Framework for PSS from Service' Perspective

Lujing. Yang, Ke. Xing and Sang-Heon Lee

***Abstract*---Product Service Systems (PSS) is a concept which means product and service are integrated to meet customer requirements. It has many applications in several industries. In current researches, Product Life Cycle Modelling and Service Engineering (SE) are main methodologies to design and model PSS. This paper proposes a framework of service life cycle integrating product life cycle. Each stage of service life cycle contains a number of service processes. Each service process is modelled using Service Engineering. This paper also proposes a primary input & output parameters system for the service process model, which integrates costs, resource consumptions and states of product or customer. At the end of the paper, the authors discuss the future work to improve this model.**

***Index Terms*--- Product Service System, Life Cycle Model, Service Engineering**

I. INTRODUCTION

Product Service Systems (PSS) is a system that integrates product and service to meet customer requirements and to reduce the environment impact. It is classified into three types: Product-Oriented PSS, Use-Oriented PSS and Result-Oriented PSS (Cook 2006). In recent years, some organizations have adopted the PSS into their business operation and each type of PSS is applied in different industries. Product-Oriented PSS is used in some cases which company integrates services into product life cycle management. The typical applications of Use-Oriented PSS are car sharing, car pooling and car leasing. Result-Oriented PSS' applications include washing centre and chemical management service.

In this paper, literatures are reviewed from three aspects: the concept, classification and application of Product Service System; product life cycle model in PSS modelling; Service model in PSS modelling. The first part of literature review is background information of product service system. The other two parts of literature review concern on the current modelling methodology of PSS. In current researches, product life cycle model and service modelling are widely used in PSS modelling. Many researchers integrate services into product life cycle and develop some models for Product-Oriented PSS. For the service model in PSS modelling, the blueprint is used in some papers, and Service Engineering is another more important methodology for service modelling. The typical application of Service Engineering on PSS modelling is proposed by Komoto and Tomiyama (2008), who integrate the service CAD with the product life cycle simulator.

From the literature review especially for the last two parts, three main limitations in current researches on PSS modelling are identified. The first limitation is that few PSS models are developed from service' perspective; the second limitation is the consideration of customer behaviour factors is very lack in current researches; the third limitation is current PSS models need more quantitative evaluation.

In order to overcome these gaps, a new framework for PSS is proposed in this paper. The framework is based on service life cycle instead of product life cycle. The service life cycle includes many service processes, which can be modelled using service engineering. In addition, this paper proposes a basic structure for service process model. This structure integrates customer behaviour factors. The whole framework has a set of indicators are outputted from model that can be used to evaluate the performance of system. Consequently, this framework has a set of parameters to evaluate a Product Service System's performance quantitatively.

The remaining parts of this paper are organized as following. Part II is the literature review. Part III describes limitations of the current research that are identified from literature review and Part IV proposes a framework to overcome these limitations.

II. REVIEW OF LITERATURES AND CURRENT RESEARCH LIMITATIONS

A. Concept, Classification and Application of Product Service System

Cook (2006) defines Product Service System as a system that integrates prouct and service to meet customer requirement and to decrease the environment impact. According to the research of Mont (2002), PSS is developed with the concept of functional economy and defined as "a marketable set of products and services capable of jointly fulfilling a user's need. Product/service ratio in this set can vary, either in terms of function fulfillment or economic value (Goedkoop, et al. 1999)".

PSS is classified by Cook (2006) into three types: Product-Oriented PSS, Use-Oriented PSS and Result-Oriented PSS. In different types of PSS, product and service have different levels of importance. Generally

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speaking, in Product-Oriented PSS, product is core part whilst service is designed and provided according to the life cycle of the physical product. In Use-Oriented PSS, the product's function is to provide services to customers. In Result-Oriented PSS, service can replace product to provide desired results to customers. The work of Tukker (2004) reveals relationships between service patterns and types of PSS, which is demonstrated in Figure 1.

