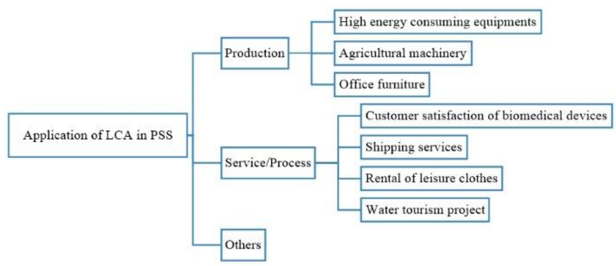


Fig. 3. Researches on application of LCA in PSS.

The life cycle analysis of products mainly includes mechanical manufacturing, energy (Alstone et al, 2014) and waste recycling. The main research is mechanical manufacturing. In the field of mechanical manufacturing, Zhang et al (2018) focuses on manufacturing high energy-consuming equipment and life cycle management. The results show that the additional economic benefits of manufacturer and customer are related to the increase of investment, environmental burden and risk. Therefore, not all PSS have environmental benefits in the field of high energy-consuming equipment industry. Similar conclusions also exist in the analysis of agricultural machinery. Glatt et al (2019) believes that technological products account for a large proportion of Cumulative Energy Demand (CED) in PSS system. That is, product technology is still the main factor of environmental pollution. Costa et al (2015) takes office furniture design and manufacturing company as an example to discuss the application of LCA in furniture recycling and remanufacturing of PSS from the economic, environmental and social perspectives. Lelah et al (2014) proposed an enhanced PSS for waste glass recycling and demonstrated that this system is conducive to reducing environmental impact.

Life cycle management for a service or process mainly includes decision support analysis for a specific method and process in developing PSS, comparative study of multiple schemes, etc. (Lindahl et al, 2014). In the field of biomedical equipment manufacturing, according to Fargnoli et al. (2018) research conclusions, market demand and customer demand analysis based on Quality Function Development (QFD) has obvious advantages in the development of sustainable PSS solutions. This advantage is mainly reflected in the improvement of customer satisfaction, the alleviation of environmental problems and the reduction of costs. However, Glatt et al. (2019) based on part of the LCA assessment, concludes that services for agricultural machinery have less impact on the environment and sustainability. However, some specially involved services may have a positive impact on the environment. The impact of this specially designed service is described as the energy leverage effect of the service. In shipping services, although PSS may reduce the cost of life cycle, the use of PSS may also lead to the complication of service strategy formulation (Pragoropoulos et al, 2017). Therefore, PSS in shipping service industry is not necessary. However, in the process of household appliances rental service, the use and promotion of PSS has shown a significant positive role (Allais and Gpbet, 2016). Similar conclusions also exist in the business model of leisure clothing rental (Piontek, Mueller, 2018) and the design scheme of water tourism (Scheepens et al, 2016).

Additionally, since few people can imagine and develop a vision of how the future sustainable product and service system will reflect, some studies have focused on the application of LCA to PSS at the enterprise level. Sinclair et al (2018) proposed the concept of consumer intervention mapping and used it as a tool to create future product strategies. By modeling and visualizing the impact of stakeholders in the product life cycle, a scenario describing existing product service systems and new product concepts adapted to circular economy is successfully created.

Because the main principles of circular economy include reduce, reuse and recycle, the current application of LCA in PSS system mostly concentrates on the initial production stage, that is, trying to solve the problem of reduce, but not enough attention has been paid to the two principles of reuse and recycle. This leads to the current research on LCA in PSS mostly focused on a manufacturing process, and less on waste management. This is also one of the research directions of LCA in PSS application in the future.

At the same time, because of the complexity of the analyzed system in each stage of the life cycle, it is not scientific to simplify the results of LCA into a single comprehensive score or number. At the same time, LCA evaluation needs a large number of parameters and production data from enterprises. Therefore, some indicators in LCA are selected as the criteria for environmental impact assessment. It should be noted that in the process of building this simplified model, attention should be paid to whether the neglected evaluation indicators will have a greater impact on the evaluation results, thus affecting the accuracy of the evaluation results. In order to ensure the accuracy, practicability and operability of life cycle assessment, the implementers of enterprise evaluation should timely modify its purpose and scope according to the principles and framework of life cycle assessment and specific application intentions.