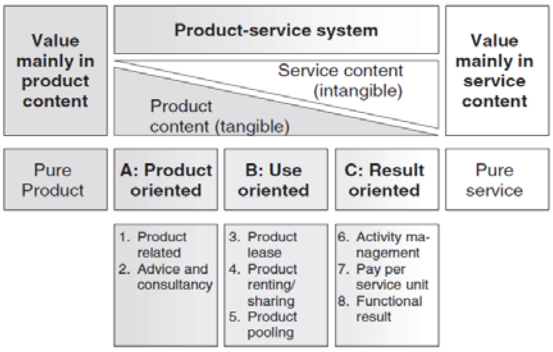

Figure 1: Main and subcategories of PSS

In recent years, some companies and organizations integrate services into the whole product life cycle. This type of PSS is Product-Oriented. Xerox, as an example, provides asset management for all life cycle stages after the sale of their products in order to minimise environment impacts of ownership (McAloone & Andreasen 2004). DuPont Flooring Systems (USA) has changed the business from just selling floor coverings to providing total service packs to customers that covers 'gate-to-grave' stages of product life cycle, including installation, tailored maintenance, take-back, and recycling (Goedkoop et al. 1999).

One typical application of Use-Oriented PSS is car sharing, car pooling and car leasing, Williams (2007) introduces that one in four cars are purchased through leasing arrangements in Germany. For car sharing, customers can use and reserve cars when there is a need and pay rental-fees on a variable basis (e.g. per kilometer or per unit of time). This type of business can bring more efficient usage of cars (Yang et.al 2008). Another example is Swiss Mobility Schemes, which is the largest car sharing service provider in the world, has almost 60,000 members in 2004.

Roy (2005) describes the application of Result-Oriented PSS in Netherland. The government has supported building washing centres to provide washing services for residents in communities. This system can reduce water and energy consumptions. This concept also can be applied for other household services such as heating, cooling, lighting, shopping cooking and eating. Another area which the Result-Oriented PSS is applied widely is chemical management service. Yang et.al (2007) introduce that this business model means customer purchases a chemical service instead of chemicals themselves. Customers pay fees based on the quality and quantity of services provided rather than the volume of chemicals sold. Kauffman et.al (1999) point out that this mode can reduce chemical lifecycle costs, risks, and environmental impacts.

B. Product Life Cycle Model in PSS Modelling

Product life cycle is main focus for PSS. For many researches on PSS, product life cycle management and modelling is an important issue.

Mien, Feng and Leng (2005) proposed a basic framework of Product Service Systems integrated with manufacture, which is called 'Integrated Manufacturing and Product Service System (IMPSS)'. This framework identifies several stages of product life cycle and services around these stages. Figure 2 displays this framework.

Obviously, this framework is a typical Product-Oriented PSS suitable for traditional manufacturer to add services to their products, and upgrade an old business model to a new PSS model.

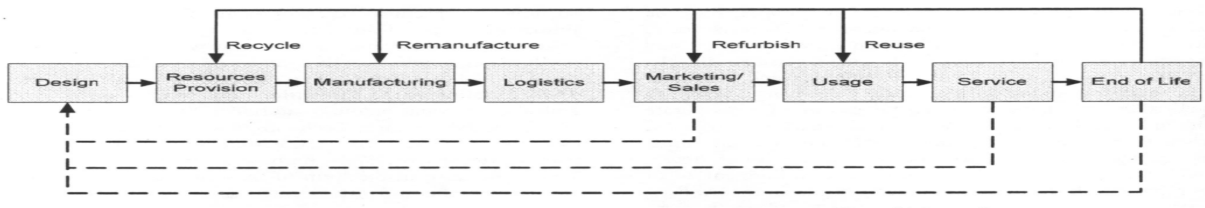

Figure 2: Framework of IMPSS (Mien al. etc 2005)

It is similar to the research of Aurich, Schweitzer and Fuchs's research (2006). In this paper, researchers assert that the Product Life Cycle Management is the core issue for the design of PSS.

However, it is difficult to obtain enough information and data about product life cycle just depending on conceptual models and frameworks. Therefore simulation approaches are applied in the research. Takata and Umeda (2003) discuss an indicator system that is used to evaluate a product life cycle, and differences between life cycle assessment and life cycle simulation. Nonomura and Umeda (1999) also discuss the advantages of life cycle simulation in comparison with the life cycle assessment. In addition, they proposed a simulation model for product life cycle as a network of processes such as manufacturing, operation, recycling and remanufacturing.

Some researchers pay their attention to developing simulation models for particular products. Hata etc (2000) developed a simulation model for air conditioners. The model is developed as a set of simulation events based on the usage process flow of different components of air conditioners.

Komoto, Tomiyama and Ngel (2005) tried to use life cycle simulation to analyse the product service systems. They identified the objects and relationships in a PSS. Their research illustrates that events in product life cycle will be parts of events in the PSS. Therefore, they integrated these events into the PSS simulation model.

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C. Service Model for PSS Modelling

From the definition of PSS, in many cases, service plays a more important role than the product, especially for User-Oriented PSS and Result-Oriented PSS. Therefore, service is another key area for the PSS researchers.

Many researchers propose methods to design and modelling PSS system. Boughnim and Yannou (2005) use the Blueprint to design a PSS. They decompose PSS into four dimensions, product, service, infrastructure and network, and emphasis service engineering. In this paper, Boughnim and Yannou design the service process and identify the questions that the Service Blueprint should answer: Who does What, To Whom, How often and under what conditions.

Similarly, Morelli (2006) also provides the design of the service process in a PSS's structure using blueprint. Moreover, he uses an interaction map for indicating relationships and interactions between different actors in a system, and applies it to some cases such as shopping centres.

Service Engineering is very important in PSS design and modelling. It is defined by Zirpins, Baier and Lamersdorf (2003) as the manufacturer can build customized services to their products. The service design includes the issues of modelling, adaptation, aggregation and coordination. Sakao and Hara (2006) define service as 'the activities between the service provider and the service receiver that can change the state of receiver'. It is considered that service has three elements: service goal, service environment and service channel (Tomiyama 2001). The content of service are delivered through service channel. Moreover, Sakao and Hara introduce a service functional structure including flow model, view model and scope model, which is shown in Figure 3.

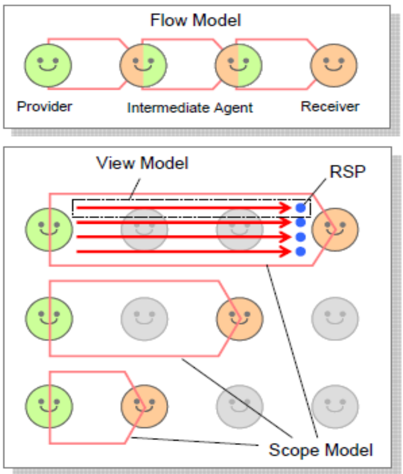

Figure 3: The relation among three sub models (Sakao & Hara 2006)

While a few researchers develop a computer-aided service design systems called service explorer (Hara, Arai & Shimomura 2006). Others, such as Sakao in 2006 focus on connecting service engineering with the computer-aided design (CAD) system for service development. The work of Komoto and Tomiyama (2008) propose to integrate the service CAD with the product life cycle simulator for the PSS modelling. In another research of Yoshimitsu et al. (2006) investigation was conducted about the evaluation a service from the customer's view. They provided a function to calculate the receiver satisfaction and the relationship between the receiver satisfactions and attribute values of service. In this paper, Yoshimitsu et al. cite the customer satisfaction model proposed by Kano to classify the receivers' satisfaction's type when receive different services.

Meanwhile, Longo and Motta (2006) present business processes as a service chain supported by produce life cycle management. They want to use the model to evaluate the sustainable performance of a business process model.

Lindahl etc (2006) discuss the necessity to integrate product engineering with service engineering and introduce the concept of 'Integrated Product and Service Engineering (IPSE)'. Aurich, Fuchs and Wagenknecht (2006) provide a technical service model that is object-oriented and have discussed the concurrent design service and product for achieving modularized PSS modelling. Furthermore, Zhao et al. develop (2008) the service models based on the product life cycle for the manufacturing who is service oriented. The models include the framework, the development flow and information model of service design.

III. CURRENT LIMITATIONS

A. Limitations in Modelling PSS from Service' view

PSS system has three types that are Product-Orientated PSS, Use-Orientated PSS and Result-Orientated PSS. However, most researches on modelling PSS so far have only focused on Product-Orientated PSS and have service options part of product life cycle model, e.g. Aurich, Fuchs and Wagenknecht (2006). However, in the concept of Use-Oriented and Result-Oriented PSS, service is core part and physical products are only carriers for service delivery. Therefore, it is necessary to develop a new model which is suitable for these two types of PSS, and the model should be developed from the service's perspective.