## 4. Applications of PSS in circular economy

At present, the research on circular economy and sustainable development of ecological innovation can be divided into four perspectives: green and sustainable product development, business model or supply chain integration, green marketing and sustainable consumption, and hybrid model construction and optimization (Kuro, Smith, 2018). At present, there are more studies on green and sustainable development, less on hybrid model construction and optimization, and more theoretical studies, while less empirical support. The research on business model or supply chain integration and sustainable consumption is growing rapidly, although it started late. This shift from ownership to development, application and evaluation of business models based on consumption and innovation is the main research content of PSS in circular economy (Cherry, Pidgeon, 2018). Traditionally, when a product is sold, it is difficult for an enterprise to track what the user has done to the product. However, the behavior of key users has a great impact on the use and recycling of products (Wastling et al, 2018). In fact, besides product design itself, service also affects user behavior. Modeling and analyzing consumer behavior to analyze the obstacles and solutions of current PSS application in circular economy is an important part of current PSS research in the field of circular economy. The current main researches on applications of PSS in circular economy is in Fig.4.

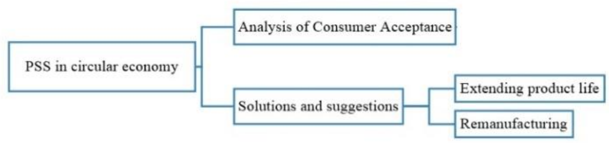


Fig. 4. main researches on applications of PSS in circular economy.

Consumer acceptance of the new business model of circular economy represented by PSS requires a certain process, in which they will encounter some problems (Camacho-Otero et al, 2017). If these problems cannot be handled properly, the development of PSS in the field of circular economy will encounter bottlenecks (Lieder et al, 2017). To this end, some scholars have carried out relevant research, including the electronics manufacturing industry (Hobson et al, 2018; Gnoni et al, 2017), horse industry (Nasiri et al, 2018), household appliances manufacturing industry (Lieder et al, 2018; Sousa-Zomer et al, 2017; Gnoni et al, 2017), clothing industry (Stal, Jansson, 2017; Raebild, Bang, 2017), Internet of Things services (Alayaga, Hansen, 2017) and so on. At present, some specific circular economy service industries, such as the shared economy (Ameli, 2017), have been practiced in many regions. Barbu et al (2018) analyzed the impact mechanism of shared economy on consumer behavior. This study has a certain reference significance for the analysis of consumer acceptance of the new circular economy business model. Similarly, Lunascu and Lonascu (2018) analyzed the green business model behavior of Romanian companies represented by leasing, believing that leasing is conducive to improving corporate performance. Chamberlin and Boks (2018) analyzed the behavioral barriers and incentives for consumers to accept the new business model of circular economy represented by PSS. Based on the analysis of communication networks of four recycling products and services retailers, the author believes that design framework can provide more powerful support for the analysis of marketing strategies than green marketing. Lin (2016) studied recycling economy of glass industry in Taiwan to strengthen recycling incentives in recycling economy. Due to the insufficient understanding of market demand of various glass recycling products by manufacturers, product design and user barriers of glass remanufacturing from different sources are caused. This study provides decision-making information for intelligent production by identifying key user characteristics. Schallehn et al (2019) analyzed the customer experience of the product service system related to second-hand products, believed that there were still many deficiencies in the current PSS system used in the recycling industry, and emphasized the necessity of information and communication technology in the PSS system. The application of PSS in circular economy in different industries and ranges is shown in Table 1.

Table 1. Application of PSS in circular economy in different industries and ranges.

| | Reducing | Reusing | Recycling |
|---|---|---|---|
| Horse industry | | | X |
| Glass industry | | | X |
| Appliance industry | X | X | |
| Electronics industry | X | X | |
| Garment Industry | | X | X |

Note: The bland marked by X means there is at least one related research on this issue.

According to Table 1, the current research covers a wide range of areas, and there are still some gaps in many areas that need to be supplemented by further research. It should be noted that not all product and service systems are conducive to reducing environmental impacts. Some new service behaviors and corresponding product and service systems due to social and economic development consume more resources than traditional methods (Linder, Williander, 2017). Retamal and Schandl (2018) analyzed three laundry behaviors in Manila, Philippines, including hand washing, home washing machine and laundry service, and proposed the trend of excessive laundry behavior to product service system. However, this trend does not have an environmental impact. Conversely, the shift from hand washing to laundry is more energy-intensive.

Therefore, how to design PSS is very important (Pieroni et al, 2017). Researchers have put forward solutions for the application and promotion of PSS in circular economy (Blomsma et al, 2018; Yang et al, 2018; Pialot et al, 2017) from different perspectives, though the scope of application of these solutions is relatively small and mostly framework rather than a mature system. However, it still provides some ideas for the promotion of PSS in circular economy and hints the future research direction. Khan et al (2018) summarizes the application of upgradable product service system in circular economy from the perspective of prolonging product life. The results show that the strategy of product life extension has great potential, especially in the mid-life management under PSS environment. At the same time, product scalability promotes the widespread use of recycling economy (Bridgens, Lilley, 2017), PSS and remanufacturing (Moreno et al, 2017). However, the existing research is still in the theoretical aspect, and more case studies and empirical studies are needed to determine the concept of upgradable PSS (Ackermann et al, 2018). In terms of system development, some scholars believe that it is necessary to plan products and services at the design stage (De Los Rios et al, 2017). Chen (2018) put forward the theoretical guidance for developing sustainable product services in the early planning stage and illustrated the calculation steps based on a case. Remero and Rossi (2017) proposed a circular lean product service system for creating customer-oriented circular economy solutions.

According to the existing literature, the research of PSS in circular economy and circular industry mainly focuses on the analysis of potential problems in development, theoretical elaboration of possible solutions and case analysis. The case analysis is mostly about the framework construction of environmental assessment module in PSS, while the research on the technology module construction of the application of PSS in circular economy is rare. In addition, there are fewer examples of the application of PSS system in circular economy. This paper holds that there are two main reasons for this phenomenon. On one hand, although circular economy is not a very new issue in academia, while circular economy is still in the trial stage in many industries, and there is no standardized and flow-based management model. Therefore, there is few development and analysis of relevant PSS systems. On the other hand, recycling economy poses new challenges to the assessment and management of PSS system in terms of environment and sustainability. The diversity of environmental assessment methods, the complexity of models, the difficulty of data acquisition and the technical barriers of data integration lead to the lack of environmental assessment module in PSS which can fully realize real-time dynamic assessment.

Therefore, this paper holds that the future research directions are mainly reflected in two aspects. From the perspective of industrial development, some specific problems in the development of circular industry should be solved, such as participating in the evaluation and management process of circular economy for some specific industries and processes and evaluating the model effect of circular economy in PSS system. From the technical point of view of the development of PSS system, future research mainly needs to solve the problem of data integration, targeted model construction and simplification, so that the PSS including environmental assessment can be used in the circular economy industry.

## 5. Concluding remarks

This paper reviews the current research on LCA integrated PSS in circular economy from the perspectives of methods and industries. At the same time, the applications of PSS system in circular economy is summarized, promoting a more comprehensive understanding of the application of LCA in PSS system and making the goal of combining LCA with PSS clearer. Moreover, these methods and frameworks of integration with PSS helps to provide some enlightenment for the related research on the combination of LCA and PSS.

LCA is a specific product analysis, and the production processes and products between enterprises in the same industry are still quite different. Moreover, data collection and import at present rely on manual operation, LCA evaluation of many products requires a lot of time and cost. Therefore, this paper argues that attention should be paid on the balance of flexibility and comparability of LCA analysis in PSS, considering more about timeliness. Specifically, the potential research directions, challenges and possible solutions for the future integration of LCA and PSS in the field of circular economy are as follows.

Firstly, in terms of data integration of LCA and PSS, LCA analysis has the characteristics of timeliness. For example, most of the environmental costs of a product have been determined at the design stage of the product, and the improvement at the later stage of product development can only play a very limited role, so the ideal time to carry out life cycle assessment is at the early design stage of the product. However, in the early stage of product design, product characteristics are often uncertain - raw materials may not be selected, and production equipment and packaging methods have not yet been finalized, so that a LCA cannot be completed in the most needed evaluation. However, because the current LCA relies on manual importation of data, it is possible to miss the best evaluation opportunity even if it consumes a lot of time and cost. Therefore, this paper argues that from the perspective of methodology, the establishment of a dynamic LCA analysis module in a data integration-based PSS system is one of the future research directions. To achieve data integration, on the one hand, some technical support for data platform construction is needed. On the other hand, a comprehensive understanding of the technology and related parameters of LCA products is necessary in a certain industry.