B. Limitations in Customer Behaviour Modelling for PSS

Based on the review, most research on the modelling of PSS does not include the influence of customer behaviour on the life cycle of a product, and the options of service. The framework of IMPSS proposed by Mien, Feng & Leng (2005) does not reflect the customer perspectives. Hu, Wang and Bidana (2007) introduce customer consideration into product life cycle model and divide them into three types. However, the influences of customer behaviour on product life cycle and service, are not considered, for instance, a user use product with high usage intensity will shorten the product's lifetime, increasing the failure rate. On the other side, some research work on service engineering such as Yoshimitsu (2006), only considers the satisfactions of customer while falls short in studying the influence of customer behaviour to the system performance and having them reflected in the model. In fact, an important characteristic of PSS is that business process is customer centred so that customer behaviours will exert significant impact to the implementation and performance of PSS. Therefore, modelling of PSS should incorporate the customer behaviour factors, including customer preferences and usage pattern.

C. Limitations in Model Evaluation

From the literature reviewed above, many PSS models present conceptual framework which only have qualitative analysis and are lack of quantitative measure. For example, the model of Closed loop Logistic Systems developed by Hu, Wang & Bianda (2007) and a framework called 'Integrated Manufacturing and Product Service System (IMPSS)' proposed by Mien, Feng and Leng (2005) are both short of quantitative analysis in the evaluation methods. These conceptual frameworks and roadmaps are effective in prescribing strategies and key processes for making business paradigm changes. However, they are very difficult for companies to use in making informed decisions with clear understandings on the possible economic, environmental, and operational implications of different strategies/options for product-service delivery. Consequently, research on the evaluation of a PSS model should be strengthened with more emphasis on using quantitative approaches to support decision making.

IV. CONCEPTUAL MODEL OF PSS FROM SERVICE'S PERSPECTIVE

In order to overcome the first limitations mentioned above, the PSS framework is proposed as a service-based model in this paper. Whole PSS system model is based on a service life cycle's perspective including pertinent operations processes. The concept of service life cycle has introduced in IT area. For example, Ives and Mason (1990) propose a framework of 'customer service life cycle' for e-commerce, which is shown as Figure 4.

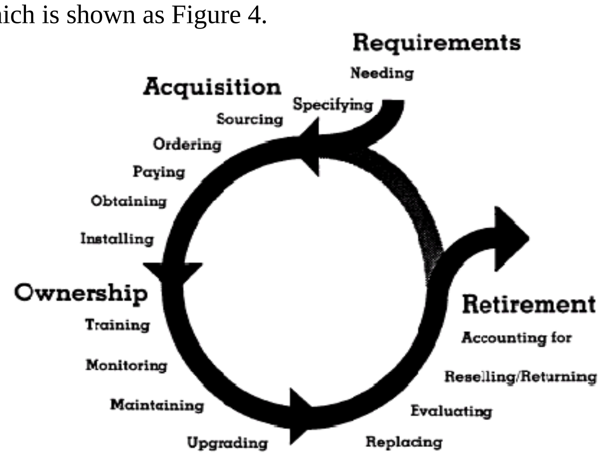

Figure 4: Customer Service Life Cycle (Ives & Mason, 1990)

They divide a service life cycle into four stages and each stage includes several service activities. Stage of 'Requirements' includes Needing and Specifying; 'Acquisition' has activities of Sourcing, Ordering, Paying Obtaining and Installing. This stage starts to provide service to customer; 'Ownership' includes the activities of Training, Maintaining, Monitoring and Upgrading. Retirement is the last stage, which includes Replacing, Evaluating, Reselling and Accounting.

In this paper, service life cycle's framework is developed based on the framework shown in Figure 4. The modified service life cycle framework integrates product life cycle, which emphasizes the combination of service life cycle and product life cycle. In fact, this service life cycle is a service pack that business provides to a customer. This service life cycle has four stages i.e. Service Requirement, Service Deployment, Service Processing and Service Retirement, which is shown in Figure 5:

- *Service Requirement* is the beginning of all life cycle. In this stage, PSS provider analyses customer requirement, product & service selling, and service customization. In fact, the Service Pack is designed in this stage.
- *Service Deployment* includes service processes of product installation, paying, product delivering and training. In this stage, service and product are deployed and start to provide functions to customer.
- *Service Processing* includes the processes that remain quality of service, including product maintenance, repairing, upgrading, service monitoring, service renew and retraining.
- *Service Retirement* is the end of service life cycle, which includes service processes such as service evaluation and product take-back.

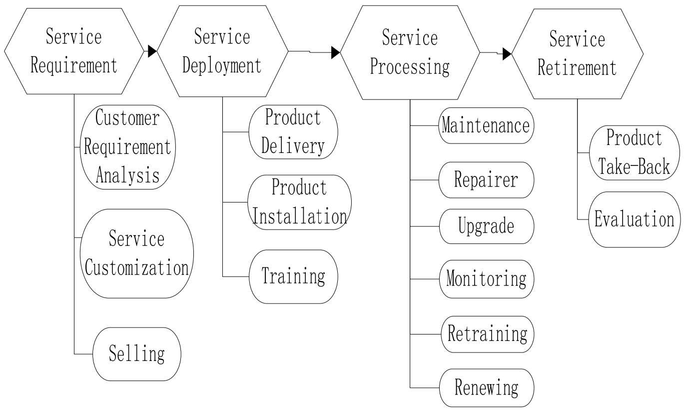

Figure 5: Service Life Cycle Framework

This framework of service life cycle can resolve current limitation in modelling PSS because the product life cycle is integrated into service life cycle. Service is core part in this framework and product's function is delivering service to customer. Therefore it is more suitable for modelling Use-Oriented PSS and Result-Oriented PSS.

As shown in Figure 5, in this framework, each stage of service life cycle contains a set of business processes, which can be modelled as service process. Each service process can be modelled using Service Engineering methodology.

Each service process model has functions that manipulate a set of input parameters to calculate out a series of results as output parameters. Also, the service process model should consider constraints. The output parameters will be used to evaluate system's performance.

The Figure 6 shows the conceptual model for service process including basic construct of constraints, input and output parameters.

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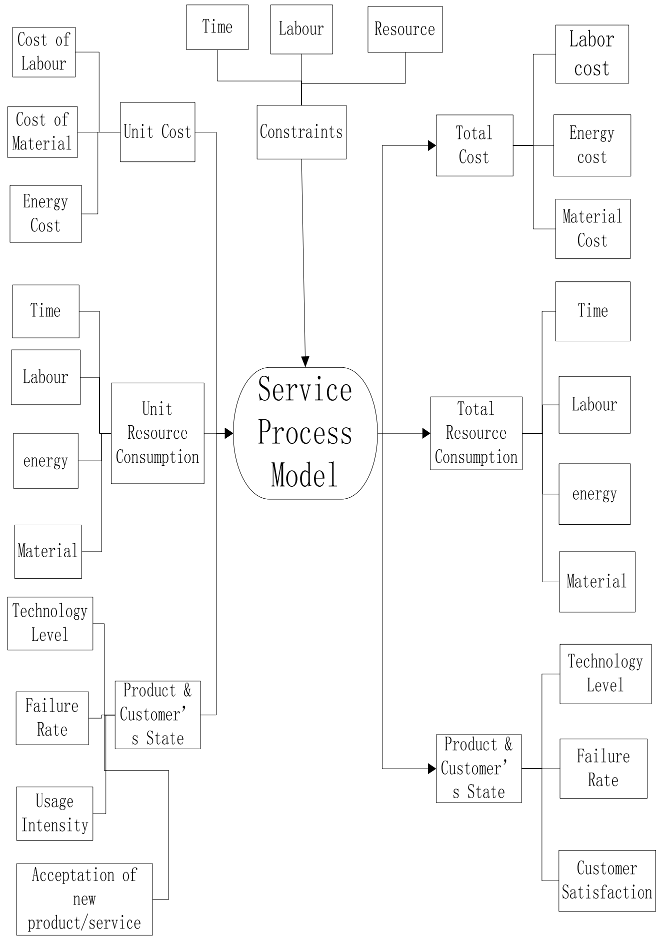

Figure 6: Basic Service Model Structure

The constraints system contains constraints in terms of time, labour and other resources such as space, money and energy. These constraints are considered in the service modelling.