The second challenge is in the construction of LCA model applied to PSS. For the builder of LCA module, more attention should be paid to the universality of the application of LCA system in the same type of enterprises. The information obtained by LCA research can only be applied as part of a far more comprehensive decision-making process, or to understand widespread or general trade-offs and compromises. For different LCA studies, it is possible to compare their results only when their assumptions and background conditions are the same. Therefore, this paper argues that in the process of model building in LCA and PSS analysis modules, research methods should be standardized, such as using internationally recognized data units to conduct qualitative and quantitative research on the environmental impact of the system. This is not only conducive to the progress of research work, but also more conducive to timely and effective application of research results, ensuring the value of research work itself, and will also reduce the cost of recipients of research results.

Finally, in the case of different industries, there is no scientific basis to simplify the results of LCA into a single comprehensive score or number because of the complexity of the analyzed system in each stage of the life cycle, though the general model is beneficial to the construction of LCA module in PSS system. As a result, LCA research has flexibility. To ensure the accuracy, practicability and operability of life cycle assessment, the implementers of enterprise evaluation should timely modify its purpose and scope according to the principles and framework of life cycle assessment and specific application intentions. This is also the focus of most current case studies on LCA and PSS, though these cases only cover a small part of the entire manufacturing industry. Therefore, this paper argues that from the perspective of case studies, more accurate and practical case studies can be used to analyse more micro and targeted manufacturing processes.

## References


Ackermann, L., Mugge, R., & Schoormans, J. (2018). Consumers' perspective on product care: An exploratory study of motivators, ability factors, and triggers. Journal of Cleaner Production, 183, 380-391. doi:10.1016/j.jclepro.2018.02.099

Alcayaga, A., & Hansen, E. G. (2017). Smart-circular systems: a service business model perspective.

Allais, R., & Gobert, J. (2016). A multidisciplinary method for sustainability assessment of PSS: Challenges and developments. Cirp Journal of Manufacturing Science and Technology, 15, 56-64. doi:10.1016/j.cirpj.2016.04.007

Alstone, P., Lai, P., Mills, E., & Jacobson, A. (2014). High Life Cycle Efficacy Explains Fast Energy Payback for Improved Off-Grid Lighting Systems. Journal of Industrial Ecology, 18(5), 722-733. doi:10.1111/jiec.12117

Amaya, J., Lelah, A., & Zwolinski, P. (2014). Design for intensified use in product-service systems using life-cycle analysis. Journal of Engineering Design, 25(7-9), 280-302. doi:10.1080/09544828.2014.974523

Ameli, N. (2017). Design for sharing: libraries of things as a product-service system.

Barbu, C. M., Florea, D. L., Ogarca, R. F., & Barbu, M. C. R. (2018). FROM OWNERSHIP TO ACCESS: HOW THE SHARING ECONOMY IS CHANGING THE CONSUMER BEHAVIOR. Amfiteatru Economic, 20(48), 373-387. doi:10.24818/ea/2018/48/373

Blomsma, F., Kjaer, L., Pigosso, D., McAloone, T., & Lloyd, S. (2018). Exploring circular strategy combinations - towards understanding the role of PSS. In A. Laurent, A. Leclerc, M. Niero, Y. Dong, S. I. Olsen, M. Owsianiak, N. Bey, M. Ryberg, & M. Z. Hauschild (Eds.), 25th Cirp Life Cycle Engineering (Vol. 69, pp. 752-757).

Bridgens, B., & Lilley, D. (2017). Understanding material change: design for appropriate product lifetimes.

Camacho-Otero, J., Pettersen, I. N., & Boks, C. (2017). Consumer and user acceptance in the circular economy: what are researchers missing?

Chamberlin, L., & Boks, C. (2018). Marketing Approaches for a Circular Economy: Using Design Frameworks to Interpret Online Communications. Sustainability, 10(6). doi:10.3390/su10062070

Chen, C. W. (2018). Guidance on the Conceptual Design of Sustainable Product-Service Systems. Sustainability, 10(7). doi:10.3390/su10072452

Cherry, C. E., & Pidgeon, N. F. (2018). Why Is Ownership an Issue? Exploring Factors That Determine Public Acceptance of Product-Service Systems. Sustainability, 10(7). doi:10.3390/su10072289

Corti, D., Fontana, A., & Montorsi, F. (2016). Reference data architecture for PSSs Life Cycle Inventory. In S. Cavalieri, E. Ceretti, T. Tolio, & G. Pezzotta (Eds.), Product-Service Systems across Life Cycle (Vol. 47, pp. 300-304).