The input parameters system includes three main types, which are unit cost, unit resource consumption and product & customer's state. Unit cost is the cost that this service process will spend in one time, which includes the cost of labour, the cost of energy and other cost. Unit Resource Consumption is the amount of resource that this service process will consume one time. The types of resource are time, labour and other resources.

Product and Customer States is a set of Receiver State Parameters. According to concept of Service Engineering, service is a process that can change the receiver's state and state is represented by a set of Receiver State Parameters (RSPs) (Sakao et.al 2006). In this model, the attributes of service receiver, both of product and customer, are very important. The attributes represent the state of service receiver and different characters of customer or product that will impose on performance of system and these services can change the conditions of receivers, which may include product or customer.

Product's states include technology level, failure rate, etc. These attributes represent condition of product that can be changed by some service processes. For example, an upgrade service process can change the technology level of product, and a maintenance service process can lower failure rate of product.

The introducing of Customer's attributes can overcome the second limitation mentioned part III. Customer's attributes represent behaviour and state of customer. The customer behaviour attributes can influent the product's state and service cost. For example, the higher usage intensity is, the lifetime of product is shorter. As the result, the maintenance service is required more frequently. Therefore, this service model can reflect the influence of customer behaviour through integrating customer's attributes into model.

The customer state attributes in this model are Usage Intensity, which represents how often or how long of customer requires or uses this service or product, and Acceptation of new product & service, which represents customer's willingness of adopting or changing to new service or product.

The outputs of the service process model are the parameters that used to evaluate the performance of system including mainly three types and nine categories also. The first two types of parameters are calculated in service model according the input parameters. The output of total cost, labour cost, energy cost and other cost, are calculated according unit labour cost, unit energy cost and other unit cost, which are input parameters of the model. Total resource consumption is another result that the model calculates from input parameters of unit resource consumption. The Product & Customer's State in output system is state attributes. In fact, from the viewpoint of Service Engineering, they are Receiver State Parameters changed by service model, including product's technology level, product's failure rate and customer's satisfaction.

In sum, some parameters are inputted into the model of each service process and the model manipulates them then a set of indicators are outputted from model that can be used to evaluate the performance of system. This feature of framework can help researchers overcome the current limitation on model evaluation. Consequently, a Product Service System's performance can be evaluated quantitatively when the input & output parameter system is developed in future.

V. CONCLUSION and FUTURE WORK

Product Service System (PSS) is a new business mode that can help people build a sustainable world. Besides discussion of concept and classification of PSS, how to model and design PSS is another main area interested by researchers. Some researchers use Service Engineering to develop service and integrated them into product life cycle management.

In this paper, this conceptual model of PSS is developed based on service life cycle' perspective, and product life cycle is integrated into service life cycle. This type of framework is more suitable for Use-Oriented PSS and Result-Oriented PSS, which product life cycle management is invisible for customer usually. In this model, product is a tool to provide service to customer so service is the core part. Therefore the limitation of modelling PSS from service' perspective is overcome in this framework. Moreover, the customer behaviours are integrated into service process model and a set of parameters is identified to calculate system performance. So the other two limitations mentioned in part III are also overcome.

However, the service life cycle framework and service model that are proposed in this paper is till in a basic and conceptual form. It is yet to have mathematical models formulated and incorporated to enable design and analyse of a PSS in a quantitative manner. Therefore, the future works of this research includes:

- The service life cycle framework should be specialized. More service processes will be identified and introduced into service life cycle.
- An indicator system for this model will be developed. The input parameter and output parameter system will be identified in advance. Some uncertain parameters, such as use intensity, acceptation of new service or product and customer satisfaction, will be quantized;
- Developing mathematical functions of every service process model. These functions can manipulate input parameters and translate them to output parameters of model.