Costa, F., Prendeville, S., Beverley, K., Teso, G., & Brooker, C. (2015). Sustainable product-service systems for an office furniture manufacturer: How insights from a pilot study can inform PSS design. In X. Boucher & D. Brissaud (Eds.), 7th Industrial Product-Service Systems Conference - Ipss, Industry Transformation for Sustainability and Business (Vol. 30, pp. 66-71).

Dal Lago, M., Corti, D., & Wellsandt, S. (2017). Reinterpreting the LCA standard procedure for PSS. In T. C. McAloone, D. C. A. Pigosso, N. H. Mortensen, & Y. Shimomura (Eds.), 9th Cirp Industrial Product/Service-Systems (Vol. 64, pp. 73-78).

De los Rios, I. C., & Charnley, F. J. S. (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design. Journal of Cleaner Production, 160, 109-122. doi:10.1016/j.jclepro.2016.10.130

Doualle, B., Medini, K., Boucher, X., & Laforest, V. (2015). Investigating sustainability assessment methods of product-service systems. In X. Boucher & D. Brissaud (Eds.), 7th Industrial Product-Service Systems Conference - Ipss, Industry Transformation for Sustainability and Business (Vol. 30, pp. 161-166).

Fargnoli, M., Costantino, F., Di Gravio, G., & Tronci, M. (2018). Product service-systems implementation: A customized framework to enhance sustainability and customer satisfaction. Journal of Cleaner Production, 188, 387-401. doi:10.1016/j.jclepro.2018.03.315

Glatt, M. F., Yi, L., Mert, G., Linke, B. S., & Aurich, J. C. (2019). Technical Product-Service Systems: Analysis and reduction of the Cumulative Energy Demand. Journal of Cleaner Production, 206, 727-740. doi:10.1016/j.jclepro.2018.09.229

Gnoni, M. G., Mossa, G., Mummolo, G., Tornese, F., & Verriello, R. (2017a). CIRCULAR ECONOMY STRATEGIES FOR ELECTRIC AND ELECTRONIC EQUIPMENT: A FUZZY COGNITIVE MAP. Environmental Engineering and Management Journal, 16(8), 1807-1817.

Gnoni, M. G., Mossa, G., Mummolo, G., Tornese, F., & Verriello, R. (2017b). Supporting circular economy through use-based business models: the washing machines case. In T. C. McAloone, D. C. A. Pigosso, N. H. Mortensen, & Y. Shimomura (Eds.), 9th Cirp Industrial Product/Service-Systems (Vol. 64, pp. 49-54).

Hobson, K., Lynch, N., Lilley, D., & Smalley, G. (2018). Systems of practice and the Circular Economy: Transforming mobile phone product service systems. Environmental Innovation and Societal Transitions, 26, 147-157. doi:10.1016/j.eist.2017.04.002

Ionascu, I., & Ionascu, M. (2018). BUSINESS MODELS FOR CIRCULAR ECONOMY AND SUSTAINABLE DEVELOPMENT: THE CASE OF LEASE TRANSACTIONS. Amfiteatru Economic, 20(48), 356-372. doi:10.24818/ea/2018/48/356

Khan, M. A., Mittal, S., West, S., & Wuest, T. (2018). Review on upgradability - A product lifetime extension strategy in the context of product service systems. Journal of Cleaner Production, 204, 1154-1168. doi:10.1016/j.jclepro.2018.08.329

Kjaer, L. L., Pagoropoulos, A., Schmidt, J. H., & McAloone, T. C. (2016). Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. Journal of Cleaner Production, 120, 95-104. doi:10.1016/j.jclepro.2016.01.048

Kjaer, L. L., Pigosso, D. C. A., McAloone, T. C., & Birkved, M. (2018). Guidelines for evaluating the environmental performance of Product/Service-Systems through life cycle assessment. Journal of Cleaner Production, 190, 666-678. doi:10.1016/j.jclepro.2018.04.108