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REFERENCE

[1] Aurich.J, Fuchs.C & Wagenknecht.C 2006, 'Modular design of technical product-service systems', Innovation in Life Cycle Engineering and Sustainable Development, Springer Netherlands

[2] Boughnim. N, Yannou. B 2005, Using Blueprinting Method for Developing Product Service Systems, proccessed for International Conference on Engineering Design

[3] Cook. M, Bhamra. T, Lemon. M 2006, 'The transfer and application of Product Service Systems: from academia to UK manufacturing firms', *Journal of Cleaner Production*, Vol. 14, pp.1455-1465

[4] Goedkoop. M, van Haler. C, Riele. H, Rommers. P 1999, Product Service-Systems, ecological and economic basics. Report for Dutch Ministries of Environment(VROM) and Economic Affairs (EZ)

[5] Hata. T, Kato. S, Sakamoto. H, Kimura. F, Suzuki. H 2001, *'Product life cycle simulation with quality model'*, Department of Precision Machinery Engineering, The University of Tokyo, viewed June 2009, <http://www.cim.pe.u-tokyo.ac.jp/lc/pub/CirpLceNov2000-Paper.pdf>

[6] Hara. T, Arai. T, Shimomura. Y 2006, A Concept of Service Engineering: A Modelling Method and A Tool for Service Design, Proceeded for 2006 International Conference on Service Systems and Service Management, vol 1, pp 13-18

[7] Hu. G, Wang. L, Bidanda. B 2007, A New Model for Closed-loop Product Lifecycle Systems, Proceedings of the 2007 Industrial Engineering Research Conference

[8] Ives. B, Mason. R, 1990, 'Can Information Technology Revitalize Your Customer Service?', Academy of Management Executive, pp. 52-69

[9] Komoto. H, Tomiyama. T & Nagel. M 2005, Life Cycle Simulation for Analyzing Product Service Systems, International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Eco Design 2005, v 2005, p 386-393

[10] Lindahl. M, Sundin. E, Rönnbäck.A, Ölundh2. G, Östlin. J 2006, Integrated Product and Service Engineering – the IPSE project, Proceeded for Changes to Sustainable Consumption, Copenhagen, Denmark

[11] Meier. H, Völker. O 2008, Industrial Product-Service-Systems -Typology of Service Supply Chain for IPS² Providing, processing on The 41st CIRP Conference on Manufacturing Systems

[12] Mont O. K 2002, 'Clarifying the Concept of Product-Service System', *Journal of Cleaner Production*, vol. 10, no. 3, pp. 237-245

[13] Morelli. N 2006, 'Developing new product service systems (PSS): methodologies and operational tools', *Journal of Cleaner Production*, vol. 14, no. 17, pp. 1495-1501

[14] Mien. L & Feng. L 2005, An integrated manufacturing and product services system (IMPSS) concept for sustainable product development, paper presented on Fourth International Symposium on Environmentally Conscious Design and Inverse Manufacturing

[15] Roy. R 2000, 'Sustainable product-service systems', *Futures*, Vol. 32, Issue 3-4, pp. 289-299

[16] Sakao. T, Shimomura. Y, Sundin. E, Comstock. M 2009, 'Modelling design objects in CAD system for Service/Product Engineering', *Computer-Aided Design*, Vol 41, pp 197-213

[17] Sakao. T, Shimomura. Y 2007, 'Service Engineering: a novel engineering discipline for producers to increase value combining service and product', Journal of Cleaner Production, vol 15, pp 590-604

[18] Tomiyama. T 2001, Service engineering to intensify service contents in product life cycles, Proceedings Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing, p 613-618

[19] Takata. S, Umeda. Y 2003, Framework for Systematic Evaluation of Life Cycle Strategy by means of Life Cycle Simulation, Proceeded for EurDeslgn2003: Third International Symposium on Environmentally Conscious Design and Inverse Manufacturing Tokyo, Japan

[20] Yoshimitsu. Y, Hara. T, Arait. T, Shimomura. Y 2006, An Evaluation Method for Service in the Point of Customers' View, Processed for 2006 International Conference on Service Systems and Service Management

[21] Zhao. L, Wan. J, Jiang. P, Qin. Y 2008, Service Design for Product Lifecycle in Service Oriented Manufacturing, Intelligent Robotics and Applications. Proceeded for First International Conference, ICIRA 2008, pp 733-742

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