Kuo, T. C., & Smith, S. (2018). A systematic review of technologies involving eco-innovation for enterprises moving towards sustainability. Journal of Cleaner Production, 192, 207-220. doi:10.1016/j.jclepro.2018.04.212

Lelah, A., Mathieux, F., & Brissaud, D. (2011). Contributions to eco-design of machine-to-machine product service systems: the example of waste glass collection. Journal of Cleaner Production, 19(9-10), 1033-1044. doi:10.1016/j.jclepro.2011.02.003

Lieder, M., Asif, F. M. A., & Rashid, A. (2017). Towards Circular Economy implementation: an agent-based simulation approach for business model changes. Autonomous Agents and Multi-Agent Systems, 31(6), 1377-1402. doi:10.1007/s10458-017-9365-9

Lieder, M., Asif, F. M. A., Rashid, A., Mihelic, A., & Kotnik, S. (2018). A conjoint analysis of circular economy value propositions for consumers: Using "washing machines in Stockholm" as a case study. Journal of Cleaner Production, 172, 264-273. doi:10.1016/j.jclepro.2017.10.147

Lin, K. Y. (2018). User experience-based product design for smart production to empower industry 4.0 in the glass recycling circular economy. Computers & Industrial Engineering, 125, 729-738. doi:10.1016/j.cie.2018.06.023

Lindahl, M., Sundin, E., & Sakao, T. (2014). Environmental and economic benefits of Integrated Product Service Offerings quantified with real business cases. Journal of Cleaner Production, 64, 288-296. doi:10.1016/j.jclepro.2013.07.047

Linder, M., & Williander, M. (2017). Circular Business Model Innovation: Inherent Uncertainties. Business Strategy and the Environment, 26(2), 182-196. doi:10.1002/bse.1906

Moreno, M., Turner, C., Tiwari, A., Hutabarat, W., Charnley, F., Widjaja, D., & Mondini, L. (2017). Re-distributed manufacturing to achieve a Circular Economy: A case study utilizing IDEF0 modeling. In M. M. Tseng, H. Y. Tsai, & Y. Wang (Eds.), Manufacturing Systems 4.0 (Vol. 63, pp. 686-691).

Nasiri, M., Rantala, T., Saunila, M., Ukko, J., & Rantanen, H. (2018). Transition towards Sustainable Solutions: Product, Service, Technology, and Business Model. Sustainability, 10(2). doi:10.3390/su10020358

Pagoropoulos, A., Kjaer, L. L., Andersen, J. A. B., & McAloone, T. C. (2017). The influence of costs and benefits' analysis on service strategy formulation: Learnings from the shipping industry. Cogent Engineering, 4(1). doi:10.1080/23311916.2017.1328792

Pialot, O., Millet, D., & Bisiaux, J. (2017). "Upgradable PSS": Clarifying a new concept of sustainable consumption/production based on upgradablility. Journal of Cleaner Production, 141, 538-550. doi:10.1016/j.jclepro.2016.08.161

Pialot, O., Millet, D., Cor, E., & Bisiaux, J. (2015). A method helping to define eco-innovative systems based on upgradability. In X. Boucher & D. Brissaud (Eds.), 7th Industrial Product-Service Systems Conference - Ipss, Industry Transformation for Sustainability and Business (Vol. 30, pp. 185-190).

Pieroni, M. D., Marques, C. A. N., Moraes, R. N., Rozenfeld, H., & Ometto, A. R. (2017). PSS design process models: are they sustainability-oriented? In T. C. McAloone, D. C. A. Pigosso, N. H. Mortensen, & Y. Shimomura (Eds.), 9th Cirp Industrial Product/Service-Systems (Vol. 64, pp. 67-72).

Piontek, F. M., & Muller, M. (2018). Literature reviews: Life Cycle Assessment in the context of Product-Service Systems and the Textile Industry. In A. Laurent, A. Leclerc, M. Niero, Y. Dong, S. I. Olsen, M. Owsianiak, N. Bey, M. Ryberg, & M. Z. Hauschild (Eds.), 25th Cirp Life Cycle Engineering (Vol. 69, pp. 758-763).

Raebild, U., & Bang, A. L. (2017). Rethinking the Fashion Collection as a Design Strategic Tool in a Circular Economy. Design Journal, 20, S589-S599. doi:10.1080/14606925.2017.1353007

Retamal, M., & Schandl, H. (2018). Dirty Laundry in Manila: Comparing Resource Consumption Practices for Individual and Shared Laundering. Journal of Industrial Ecology, 22(6), 1389-1401. doi:10.1111/jiec.12696

Romero, D., & Rossi, M. (2017). Towards Circular Lean Product-Service Systems. In T. C. McAloone, D. C. A. Pigosso, N. H. Mortensen, & Y. Shimomura (Eds.), 9th Cirp Industrial Product/Service-Systems (Vol. 64, pp. 13-18).

Sakao, T., Liu, Y., Gustafsson, R., & Thornblad, G. (2017). A Method for Lifecycle Design of Product/Service Systems Using PLM Software. In J. Rios, A. Bernard, A. Bouras, & S. Foufou (Eds.), Product Lifecycle Management and the Industry of the Future (Vol. 517, pp. 710-718).

Santana, F. S., Barberato, C., & Saraiva, A. M. (2010). A Reference Process to Design Information Systems for Sustainable Design Based on LCA, PSS, Social and Economic Aspects. In J. Berleur, M. D. Hercheui, & L.

M. Hilty (Eds.), What Kind of Information Society? Governance, Virtuality, Surveillance, Sustainability, Resilience (Vol. 328, pp. 269-280).

Schallehn, H., Seuring, S., Strahle, J., & Freise, M. (2019). Customer experience creation for after-use products: A product-service systems-based review. Journal of Cleaner Production, 210, 929-944. doi:10.1016/j.jclepro.2018.10.292

Scheepens, A. E., Vogtlander, J. G., & Brezet, J. C. (2016). Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: making water tourism more sustainable. Journal of Cleaner Production, 114, 257-268. doi:10.1016/j.jclepro.2015.05.075

Sinclair, M., Sheldrick, L., Moreno, M., & Dewberry, E. (2018). Consumer Intervention MappingA Tool for Designing Future Product Strategies within Circular Product Service Systems. Sustainability, 10(6). doi:10.3390/su10062088

Sousa-Zomer, T. T., Magalhaes, L., Zancul, E., & Cauchick-Miguel, P. A. (2017). Lifecycle management of product-service systems: a preliminary investigation of a white goods manufacturer. In T. C. McAloone, D. C. A. Pigosso, N. H. Mortensen, & Y. Shimomura (Eds.), 9th Cirp Industrial Product/Service-Systems (Vol. 64, pp. 31-36).

Stal, H. I., & Jansson, J. (2017). Sustainable Consumption and Value Propositions: Exploring Product-Service System Practices Among Swedish Fashion Firms. Sustainable Development, 25(6), 546-558. doi:10.1002/sd.1677

Vezzoli, C., & Sciama, D. (2006). Life Cycle Design: from general methods to product type specific guidelines and checklists: a method adopted to develop a set of guidelines/checklist handbook for the eco-efficient design of NECTA vending machines. Journal of Cleaner Production, 14(15-16), 1319-1325. doi:10.1016/j.jclepro.2005.11.011

Vogtlander, J. G., Bijma, A., & Brezet, H. C. (2002). Communicating the eco-efficiency of products and services by means of the eco-costs/value model. Journal of Cleaner Production, 10(1), 57-67. doi:10.1016/s0959-6526(01)00013-0

Wastling, T., Charnley, F., & Moreno, M. (2018). Design for Circular Behaviour: Considering Users in a Circular Economy. Sustainability, 10(6). doi:10.3390/su10061743

Xing, K., Wang, H. F., & Qian, W. (2013). A sustainability-oriented multi-dimensional value assessment model for product-service development. International Journal of Production Research, 51(19), 5908-5933. doi:10.1080/00207543.2013.810349

Yang, M. Y., Smart, P., Kumar, M., Jolly, M., & Evans, S. (2018). Product-service systems business models for circular supply chains. Production Planning & Control, 29(6), 498-508. doi:10.1080/09537287.2018.1449247

Zhang, W. J., Guo, J. F., Gu, F., & Gu, X. J. (2018). Coupling life cycle assessment and life cycle costing as an evaluation tool for developing product service system of high energy-consuming equipment. Journal of Cleaner Production, 183, 1043-1053. doi:10.1016/j.jclepro2018.02.146